PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERÚ

FACULTAD DE CIENCIAS E INGENIERÍA

DISEÑO DE UNA RED DE COMUNICACIONES PARA LA IMPLEMENTACIÓN DE UN SISTEMA DE TRANSPORTE INTELIGENTE EN EL CENTRO HISTÓRICO DE LIMA

TESIS PARA OPTAR EL TÍTULO DE INGENIERO ELECTRÓNICO

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LIMA – PERÚ

2006

RESUMEN

Todos conocemos lo grave de la situación del transporte urbano en la ciudad de Lima, por lo que muy poco se ha logrado avanzar para dar solución a este problema. En muchas otras ciudades modernas se aplican tecnologías avanzadas, tales como tecnologías de la información, de control y de las comunicaciones, logrando de alguna manera aliviar los problemas del tráfico. A este sistema se le conoce como los Sistemas de Transporte Inteligentes, que cada día esta cobrando mayor aceptación debido a que mejora los problemas del transporte.

El presente trabajo analiza los principales y más básicos componentes que actúan en un Sistema de Transporte Inteligente, de tal manera que se diseñe una infraestructura de red capaz de transmitir la información, recogida de las vías, que necesitan los operadores del tránsito, y poder así controlar mejor el transporte urbano. Para ello se toma en cuenta el uso del protocolo TCP/IP y la tecnología *Ethernet*, sobre todo este último, que ha ido creciendo en uso, no solo en las redes corporativas, sino también en las redes industriales y aplicaciones de planta externa. Este diseño será realizado en un sector del Centro Histórico de Lima, el cual no solo necesita de ordenamiento vehicular y peatonal, sino también de una estricta vigilancia y control, esto para dar una imagen de seguridad como zona turística.

En el primer capítulo se hace una revisión de la problemática del transporte y como es que los principales operadores del transporte lo manejan. El segundo capítulo ofrece un panorama general de los principales componentes que se usan en un Sistema de Transporte Inteligente, además de plantear la tecnología *Ethernet* como solución a las necesidades de transporte de datos. En el tercer capítulo se hace hincapié a las necesidades del transporte en Lima, y se analiza los requerimientos de comunicación de los componentes que actuarán en el sistema. Y para finalizar, en el cuarto capítulo se muestra el diseño parcial de la red, esto es solo para dar servicio a los alrededores de la Av. Abancay, ello para mostrar la factibilidad de realizar una red basada en tecnología *Ethernet*, además de considerar los costos de los elementos de la red. Este trabajo muestra como es que una tecnología emergente, tal como es *Ethernet*, con el uso de aplicaciones TCP/IP, usadas ampliamente en Internet, son piezas claves para el desarrollo de un Sistema de Transporte Inteligente actual y futura.

Para mi linda madre Elena
y mi querida abuela Bertha.

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INTRODUCCIÓN

El transporte urbano en todo el mundo ha crecido considerablemente, convirtiéndose en un problema público. La ciudad de Lima, y en general todas las ciudades del Perú, crecen de manera horizontal, obligando a la población a usar con mayor frecuencia el transporte. Una consecuencia de este crecimiento es el aumento del parque automotor, y debido a la falta de control en las rutas de transporte, las pistas se convierten en un caos, trayendo muchas repercusiones en varios aspectos de la vida cotidiana, así como al medio ambiente. Los métodos tradicionales para el control de transporte no son suficientes para su manejo, esto es el uso de semáforos, los cuales actúan por si solos y sin conocer el estado de su entorno. Muchos municipios continúan creyendo que la solución a este caos es la construcción de más rutas de transporte, sin saber que esto no mejora de manera considerable el problema que aqueja a los que usan el transporte. Por otra parte, ciudades desarrolladas plantean constantemente que la mejor solución a este problema es el uso de las tecnologías de la información y de control, lo cual ha demostrado en la actualidad ser una solución viable para la mejora del transporte urbano.

Desde hace dos décadas, estas tecnologías han ido desarrollándose constantemente, dando como resultado áreas urbanas ordenadas y sin caos en el tránsito. El principio de funcionamiento de estos sistemas es el uso del control inteligente, esto es conocer a detalle lo que sucede en las rutas de transporte, para luego tomar decisiones rápidas que mejoren la situación del tránsito. Este sistema se ha estandarizado en todo el mundo, dando como resultado a los Sistemas de Transporte Inteligente. Cada país, cada bloque de países, y cada continente, elaboran un sistema con determinadas características. Estas experiencias son compartidas entre todos los países que usan el sistema, ayudando a modernizar el transporte.

Un Sistema de Transporte Inteligente es producto del uso de las tecnologías de la información, de las telecomunicaciones, y algoritmos de control, los cuales en conjunto ofrecen a los operadores del transporte la facilidad de monitorear y controlar el tráfico de manera remota. Los componentes que actúan en este sistema necesitan de una infraestructura de red, que les permita transportar la información, ya sea de control o monitoreo, entre los equipos que actúan en el sistema y los que operan el transporte. Asimismo, las telecomunicaciones permiten no solo que el operador este enterado de lo que sucede en el transporte, sino también los usuarios que lo usan. Así por ejemplo, un pasajero podrá saber que ruta tomar antes de viajar, para reducir su tiempo de viaje. De esta manera, todos cooperan en el ordenamiento del tránsito.

La tecnología de las telecomunicaciones permite que los componentes de un Sistema de Transporte Inteligente se interconecten en una sola red, sin embargo, muchas veces estos componentes no son compatibles entre sí en cuanto a características de comunicación. Muchos de ellos envían su información en formatos diferentes, haciendo la comunicación e interconexión difíciles de lograr. Los fabricantes de los componentes que actúan en el sistema desarrollan su propia tecnología, y por ende las características de comunicación son propietarias, o simplemente usan diferentes estándares de comunicación. Hasta hace poco, se ha dado intentos por estandarizar el uso de los protocolos de comunicación en un Sistema de Transporte Inteligente, tal que exista interoperabiidad entre diferentes fabricantes. Un ejemplo de ello son las normas NTCIP, recomendadas en EE.UU. y que comprende una serie de protocolos y tecnologías permitidas para la interconexión de los componentes del Sistema de Transporte Inteligente. Esta investigación se basa en estas normas, ya que ha sido aceptado por muchos fabricantes de manera internacional, es frecuente ver ahora en las hojas de especificaciones de algún equipo para este sistema, el que tenga incluido el cumplimiento de las normas NTCIP. Sin lugar a duda es una iniciativa que ayudará a mejorar las comunicaciones, no solo en el ámbito del transporte, sino también en otras áreas.

Los protocolos TCP/IP están incluidos en las normas NTCIP. El uso de esta pila de protocolos está muy generalizado, ahora no solo se usa en la Internet, y en las redes corporativas, sino también en el sector industrial y de transporte. Pero esto solo permite la interoperabilidad a nivel de aplicación, mas no a nivel físico. Diferentes tipos de dispositivos estarán monitoreando y controlando las rutas de transporte, por lo que sería ideal que envíen y reciban información en una misma infraestructura de red, y evitar así la implementación de varias redes en paralelo para cada tipo de tecnología que tengan los equipos a usar. El objetivo de este documento es diseñar una red compartida, en la que dispositivos con diferentes funcionalidades puedan acceder a un mismo medio de transmisión. Para ello se ha optado por realizar el análisis en el Centro Histórico de Lima, dado que ha sido la primera zona en la que se ha implementado un sistema de semáforos inteligente en el Perú, hace 20 años. Este sistema implementado es muy antiguo, pero su análisis es valioso ya que se puede apreciar como es su funcionamiento y su arquitectura. Existe infraestructura civil que puede ser usada para la implementación de un sistema más moderno de la que existe. Para ello se ha contado con la colaboración de la Municipalidad de Lima, además de la Central 105 de la Policía Nacional del Perú, quienes están totalmente involucrados en lo que es el orden vehicular y la seguridad en las calles.

Los tecnología mas usada para implementar redes compartidas es *Ethernet*, el cual surgió para crear las redes LAN, y que ahora esta copando el campo de las redes MAN, WAN. Asimismo, ya no está orientada al sector corporativo y SOHO (*Small Office – Home Office*), sino también a otras áreas como el transporte y el sector industrial. Es por ello que se analiza la viabilidad de esta tecnología en aplicaciones para el Sistema de Transporte Inteligente, realizando para ello pruebas de tráfico en laboratorio. Este documento además de mostrar un diseño de red, demuestra que la tecnología *Ethernet* puede adaptarse a cualquier necesidad de comunicación.

CAPÍTULO I

ANÁLISIS DE LA SITUACIÓN DEL TRANSPORTE URBANO EN LA CIUDAD DE LIMA

1.1 EL TRANSPORTE EN LA CIUDAD DE LIMA

1.1.1 ANTECEDENTES

Lima es una ciudad que está en constante cambio, y uno de los cambios que ha experimentado es la de transporte. En principio, el dinamismo de la sociedad se basa en la política que se aplica en un determinado momento, y puede de cierta manera cambiar drásticamente el estilo de vida de los ciudadanos. Uno de los más notables cambios que se ha producido es el aumento del parque automotor en la ciudad de Lima, lo que se refleja en la situación actual del transporte, y que junto a la centralización del país, lo convierten en una zona caótica.

A comienzos de los años 90, el gobierno de turno aprobó una reducción de impuestos en la importación de vehículos usados, lo cual permitió a los ciudadanos, sobre todo en Lima, a adquirirlos debido a sus bajos precios. En el transcurso de los años, el parque vehicular aumentó considerablemente, sobre todo para el uso de transporte público, vale decir el uso de los vehículos como taxi, y los buses. Esto originó no solo que las calles se vuelvan más transitadas, sino que exista una oferta excesiva del servicio público, el cual se manifiesta en la competencia por captar pasajeros en los paraderos autorizados y no autorizados. (DEXTRE 2001)

El Perú tiene como principal ciudad la capital Lima, con una población de mas de 7 millones de habitantes, y constituido mayoritariamente por gente de provincia. Este fenómeno se debe a la centralización del país, y por ende la marginación y abandono de las provincias y sus poblaciones; la falta de empleo y oportunidades finalizó en la migración de la gente de provincia a la ciudad de Lima. La no planificación de la ubicación de los nuevos pobladores en la ciudad terminó por ensanchar sus fronteras, y por lo tanto la necesidad de movilizarse a mayores distancias. Como consecuencia de lo anterior, el transporte urbano evolucionó y actualmente resulta difícil de controlarlo.

Otra de las razones por la cual las calles se congestionan es el comportamiento de los conductores y transeúntes. Los ciudadanos han adquirido una conducta de rechazo a las normas que se establecen para el normal y adecuado flujo del transporte y transeúntes. Ciertamente el acatamiento de las normas ha cobrado mayor fuerza en estos últimos tiempos a través de medidas severas tales como multas de elevada suma, pero sin embargo todavía sigue habiendo una cultura de desobediencia a las leyes de tránsito y las autoridades.

1.1.2 <u>CONSECUENCIAS DEL TRANSPORTE UBANO ACTUAL</u>

Como se comentó anteriormente, las diversas políticas aplicadas en el Transporte dieron origen a los principales males de la ciudad:

- Contaminación ambienta
- Contaminación acústica
- Consumo excesivo de combustible
- Accidentes
- Pérdida de horas-hombre

1. Contaminación ambiental

La principal fuente de contaminación ambiental son los vehículos motorizados, debido a la quema de combustible. En parte, el problema radica en la antigüedad y la falta de revisiones técnicas; pero también es producto del tiempo que están los vehículos transitando en las arterias de la ciudad.

Por el mismo hecho de tener una sobrepoblación vehicular, el control del tránsito se vuelve inmanejable, provocando congestiones y por lo tanto mayor tiempo para transportarnos en la ciudad. Junto al peligro de los gases contaminantes emitidos por vehículos de una antigüedad mayor, es que se crea mayor contaminación ambiental.

El país pierde 500 millones de dólares anuales debido a la contaminación en el transporte y tiempo perdido por la congestión, esto es según el Consejo Nacional del Ambiente-CONAM (1998).

2. Contaminación acústica

Es costumbre en todo conductor el hacer sonar la bocina del vehículo al estar frente a una congestión vehicular. Según Ordenanza Municipal, en Lima solo esta permitido un ruido de 80 decibelios en zonas residenciales, 85 en zonas comerciales y 90 en zonas industriales como máximo; pero sin embargo, en la ciudad de Lima, se puede llegar a apreciar hasta 110 decibelios; este último índice de ruido indica un nivel mucho mayor que el establecido por las normas municipales, teniendo en cuenta que las unidades usadas están en una escala logarítmica.

Las consecuencias de la contaminación acústica son graves, y pueden ser de dos tipos: físico y psicológico. En el ámbito físico, el ruido causa daño al interior del oído, llegando a provocar la sordera paulatina; con respecto al ámbito psicológico, el ruido causa trastornos conductuales tales como el stress, por ser un sonido molesto e insoportable en algunas ocasiones. (DEXTRE 2001)

3. Consumo excesivo de combustible

El consumo de combustible en exceso por parte de los automóviles que circulan en la ciudad de Lima es consecuencia directa del sobre tiempo de viaje que realizan las personas al movilizarse de un lugar a otro. Esto se agrava en los embotellamientos vehiculares, resultado de una inadecuada administración y control del flujo vehicular. Esta demostrado que un vehículo consume menos combustible cuando esta circulando a altas velocidades, preemitiéndole además ahorrar tiempo en el viaje.

4. Accidentes

El crecimiento exponencial del parque automotor en la ciudad de Lima durante la última década sin el debido orden y la sistematización pertinente ha incrementado considerablemente el riesgo de accidentes de tránsito. (MINSA 2004)

Según la División de Estadística de la Policía Nacional (2004), se estima que cada 24 horas mueren 10 personas debido a estos daños y esto nos convierte en uno de los países con la tasa de mortalidad más alta de la región. Se sabe que los mayores daños se producen en las carreteras más que en el Transporte Urbano, pero de igual manera corresponde un peligro latente. Según estimaciones, los daños por accidentes de tránsito en el Perú pueden ascender a los mil millones de dólares.

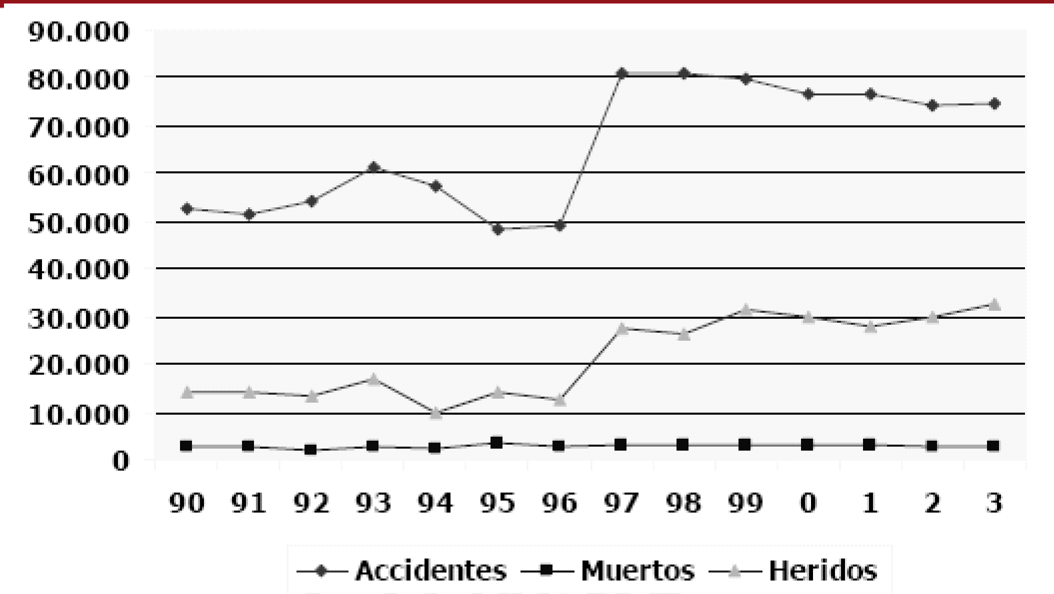

Figura 1.1 Estadística de accidentes durante las dos últimas décadas (PNP 2004)

Se puede apreciar en el gráfico como ha ido incrementándose el número de afectados por los accidentes de tránsito. Todas estas cifras corroboran el grave estado en el que se encuentra el transporte en el país. Muchos consideran que estamos ante una epidemia, y que no solo afectan a la población, sino también a la economía nacional.

5. Pérdida de horas-hombre

En la actualidad el tiempo es un factor muy valorado en el sector laboral. Una de las más graves consecuencias económicas del transporte urbano en Lima es la pérdida de horas-hombre, esto se traduce en pérdidas que ascienden a los cientos de millones de dólares para nuestra economía. Esto no es solo porque se pierde tiempo al viajar por las vías de la ciudad para llegar al centro laboral, sino también por el deterioro en la salud de la población, que tiene que soportar las consecuencias del transporte urbano.

1.2 CONTROL DEL TRANSPORTE URBANO EN LA CIUDAD DE LIMA

1.2.1 OPERADORES DEL TRANSPORTE URBANO

En la ciudad de Lima, la principal entidad encargada de regular el estado del transporte es la Gerencia de Transporte Urbano (GTU) de la Municipalidad de Lima; además de tener a su disposición la ayuda de la Policía Nacional del Perú por medio de la Dirección de Tránsito de dicha entidad.

Estas dos entidades trabajan coordinadamente para mejorar el tránsito vehicular, así también como para preservar la integridad de los transeúntes y conductores; por otro lado se tiene que cada uno maneja su propia tecnología de información y control, demostrando que la información no se comparte. El manejo individualista de la información de los acontecimientos del transporte impide que se realice una mejor labor en el control del tránsito.

1.2.2 INFRAESTRUCTURA PARA EL MANEJO DEL TRANSPORTE URBANO

En la actualidad, los esfuerzos y la decisión para mejorar el Transporte Urbano en la ciudad de Lima son notorios. Mediante proyectos de infraestructura, la Municipalidad de Lima pretende acabar con los problemas del transporte, las obras realizadas en los últimos años y los proyectos que se vienen por delante demuestran en todo sentido el compromiso de la institución.

Además de los proyectos viales, se está ofreciendo a los ciudadanos cursos de educación vial con el único propósito de reducir las faltas de tránsito y así mejorar el orden en el transporte. A pesar de todos los esfuerzos, la infraestructura que usan los operadores de tránsito para controlar el transporte en toda la ciudad no es la adecuada.

Los operadores no cuentan con la suficiente tecnología para monitorear lo que sucede en el transporte urbano, sin embargo se están realizando acciones para mejorar el manejo del tránsito en ese aspecto, y para ello cuentan con la siguiente infraestructura:

- Semáforos Inteligentes
- Circuito Cerrado de TV (CCTV)
- Controladores remotos de semáforos
- Señalización de mensaje variable
- Diseminación de Información por Internet

1. Semáforos Inteligentes

Muchas de las intersecciones de Lima no cuentan con una adecuada infraestructura de semáforos, teniendo muchos de ellos una antigüedad de más de 20 años. La ciudad de Lima cuenta con distintos tipos de semáforos: electro-mecánicos y electrónicos. La Municipalidad de Lima actualmente viene renovando su infraestructura, y para ello se esta implementado los llamados semáforos inteligentes. Aquellos semáforos trabajan de manera coordinada tal que exista un flujo rápido de vehículos.

2. Circuito Cerrado de TV (CCTV)

El Circuito Cerrado de Televisión es una infraestructura de la Policía Nacional del Perú a través de la Central 105, y que está constituida por numerosas cámaras a lo largo y ancho de los principales lugares de la ciudad de Lima. La razón primaria de tener este conjunto de cámaras es por el tema de "seguridad ciudadana". Permite a la Policía monitorear todo lo que sucede en las principales arterias de la ciudad.

Estás cámaras están situadas en lo alto de los edificios de la ciudad, y que le permite tener un panorama amplio de lo que sucede en una determinada zona, comúnmente usado para realizar seguimientos a la delincuencia común, la micro comercialización de drogas, y las manifestaciones públicas. La Central se encuentra en la Prefectura de Lima, y las cámaras están interconectadas a este local a través de enlaces microondas. Muchas veces tiene que usarse repetidores para lograr realizar el enlace debido a que existen muchos edificios altos por la zona, incrementando más el costo de la red.

El propósito secundario es el de ofrecer un panorama de lo que sucede en el tránsito, permitiendo así tomar decisiones rápidas ante un determinado incidente, ya sea un accidente o congestión vehicular. Este servicio es ofrecido al público a través de canales de cable y estaciones radiales. Diversos programas emiten imágenes del tráfico de las principales zonas de la ciudad, permitiendo al televidente tomar precauciones antes de movilizarse a un determinado lugar. También las estaciones de radio emiten información del estado de las principales avenidas para los conductores que lo estén sintonizando, esto a través de la consulta a la central 105. Las desventajas de este sistema son:

- Solo está disponible a las personan que cuentan con el servicio de cable y/o estén escuchando ciertas estaciones de radio.

- En el caso de las imágenes, solo se acceden a ellas en las mañanas y en determinados segmentos del programa.

- Para el caso de la información a través de las estaciones de radio, solo se puede acceder a determinadas horas del día, por lo general en las hora pico.

- Solo se dispone de imágenes en ciertos puntos de la ciudad, en las que se consideran las más importantes.

- La Gerencia de Transporte Urbano (GTU) no cuenta con acceso a las imágenes que la Policía Nacional obtiene.

La Municipalidad de Lima en los últimos años ha estado instalando cámaras de video en zonas que consideran importantes para monitorear, pero la cantidad de puntos que cubre no se comparan en número con las que cuenta la PNP.

3. Controladores remotos de semáforos

El DMTU cuenta con una Central de semáforos en pleno Centro de Lima, lo cual le permite tener control de la mayoría de semáforos del Cercado de Lima. Además, cuenta con un avanzado sistema que le permite sincronizar semáforos en las vías más congestionadas con la finalidad de evacuar vehículos de la manera más rápida posible. Estos semáforos conforman lo que se conoce como Semáforos Inteligentes, y que actúan conforme al fluido de vehículos a determinadas horas.

4. Señalización de Mensajes Variables

Las Señales de Mensaje Variable son paneles electrónicos que permiten mostrar todo tipo de mensajes, dependiendo de su resolución gráfica. La Municipalidad de Lima, en su plan por mejorar y modernizar el Transporte Urbano, ha adquirido e implementado una seria de paneles electrónicos a lo largo de la Vía Expresa. Estos dispositivos le permitirán al operador del tránsito mostrar todo tipo de mensajes que el conductor necesite saber, tales como algún incidente en la vía rápida.

En la actualidad, la Municipalidad de Lima cuenta con una serie de Señales Electrónicas a lo largo de toda la Vía Expresa, y que por el momento solo se encargan de mostrar información estática, es decir datos que se mantienen constantes; tales como distancia o tiempo de viaje a un destino determinado, hora actual, temperatura e información institucional.

5. Diseminación de información por Internet

Como se había comentado anteriormente, la Municipalidad de Lima cuenta con una serie de cámaras distribuida por la ciudad; pero aquellas imágenes no solo deben estar disponibles al operador, sino también al usuario del transporte. Para ello este operador cuenta con un portal Web que muestra las diferentes imágenes que las cámaras logran capturar. Hasta este momento, se sabe que el proyecto es un piloto, ya que las cámaras son reducidas y la interfase Web necesita ser mejorada.

Estamos en una época en la que cada vez son más los usuarios de Internet, lo cual se debe a la difusión de las llamadas cabinas de Internet; este fenómeno permite la aceptación del acceso a la información por medio de la Web. Es por ello que el acceso a la información a través de Internet es cada vez más difundida y por lo tanto un punto clave para la difusión de información concerniente a los intereses de la población.

Esta portal Web que ha diseñado la Municipalidad para los usuarios del transporte, se muestra muy simple y sin mayores recursos. A pesar de existir y tener acceso a las tecnologías de la información, estos no se aprovechan para mejorar la interfase que se ofrece al público. Por deberse a que están en sus comienzos, los operadores del transporte pueden aprovechar la tecnología disponible y mejorar las condiciones de acceso de parte de los usuarios a la información del tránsito. Son dos elementos que se necesitan para tener una interfaz de usuario eficiente: buenas condiciones de transmisión de datos, y un diseño de acceso (interfaz Web) que facilite la navegación a la información.

1.2.3 CONTROL DEL TRANSPORTE URBANO EN EL CENTRO HISTÓRICO DE LIMA

La función principal del DMTU es la de controlar el transporte urbano en la ciudad de Lima, sin embargo se ha tenido especial cuidado con la zona del Centro Histórico de Lima por diversas razones. La Municipalidad trata en lo posible de preservar esta zona ya que se desea recuperar el valor turístico que tenía cuando fue declarada patrimonio Cultural de la Humanidad en 1991. No solo se desea resurgir el Centro Histórico ornamentándolo, sino ordenándolo en cuanto al flujo de personas y vehículos. Esta zona es un lugar potencialmente turístico, y por lo tanto refleja y muestra el modo de vida de los peruanos hacia el mundo.

1.2.4 PROCEDIMIENTO PARA EL MANEJO DEL TRANSPORTE URBANO EN LA CIUDAD DE LIMA

Se ha elaborado un diagrama de flujo que muestra como se realiza el monitoreo y control del transporte urbano en la ciudad de Lima

MANEJO DEL SISTEMA DE TRANSPORTE EN LA CIUDAD DE LIMA METROPOLITANA

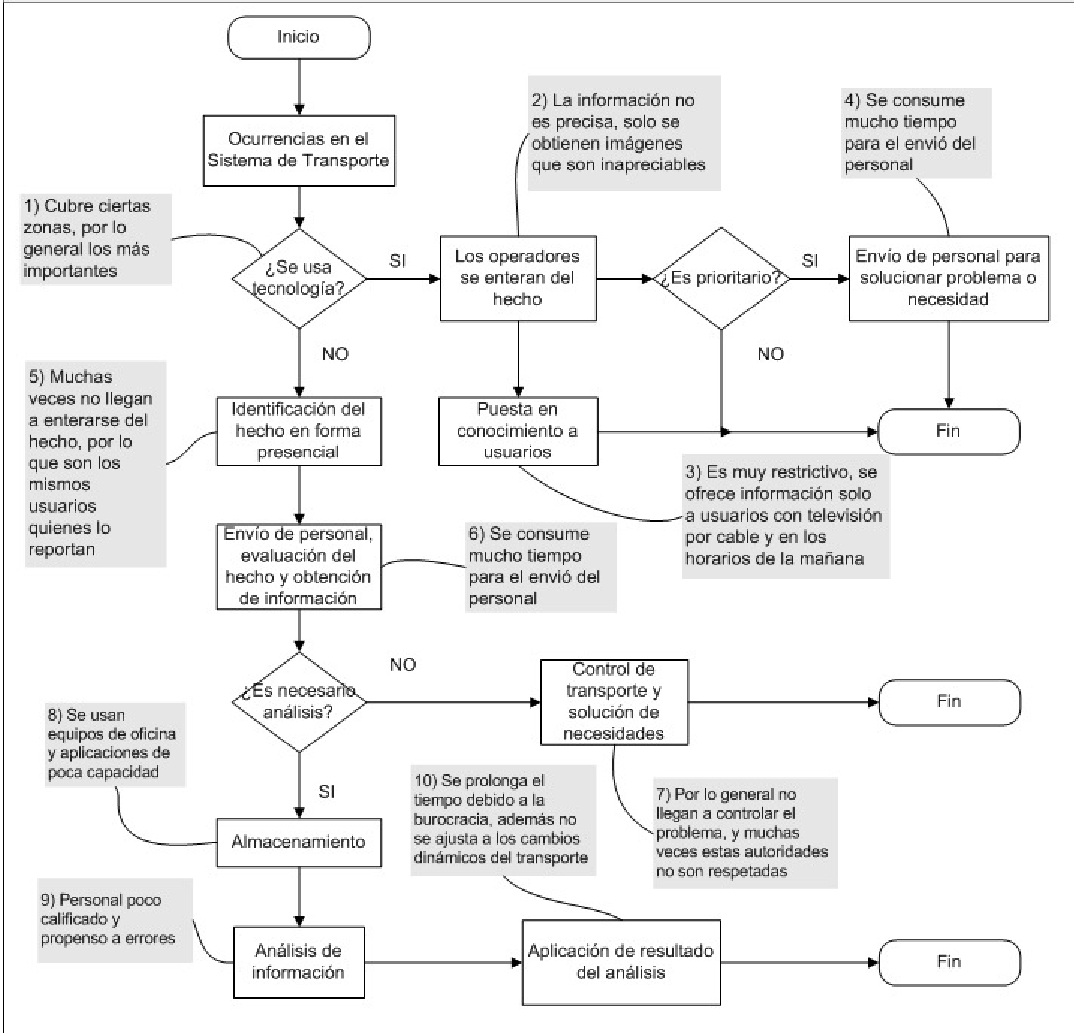

Figura 3. Variables internas.

Figura 1.2 Diagrama de flujo de administración del transporte urbano

El procedimiento de los operadores del tránsito para manejar el transporte es el siguiente:

- Se analiza si los hechos ocurridos en el transporte pueden ser captadas mediante el uso de tecnologías. En este caso, las tecnologías con las que cuentan los operadores cubren pocas áreas, y como resultado se tendrá poco conocimiento de lo que sucede en ese instante.

- Si los hechos pueden ser captadas mediante el uso de la tecnología, la misma llega a ser poco satisfactoria, es decir que el operador no llega a obtener información exacta. Por ejemplo, el operador del transporte en la ciudad de Lima puede llegar a necesitar la velocidad de un vehículo, lo cual no se obtiene con las cámaras que se tienen instaladas.

- La información que ha sido obtenida se pone en conocimiento de los usuarios, en este caso por haber sido adquirido desde las cámaras se envía dichas imágenes a las estaciones de TV para su difusión en ciertos programas. El problema está en que solo se puede dar en las mañanas y para el público que tenga servicio de cable ya que se da en espacios de dicho tipo de servicio.

- Si el hecho que ha sido registrado es de alta prioridad atenderlo, entonces se envía al personal para solucionarlo. En este caso, el envío de personal consume un tiempo considerable. Por ejemplo, los semáforos no cumplen con agilizar el tránsito, y muchas veces termina en embotellamiento por lo que son los mismos policías de tránsito quienes tienen que reordenarlo.

- En el caso de que los hechos tengan que registrarse de manera presencial, y muchas veces por medio de los transportistas y transeúntes, primero se evalúa el hecho y luego se procede a tomar acción para resolver el incidente, esto se realiza enviando al personal necesario, tomando así un tiempo considerable. Existen casos en que el hecho no se registra ni se pone en conocimiento, por ejemplo la infracción de una norma por parte de un vehículo como cruzar una intersección teniendo la luz de semáforo en rojo, esto produce que el número de infractores crezca y el transporte empeore.

- En el caso que los hechos ocurridos tengan que ser evaluados a largo plazo, los datos se almacenan y se procede a su análisis. Esto ocurre por ejemplo cuando se trata de hacer mejoras en el control del tránsito tales como mejoramiento de los tiempos de semáforo o implementar nuevas señalizaciones. Este análisis suele tomar tiempo ya que primero se recoge los datos a través de envío de personal, y luego son almacenados en el centro de operaciones para su posterior análisis. El resultado del análisis se pone en prueba dependiendo de la eficacia de la burocracia.

Como se puede apreciar, los problemas que aqueja el transporte radican en la manera de cómo se envía la información, ya sea de muestreo o de control. Esto se debe al uso de técnicas obsoletas y a la poca iniciativa que tienen los gobiernos e instituciones locales para mejorar la tecnología actual.

1.2.5 PLANES Y PROYECTOS PARA EL FUTURO DEL TRANSPORTE URBANO EN LIMA

Son muchos los esfuerzos que está realizando la Municipalidad de Lima para mejorar las condiciones de control del Transporte. En la actualidad, planean la modernización del transporte Urbano, que incluye no solo infraestructura tecnológica, sino también el desarrollo vial.

No es parte del documento el tema del desarrollo vial, sin embargo se comenta algunos proyectos que demuestran el interés por parte de los operadores del transporte con respecto al mejoramiento de la red vial y el ordenamiento del tráfico. Uno de los actuales proyectos es la Vía Expresa de Grau, infraestructura que ayudará a mejorar el flujo en la zona más congestionada del Centro de Lima. La terminación del tren Eléctrico es uno de los mayores retos ya que solucionará el problema del transporte público. Además se tiene el proyecto a futuro de los buses subterráneos de la Vía Expresa, el cual representa un gran reto para el gobierno local.

Sin embargo cabe mencionar que la solución no solo está en el aumento de más vías de tránsito. Está demostrado que aquello no mejora el tráfico vehicular, y que en muchos casos resulta ser peor que lo inicial. Son muchos factores los que intervienen en el mejoramiento del tránsito, y uno de ellos es el control constante del mismo. Si se tiene una infraestructura tecnológica que mantenga el orden vehicular, se podrá tener una mejor administración de las vías, y por lo tanto un eficiente uso de ellas.

Entre los planes del gobierno local para el desarrollo del Sistema de Transporte, la Municipalidad de Lima ha convenido dar en Licitación Pública el proyecto de "Semaforización y Control de Tránsito en la ciudad de Lima". Este proyecto representa el uso de tecnologías sofisticadas para el control de tránsito, a través de la implementación de sistemas inteligentes que puedan administrar mejor el transporte.

CAPÍTULO II

LOS SISTEMAS DE TRANSPORTE INTELIGENTE

ITS es la unión de tecnologías de información y comunicación entre los vehículos y las redes que transportan personas y bienes. "Inteligente" porque ellos brindan conocimiento extra de pasajeros y operadores; ITS ayuda a los conductores a navegar tan bien como para evitar el tráfico y los accidentes. Sobre los trenes y buses, permiten manejar óptimamente la operación de toda la flota y ofrece a los pasajeros boletería automática e información en tiempo real. Sobre las redes viales, ayuda a coordinar las señales de tráfico, detecta y maneja incidentes, muestra información y guía a los conductores, y salva vidas. (ERTICO 2005)

En este capítulo se presenta las principales tecnologías usadas en el Sistema de Transporte inteligente, sus características y beneficios; específicamente para las zonas urbanas. Cabe resaltar que existe infinidad de servicios que se pueden implementar y que no son considerados por ser redundantes en cuanto a funcionamiento en una red, es decir las mismas características en transmisión de datos.

2.1 PRINCIPALES SERVICIOS DEL SISTEMA DE TRANSPORTE INTELIGENTE

2.1.1 CONTROL DE SEÑALES DE TRÁFICO

1. Descripción

Es un sistema usado para la sincronización de tiempos de un determinado número de señales de tráfico en un área de constante tránsito, y cuyo objetivo principal es la de reducir los retrasos vehiculares provocados por el cruce de dos vías, maximizando de esta manera el tiempo de viaje. El control de estas señales varía en tipo y complejidad, se tiene desde los más simples que usan datos recolectados para configurar los planes de tiempo, hasta los más complejos como el control de señales adaptativo que usa información del tránsito en tiempo real para optimizar los planes de tiempo en una red de señales de transito.

Mientras la población aumenta en número, la demanda por el uso de nuestro sistema de transporte actual será difícil de satisfacer. La expansión de las vías de tránsito no es una solución viable debido al alto costo, por lo que el desarrollo de sistemas inteligentes tales como un control de señales de tráfico avanzado sería crítico para el aprovechamiento de la máxima capacidad de nuestro sistema de vías. En la actualidad, una pobre señalización provoca la pérdida de tiempo, combustible y dinero.

2. Terminología

La operación de las señales de tránsito se puede describir en términos de longitud de ciclo, fases de señal, y offsets. La longitud del ciclo es el tiempo requerido para una secuencia completa de las fases de señalización y está típicamente entre los 60 y 120 segundos para una intersección de 4 sentidos. El offset entre señales de tráfico sucesivos es el tiempo de diferencia entre el comienzo de la fase de verde de una intersección en un sentido y el comienzo de la fase de verde de la otra intersección en el otro sentido.

3. Alcances de control

Las señales de tránsito pueden operar independientemente o como un sistema. Se puede agrupar el alcance de las señales de tránsito en tres categorías:

- Control de Intersección Individual: Una sola señal de tránsito opera en modo pre-configurado o actuado por tráfico; ello sin afectar la operación de otras señales de tránsito.

- Control Arterial: Dos o más señales de tránsito operan de manera síncrona a lo largo de una calle en modo pre-configurado o actuado por tráfico.

- Control de red: Las señales de tránsito comprendidas en una red entera de intersecciones están coordinadas a través de un plan de señalización, o una estrategia de control adaptativo.

4. Estándares de los controladores de tráfico

Estos estándares son usados para las especificaciones técnicas de los controladores de señales en intersecciones. Es importante considerar antes de implementar una estrategia de control de señales de tráfico la capacidad de los controladores de tráfico existentes, ya que existen modelos de estos dispositivos que posiblemente no soporte la cantidad de datos que se requieren procesar. A continuación los estándares más importantes en lo que respecta a controladores de señales de tráfico:

- NEMA TS-1: El primer controlador de tráfico definido y aceptado en la industria del transporte, esta basado en conformidad con el estándar de los conectores eléctricos y mecánicos. Su arquitectura se basa en una relación cercana al usuario, el cual no permite que se cambie ni el software, hardware o la funcionalidad del producto.

- Caltrans 170: Creado por el Caltrans en los años 1970s, este controlador no solo fue definido en el estándar de su interfase, sino también en el procesador que se usaría y el mapa de memoria. Esto permitió que los desarrolladores de software crearan sus propios productos, y los operadores de tránsito se beneficien con múltiples vendedores de hardware y software. Sin embargo este producto se está desactualizando ya que no son capaces de soportar los nuevos estándares.

- NEMA TS-2: Con la necesidad de crear un nuevo controlador, NEMA publicó las especificaciones TS-2 en 1992. Este sistema utiliza una arquitectura de salidas y entradas seriales para proveer modularidad y expansibilidad para los detectores de entrada y salida. La arquitectura TS-2 se mantiene vinculado con el integrador, por lo que las limitaciones inherentes de un sistema cerrado prevalecen. A pesar de que estas especificaciones se aplicaron desde 1992, muchos creen que el estándar Caltrans 170 evitaría su amplia adopción.

- Caltrans 2070: El modelo del controlador de tráfico Caltrans 2070 ATC es un nuevo intento de satisfacer las grandes demandas de un sistema de control urbano avanzado e inteligente y de aplicaciones que requieren gran rendimiento y flexibilidad que solo les puede ofrecer este nuevo controlador.

- NTCIP: Se define protocolos de aplicación para la correcta interpretación de la información durante la comunicación entre controladores y el sistema de control.

2.1.2 <u>MONITOREO DE TRÁFICO</u>

El monitoreo del tráfico juega un rol muy importante en un Sistema de Transporte Inteligente ya que nos permite detectar incidentes, controlar el tráfico y recolectar datos para difundirlos. Los principales elementos en el sistema de monitoreo se encuentran dispuestos en las vías, ya que es preciso detectar los vehículos y transeúntes.

Son varias formas y tecnologías que se usan para poder implementar un sistema de monitoreo, por ejemplo se tiene los bucles inductivos, los cuales están siendo menos usados y reemplazados por nuevas tecnologías tales como detección por imágenes de video o por señal de radar. Se mencionarán algunos términos usados en estos dispositivos:

- Zona: Es un área en el cual los parámetros de tráfico son medidos. Una zona es una representación abstracta de un área que es independiente de la tecnología.
- Zona Virtual: Es una terminología usada para identificar una zona que es creada por el resultado de la combinación lógica de dos zonas físicas, mediante operadores lógicos tales como “AND” y “OR”.
- Sensor: Es un dispositivo físico usado para sensar tráfico. Un sensor es capaz de proveer una o más zonas de detección.

2.1.3 VIGILANCIA POR VIDEO

Los Circuitos Cerrados de TV (CCTV) son una pieza fundamental en lo que respecta a un Sistema de Control de Tráfico. Un primer beneficio de un CCTV es la capacidad de proveer información visual requerida para tomar decisiones rápidas en caso de algún incidente en el tránsito o algún desperfecto en el funcionamiento del sistema. Los CCTV son muy usados en la vigilancia de autopistas y zonas urbanas, para verificar si se ha producido accidentes de tránsito, incluso para responder a sucesos imprevistos tal como apoyar la seguridad ciudadana. En resumen se puede decir que las cámaras son útiles para realizar las siguientes tareas:

- Monitorear el movimiento del tráfico en las autopistas y vías urbanas.
- Verificar las Señales de Mensaje Variable.
- Verificación de estancamiento por fallas mecánicas de motoristas o por accidentes.
- Observar el clima local y otras condiciones peligrosas.

Actualmente se está implementando avanzados sistemas de vigilancias con cámaras de video para el control de tráfico. Una de las más recientes tecnologías usadas en una red de comunicación para los Sistemas de Transporte Inteligentes es el video digital, y que se cree será la tecnología predominante en las siguientes décadas para los sistemas de vigilancia por video. Una de las razones por las cuales se adopta el uso de este producto es por la conformación de la red en la que se implementa este sistema, el cual es netamente digital. Sin embargo por motivos de costos muchos operadores de tránsito se rehúsan a dejar el video analógico.

Muchas de las redes de video son analógicas, tanto en aplicaciones de transporte como en otras industrias, y que están típicamente basados en el uso de la técnica de transmisión por multiplexación de división de frecuencia (FDM). Está demostrado que el video analógico ofrece alta calidad en las imágenes y un relativo costo bajo. Teniendo esto en consideración, se verá el uso de este sistema analógico por muchos años más. Sin embargo debido a que las agencias de transporte están implementando redes digitales, el uso del video digital será en un futuro ampliamente usado a pesar del costo que representa; esto será posible con el surgimiento de nuevos estándares para la compresión de video como es el MPEG.

Se mencionará algunos beneficios del uso de un sistema de video digital para las agencias de transporte:

- La capacidad de interconectarse con una red pública de telecomunicación y compartir información con otras agencias de transporte.

- La capacidad de la red de no solo transportar video, sino voz y datos.

- La capacidad de transportar información a grandes distancias sin preocuparse por la degradación de la señal.

- La posibilidad de manipular e interpretar las imágenes de video usando sistemas computarizados.

- El deseo de adquirir tecnología que no se vuelva obsoleta en el futuro, es decir proteger la inversión que se realiza.

En el caso de video analógico, los estándares más usados son el PAL y el NTSC, dependiendo en que zona o país nos encontremos. Para un medio digital lo que se suele hacer es codificar las imágenes analógicas a un formato de compresión digital; en la actualidad el formato estándar es el MPEG y que comprende muchas versiones los cuales han ido mejorando según la versión. Además la cámara no solo envía imágenes, sino que recibe señales de control para el cambio en sus parámetros mecánicos, y que son el pan, tilt y zoom. El pan y tilt se refieren a los movimientos verticales y horizontales que realiza la cámara para ajustar la dirección de visión; mientras que el zoom es el ajuste del área de visión de la cámara.

A continuación se detalla los estándares de compresión más usados actualmente:

Esquema de compresión digital	Velocidad requerida (Mbps) *	Compresión espacial	Compresión temporal	Tamaño de cuadro	Cuadros por segundo
MPEG-1	0.4 - 1.5	Si	Si	352x240	25 - 30
MPEG-2	3 - 100	Si	Si	720x480	25 - 30
MPEG-4	0.5 – 1.2	Si	Si	720x480	25 - 30
M-JPEG	1 - 100	Si	No	160x120 – 640x480	1 - 30
H-261	1.5 - 2	Si	Si	176x144 – 352 x288	10 - 30
H-263	1.5 - 2	Si	Si	128x96 – 1408x1152	10 - 30
Fractal	0.1 - 4	Si	Si	160x120 – 640x480	8 - 30
Wavelet	0.1 - 4	Si	Si	160x120 – 320x240	8 - 30

* Para aplicaciones típicas

Tabla 2.1 Características de los formatos de compresión (obtenido del reporte “Digital Video for ITS”, por Mick Chawner en agosto de 1999)

2.1.4 **ALMACENAMIENTO DE DATOS DE TRÁFICO**

Los centros de control de tráfico colectan información de incidentes del tránsito acerca del sistema de transporte, estos datos son combinados con otros datos de control y operación de tal manera que se pueda controlar el transporte y además producir información para público. Almacenar esta información es una manera efectiva de dejarlo a disposición de los operadores que desean realizar mejoras en su sistema de transporte.

La información recolectada incluye generalmente:

- Volúmenes de tráfico de vehículos.
- Incidentes de tráfico (número de carriles bloqueados, accidentes, embotellamiento).

Y también pueden incluir:

- Velocidad de vehículos.
- Tiempo de viaje.
- Programación de zonas de trabajo (posición, número de carriles bloqueados, duración de los trabajos).

- Emisión de vehículos.
- Clasificación de vehículos (porcentaje de camiones por ejemplo).

Almacenar dicha información provee una manera efectiva de obtener datos que pueden ser útiles para los planificadores, diseñadores, e investigadores en el transporte con múltiples propósitos. Los datos pueden ser usados para el diseño y planificación de infraestructura, estrategias de control, seguimiento de congestión, modelamiento de emisiones, y programación de mantenimiento y construcción. Las centrales de control de trafico pueden usar esta información en particular para analizar el rendimiento de las medidas, determinar la mejor manera de manejar las crisis, y por último desarrollar nuevas tecnologías que permita mejorar el rendimiento del sistema de control de tráfico.

2.2 MODELO TEÓRICO

Con el fin de tener un eficiente uso de las vías de transporte es que surgen los Sistemas de Transporte Inteligentes. En estos días en la que el uso del transporte está creciendo vertiginosamente y la demanda por un control adecuado es indispensable, los operadores del transporte creen conveniente instalar equipos que permitan recolectar datos del tránsito, realizar el control del tráfico y tener un monitoreo constante de todo lo que sucede en las vías.

Cada día son mayores las necesidades del transporte, por lo que dichos equipos necesitan enviar información en tiempo real, de manera rápida, y con el menor error posible hacia las salas de control donde se encuentran los operadores y muchas veces hasta el mismo usuario, todo ello con la finalidad de responder rápidamente a los cambios que surgen en el tránsito y tener así un eficiente flujo de vehículos en las ciudades y autopistas. Para ello es que se constituyen infraestructuras de red a lo largo de las vías en donde se instalarán los dispositivos actuadores en la regulación del transporte. Con el avance de la tecnología, estos dispositivos son capaces ahora de enviar no solo valores numéricos, sino también voz y video.

Durante los inicios del sistema surgió una diversidad de servicios que podían implementarse para satisfacer las necesidades del transporte, de los cuales eran incompatibles entre sí en cuanto a las exigencias de interconexión, todos ellos usaban diferentes estándares de comunicación. Es por ello que se usaban diferentes plataformas de red, en las cuales se implementaban los diversos servicios que se usaban. Datos, voz y videos se transferían en diferentes infraestructuras de red, con lo cual se acrecentaban los costos en la implementación, haciéndolo inatractivo su uso e implementación.

En la actualidad el surgimiento de tecnologías de vanguardia en las telecomunicaciones hace que esta desventaja se supere, logrando implementar redes capaces de transferir datos, voz y video en una misma infraestructura de red; de esta manera se consigue una red capaz de converger y de satisfacer las necesidades de comunicación en un Sistema de Transporte Inteligente, transfiriendo información a velocidades altas y con una alta confiabilidad.

Las tecnologías ATM, SONET/SDH, DWDM, y Ethernet son las tecnologías que conforman las redes de área metropolitana, ya que cubren un área de mayor extensión que las redes de área local. Son aquellas redes las que sirven como plataforma para la implementación de los Sistemas de Transporte Inteligente. El estándar Ethernet ha logrado posicionarse con éxito en las redes locales, debido a su confiabilidad, flexibilidad, simplicidad, y primordialmente por su escalabilidad. Ciertamente Ethernet ha evolucionado con mucha rapidez, hasta el punto de alcanzar velocidades muy altas, nunca antes alcanzadas por otras tecnologías. Actualmente Ethernet está implementándose en las redes metropolitanas y se espera que se cubra también las redes de área amplia.

Por lo tanto, el Sistema de Transporte Inteligente en el Centro Histórico de Lima tendrá como plataforma una red metropolitana basada en tecnología Ethernet. Para alcanzar un buen desempeño de la red; lograr un ancho de banda capaz de soportar datos, voz y video; y además lograr expandirse hacia áreas extensas comparadas a una ciudad. Se tendrá en cuenta en el análisis el uso de fibra óptica, cobre y radio frecuencia como medios de transmisión, todas ellas soportadas por la tecnología Ethernet.

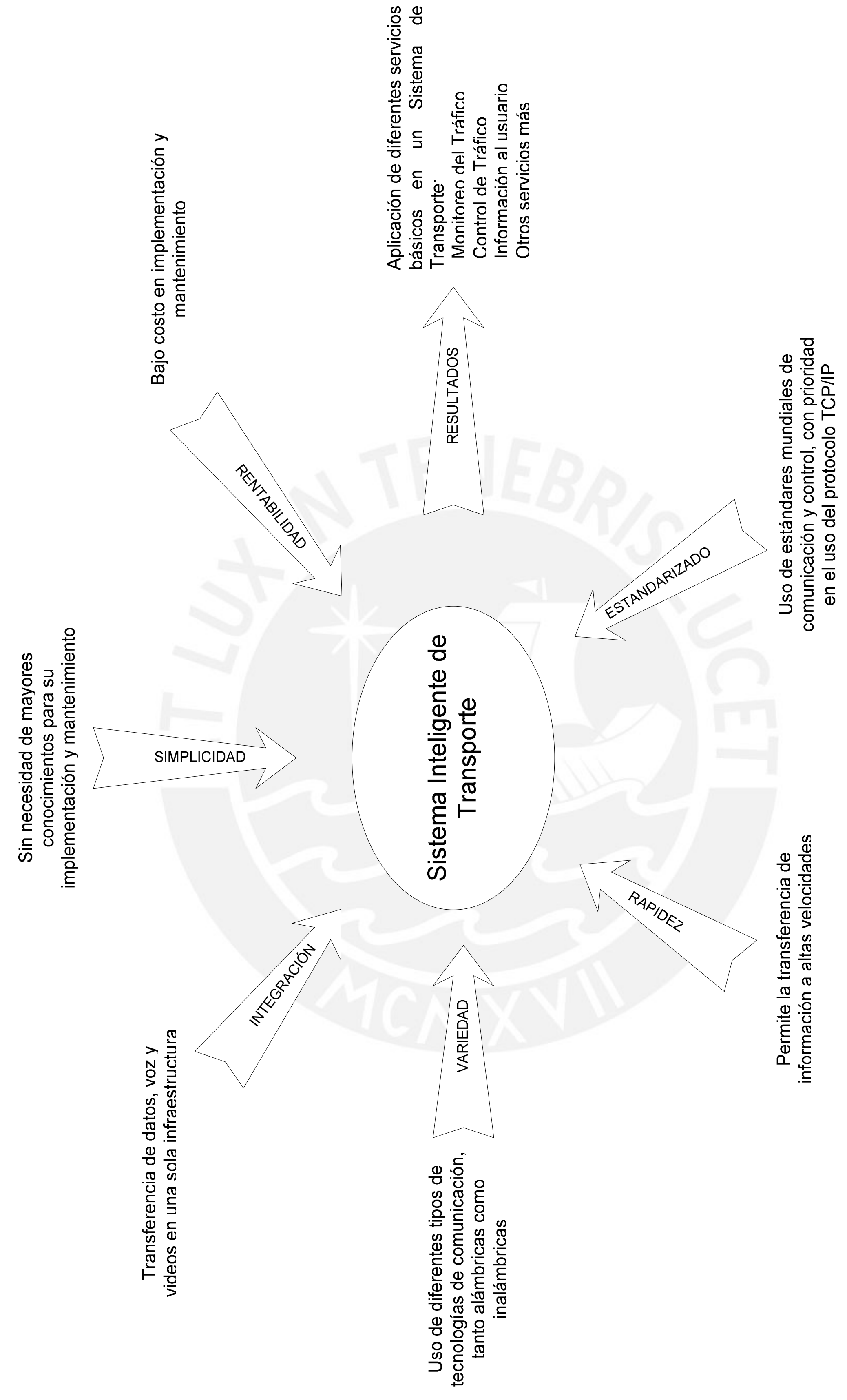

Figura 2.1 Modelo Teórico

CAPÍTULO III
ANÁLISIS DE DATOS Y REQUERIMIENTOS

3.1 UNIVERSO Y MUESTRA

3.1.1 CENTRO HISTÓRICO DE LIMA

La Municipalidad Metropolitana de Lima tiene a su cargo el control del tránsito en todas las arterias que conforman el Centro Histórico de Lima o Lima Cuadrada. Por lo tanto el presente proyecto será aplicado a esta zona cuyos límites están comprendidos por la Av. Abancay, Av. Tacna, Av. Wilson, Av. Gracilazo de la Vega, Av. Paseo Colón, Av. Paseo de la República, Av. Nicolás de Piérola y parte de la Av. Manco Capac.

3.1.2 AVENIDA ABANCAY

Para simplicidad del análisis, se pondrá énfasis en la Avenida Abancay y alrededores, el cual es la vía más importante del Centro Histórico, siendo ésta nuestra muestra en donde los resultados que se obtengan serán de validez para el resto de vías que no han sido consideradas. Los operadores del tránsito de Lima realizan su control en base al comportamiento de una determinada zona, en este caso la zona esta determinada por una avenida, calle o jirón; es por ello que la muestra estará dada por la avenida más larga y congestionada de Lima.

3.2 PRESENTACIÓN DE DATOS

3.2.1 NECESIDADES Y REQUERIMIENTOS DEL TRANSPORTE URBANO

Se tiene conocimiento que la Municipalidad de Lima pretende implementar una nueva infraestructura para el control del Transporte Urbano ya que en la actualidad la tecnología usada no se adapta a las necesidades del tránsito.

Para determinar los requerimientos de los operadores de tránsito se tuvo que estudiar la manera cómo ellos realizan el control del transporte; y según lo establecido en el primer capítulo, se llega a las siguientes conclusiones:

- Para el control de las señales de tránsito, se configuran de manera remota los tiempos de actuación de aquellos, esto desde la central de control de tránsito. Los cambios se basan en un estudio del tráfico hecho previamente a los cambios. Estos cambios solo se aplican a las principales arterias ya que no todos cuentan con este sistema. Para los que no cuentan con un enlace a la central, una persona tiene que ir físicamente al lugar en donde actúa el dispositivo y realizar el cambio manualmente.

- El estudio del tráfico se realiza mediante el conteo de vehículos a diversas horas del día y durante todos los días de la semana. Para ello se envía personal a las principales arterias de la ciudad de tal manera que se realiza el conteo manualmente.

Como se pudo apreciar el sistema solo consta de semaforización, más no de otros servicios que surgieron para el mejor control del tráfico y que existen en otras urbes. Por lo tanto en los requerimientos del transporte se considerará los servicios más usados y básicos que existen en la actualidad. A partir de lo que se pudo observar se presenta los principales requerimientos del Transporte Urbano en Lima:

- Sistema de Semaforización moderno, esto permite un mejor control del tránsito operándolo de manera remota y en tiempo real. Además podrá trabajar con diversas tecnología tales como sensores de tráfico de tal manera que actúe de forma autónoma.

- Sistema de adquisición de datos, esto evitará usar personal y ahorrar tiempo en la recolección de datos, ya que se hará en tiempo real y podrá almacenarse para un análisis en tiempo real o posterior. Esto se logra mediante el uso de sensores de tráfico, ubicados en los puntos en donde sucede el tráfico.

- Vigilancia por cámaras, no solo para tener un panorama del transporte sino también para la seguridad ciudadana. Como se sabe la Dirección de Seguridad de la PNP cuenta con cámaras de video en todo el Centro Histórico de Lima, pero cuya información no es compartida con la Gerencia de Transporte Urbano.

- Almacenamiento masivo, de tal manera que los datos recolectados puedan estar disponibles para un análisis en tiempo real o posterior.

- Herramientas para el procesamiento de datos, control y monitoreo del tránsito, esto se logra a través del uso de servidores y estaciones de trabajo.

- Infraestructura de red, para la interconexión de los diferentes elementos que actuarán en el sistema. Se necesita que la red sea un medio compartido de tal manera que todos los equipos puedan enviar y recibir información a través de una sola infraestructura.

No obstante, se tiene que considerar futuras aplicaciones para el Sistema de Transporte Inteligente, ya que la idea es integrar todos los servicios en una sola infraestructura.

3.2.2 INFRAESTRUCTURA DE SOPORTE

La Municipalidad de Lima cuenta con locales de infraestructura para el desarrollo e implementación de tecnologías que permitan el control del transporte urbano, además de elementos necesarios que facilitarán el diseño e implementación de un Sistema de Comunicación en el Cercado de Lima:

1. Central de Control de Tráfico

La Municipalidad de Lima cuenta con un local destinado a ser el Centro de Control de Tráfico, y en donde residen los equipos de control maestro del sistema de semaforización actual. Este local se encuentra ubicado en el Jirón Lampa #971, en pleno centro de Lima, y tiene acceso a los ductos de comunicación que existe en Centro Histórico de Lima, destinada actualmente al sistema de semaforización.

Como se puede apreciar en la figura, se tiene un bosquejo de lo que es actualmente la central de tráfico, y cuyas medidas son aproximadas a las reales. La Sala de Control tiene una altura de 5 metros, al igual que los dos niveles que funcionan como almacén y laboratorio, cada uno con 2.5 metros de altura y que pueden funcionar como cuarto de equipos.

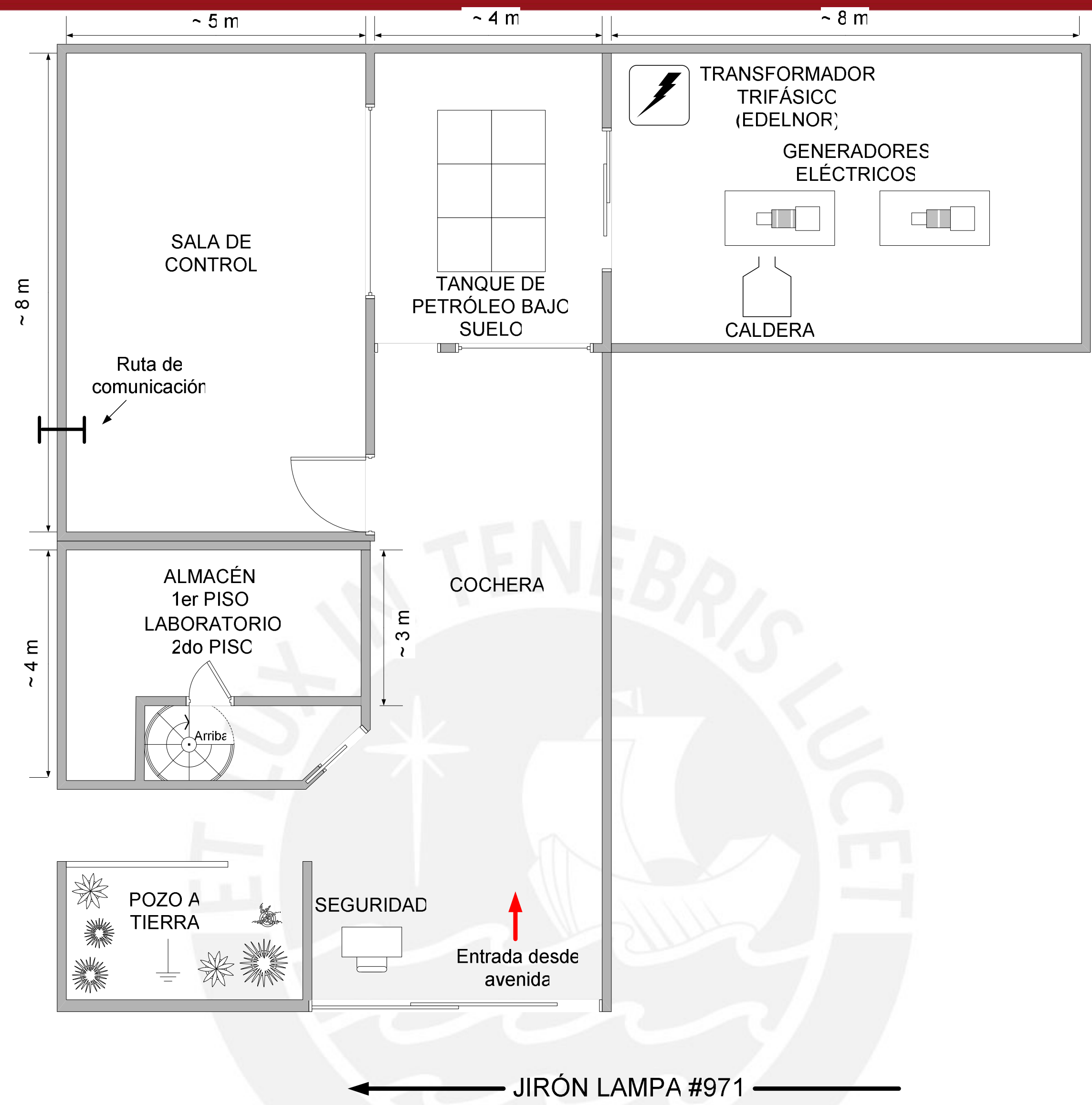

Figura 3.1 Esquema del local de la central de tráfico

También se puede apreciar en la sala de control el acceso hacia el sistema de ductos de comunicación del sistema. Al lado de la sala de control se encuentra un patio de aproximadamente 20 metros cuadrados, en el cual se ubica un tanque bajo suelo, destinado al almacenamiento de petróleo. Luego, al lado del patio, está una sala que funciona como almacén, pero cuyo propósito principal es la de albergar la planta de energía requerida por el Sistema de Semáforos y la Central de Tráfico. En esta sala se ubica un transformador trifásico de energía pública (Compañía Edelnor), dos generadores eléctricos y una caldera que sirve para la combustión de petróleo, necesario en la generación de energía. Además, la Central cuenta con su propio pozo de tierra, ubicada en el pequeño jardín, al costado de la puerta principal. Este local cumple con los requerimientos de seguridad, ya que cuenta con vigilancia las 24 horas, y su estructura esta protegida en caso de intentos de robo y atentados.

2. Ductos de comunicación

A comienzos de los años 90 la Municipalidad de Lima inició la construcción de canales subterráneos a lo largo de todo el Centro Histórico de Lima el cual permitiría implementar la red para el Sistema de Semaforización Centralizada. Actualmente es usada para este propósito. Para mayor detalle véase el Anexo 4.

Como se muestra en la Fig. 4.3, los ductos traspasan diferentes zonas en la ciudad, tales como veredas, jardines y asfaltado. La canalización está implementada por medio de tubo PVC de 3'', además de cajas de paso de 0.5 x 1 metros según la Fig. 4.2, espaciados a distancias que varían entre 20 a 50 metros, permitiendo de esa manera realizar el tendido de cualquier tipo de medio de transmisión.

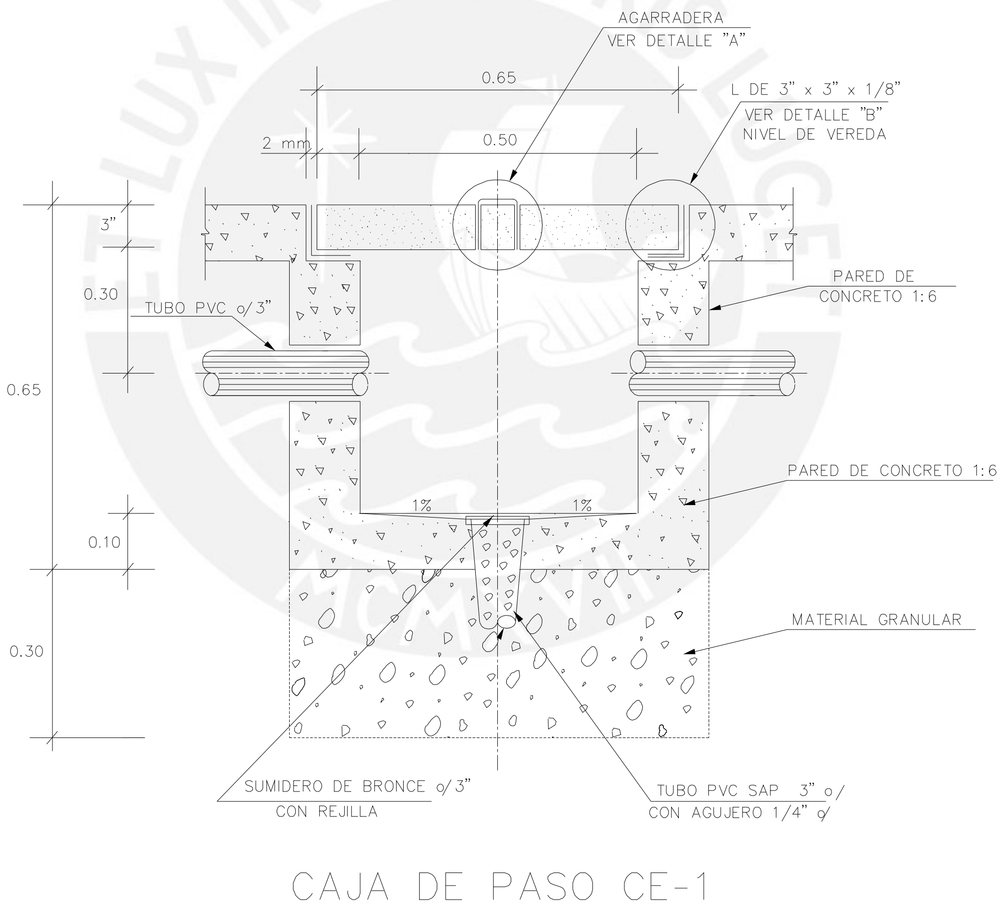

Figura 3.2 Detalle de caja de paso en la canalización

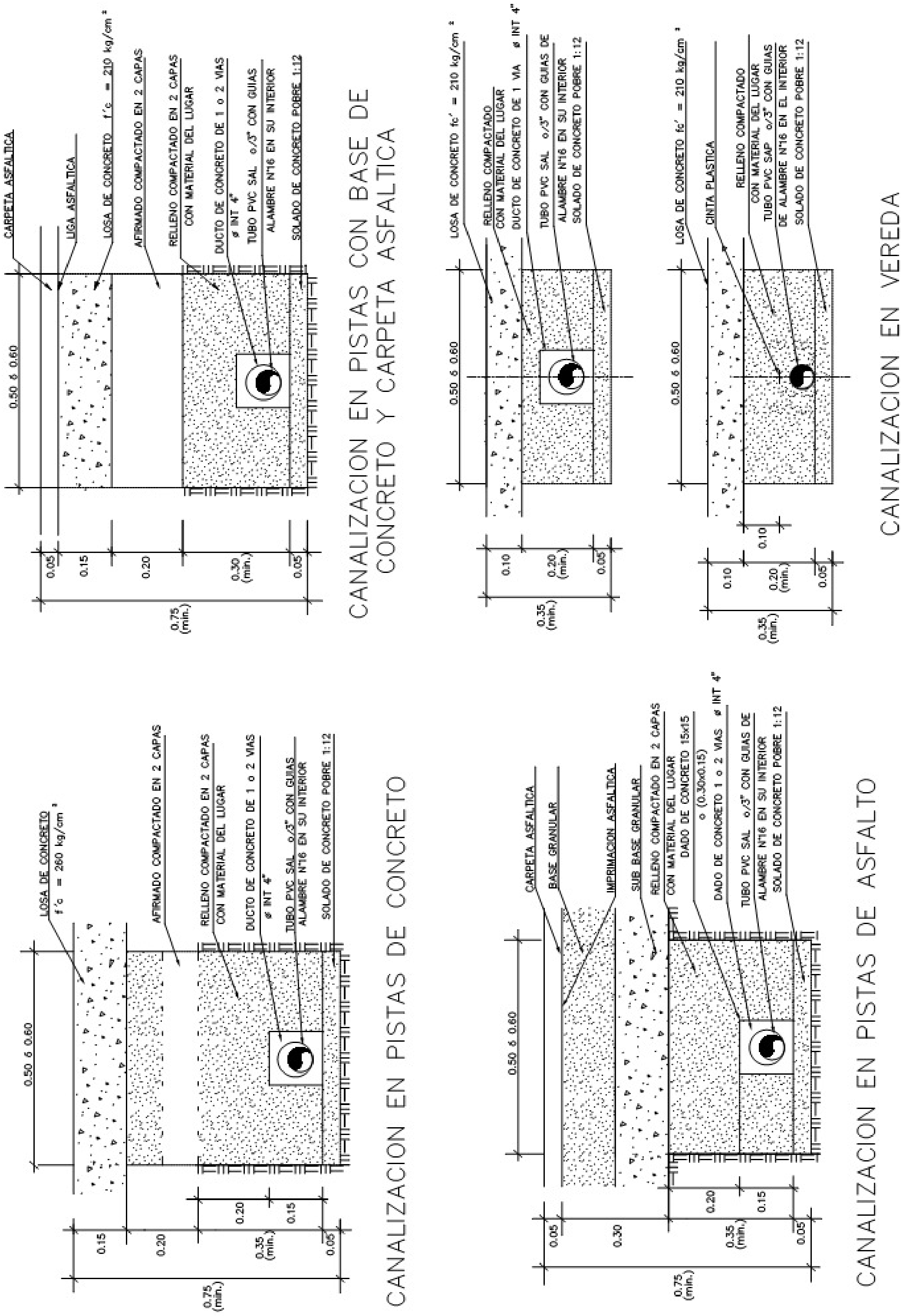

Figura 3.3 Canalización existente en el Cercado de Lima

3. Pozos de tierra

Cuando se produce una falla en los equipos electrónicos, la corriente eléctrica retorna a la fuente de suministro si éste no encuentra una conexión a tierra. Esto puede dañar tanto al equipo como a la persona que este operándolo. Por ello es que los pozos de tierra son de suma importancia en los sistemas electrónicos, más aún cuando se trata de equipos muy sensibles como son los que se usan en una red de comunicación.

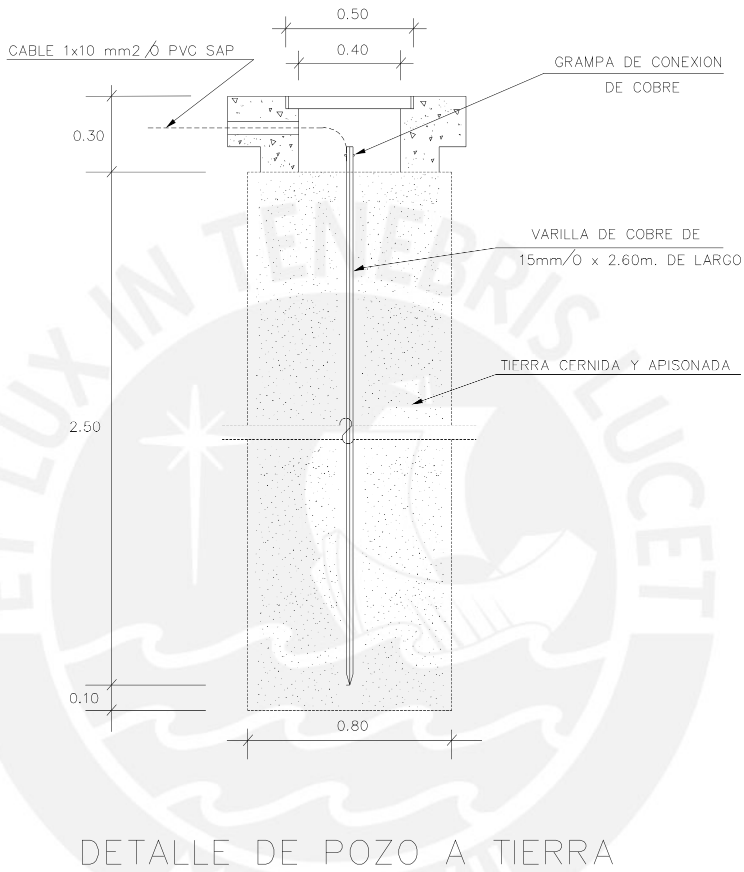

Figura 3.4 Detalle del perfil de excavación de los pozos de tierra

Como se puede apreciar en la Fig. 3.4, se tiene un pozo de tierra usado para la protección de los equipos actuales de control de semáforos. Estos están ubicados no solo en la Central de Control, sino también en las intersecciones del Centro Histórico de Lima, los cuales brindan protección a los equipos que controlan el tráfico y sobre todo a los transeúntes que circulan por la zona, debido a que la caja y poste que albergan estos equipos son de metal. Está conformado por una barra de cobre (electrodo), enterrado en el suelo por medio de tierra cernida, y mezclada con productos químicos que le dan menor resistividad al pozo a tierra.

3.2.3 ELEMENTOS QUE ACTUARÁN EN EL SISTEMA

Se tiene entendido que la Municipalidad de Lima no cuenta con tecnología moderna que permita implementar un Sistema de Transporte Inteligente. Por esta razón es que se propondrá algunas tecnologías que ofrezcan servicios capaces de cumplir los requerimientos establecidos.

Según lo dispuesto en las necesidades y requerimientos de los operadores de tránsito, se puede establecer que las principales tecnología a usar y que se detallará mas adelante son las siguientes:

1. Equipos de campo

Entre los equipos de campo, es decir los equipos que actuarán en el monitoreo y control de tránsito, están los controladores de señal de tráfico, los sensores de tráfico, y las cámaras de video. Existen otros equipos y dispositivos que permiten ofrecer infinidad de servicios para el transporte urbano, hoy existentes en ciudades modernas, pero que no serán considerados ya que aquello forma parte de un planeamiento estratégico de parte de los operadores de transporte y todos los que están relacionados a ello. Cabe resaltar que el objetivo principal es el de soportar los servicios básicos, pero también existe la posibilidad de adicionar servicios ya que la idea es el de diseñar una red que converge a nuevos requerimientos.

Uno de los datos necesarios para poder realizar el diseño de la red es la ubicación de los equipos de campo:

- Cámaras de video: La ubicación de los semáforos es información clave para el diseño de la red, ya que estos equipos son los que generan mayor tráfico en una red y su análisis en el diseño es vital. Para ello se consultó con las autoridades de la Central 105 de la PNP (Policía Nacional del Perú), ya que son ellos los que actualmente cuentan con cámaras de video en la ciudad de Lima, y su criterio en el diseño del Sistema de Vigilancia es importante para poder construir la red de datos. Analizando la zona del Centro Histórico de Lima junto con los operadores del Sistema de Vigilancia de la Central 105, se determinó en donde se ubicarían las cámaras de video, considerando la cantidad de tráfico y la tasa de delincuencia, además de la importancia de la zona.

Cámara	Ubicación	Motivo
1	Jr. Lampa y Av. Colmena	Vigilancia de zona de alto tráfico y de JNE (Jurado Nacional de Elecciones).
2	Jr. Carabaya y Av. Colmena	Vigilancia de zona de tráfico moderado y de la Plaza San Martín
3	Av. Nicolas de Piérola y Av. Abancay	Vigilancia de zona de alto tráfico y del Parque Universitario
4	Jr. Montevideo y Av. Abancay	Vigilancia de zona de alto tráfico (centro de agencias de transporte interprovincial).
5	Av. Emancipación y Av. Abancay	Vigilancia de zona de alto tráfico, del Ministerio Público y de alta tasa delincuencial.
6	Jr. Junín y Av. Abancay	Vigilancia de zona de alto tráfico y del Congreso de la República.
7	Jr. Amazonas y Av. Abancay	Vigilancia de zona de tráfico moderado y parte del límite entre el Cercado y el Rimac.
8	Jr. Ucayali y Jr. Azángaro	Vigilancia de entrada a Palacio de Gobierno.
9	Jr. Miro Quesada y Jr. Lampa	Vigilancia de zona de tráfico moderado y centro financiero.
10	Jr. Carabaya y Jr. Junín	Vigilancia de la Plaza de Armas, Palacio Municipal y Palacio de Gobierno.
11	Jr. Ancash y Jr. Lampa	Vigilancia de zona de alta tasa delincuencial.
12	Jr Carabaya y Av. Emancipación	Vigilancia de zona de tráfico moderado.
13	Jr. Cailloma y Av. Cusco	Vigilancia de zona de alta tasa delincuencial.
14	Jr. Rufino Torrico y Jr. Ica	Vigilancia de zona de alta tasa delincuencial.
15	Jr. Conde de Superunda y Av. Tacna	Vigilancia de zona de tráfico moderado y parte del límite entre el Cercado y el Rimac.
16	Av. Colmena y Av. Tacna	Vigilancia de zona de alto tráfico y alta tasa delincuencial.
17	Av. Roosevelt y Av. Paseo de la República	Vigilancia de zona de alto tráfico y Palacio de Justicia.
18	Av. 09 de Diciembre y Av. Paseo de la República	Vigilancia de zona de alto tráfico en Av. Grau y Av. Paseo de la República, y Palacio de Justicia.
19	Av. Roosevelt y Av. Inca Garcilazo de la Vega	Vigilancia de zona de alto tráfico.
20	Plaza Bolognesi	Vigilancia de zona de alto tráfico en intersección de varias avenidas.
21	Av. Uruguay y Av. Alfonso Ugarte	Vigilancia de zona de alto tráfico y alta tasa delincuencial.
22	Jr. Andahuaylas y Jr. Puno	Vigilancia de zona de alto tráfico y alta tasa delincuencial.

Tabla 3.1 Ubicación actual y futura de las cámaras de video (Central 105)

- Controladores de semáforos: Como se explicó anteriormente, la Municipalidad de Lima inicialmente instaló controladores de semáforos en todas las intersecciones del Centro Histórico de Lima, los cuales son aproximadamente 120, todos ellos manejados por cuatro controladores maestros. En el Sistema de Transporte Inteligente, estos controladores deben estar controlados por un Sistema Central, es por ello que la red debe de llegar a todas las intersecciones en donde existan controladores de semáforos.

- Sensores de tráfico: Inicialmente estos equipos deben de cubrir las intersecciones más importantes de la ciudad, en las que se aprecie mayor congestión vehicular, de tal manera que los operadores de tránsito infieran el comportamiento de una determinada zona, o controlar el tráfico en tiempo real a través de los semáforos. En este proyecto no se tomará en cuenta en donde se ubicarán estos equipos, ya que con la información de los controladores de semáforos es suficiente para el diseño de la red. En donde esté instalado un controlador de semáforos, puede instalarse un sensor de tráfico.

2. Servidores de aplicación

Las principales acciones que se realizarán con los equipos de campo son básicamente dos: control y recolección de datos.

- Control: Los equipos que serán controlados constantemente son los controladores de semáforos y las cámaras de video. Para los controladores de semáforos es indispensable el configurar sus parámetros, tal como puede ser los tiempos de fase. En cuanto a la cámara de video, es necesario controlarlo de manera remota, manipulando parámetros tales como *pan*, *tilt* y *zoom*.

- Recolección de datos: Los dispositivos que actuarán como monitores del tráfico son los sensores de tráfico y las cámaras de video, además también los controladores de semáforos ya que se necesita información en tiempo real del estado de los semáforos.

Todas las funcionalidades del sistema antes descritas serán gestionadas por servidores, los cuales son computadores con alta capacidad de procesamiento de información y con características especiales. Estos equipos serán usados para implementar o desarrollar aplicaciones que permitan administrar el sistema y que sean de tipo servidor/cliente, es decir que atiendan consultas o requerimientos de los operadores del tránsito y otro tipo de usuarios. Teniendo una idea clara de cómo será el sistema, se ha propuesto que este tenga los siguientes servidores:

- Servidor de aplicaciones para el tránsito: Este equipo será usado para administrar, gestionar y controlar los equipos que están relacionados al control del tráfico, esto es controladores de semáforos y sensores de tráfico. En ella se puede ejecutar desde aplicativos que permitan el control manual del tránsito, así también como aplicaciones complejas que automatice el control del tránsito.

- Servidor de video: El sistema de vigilancia funciona independientemente del sistema de control de tráfico, es por ello que necesita de un equipo independiente para manipular información proveniente de de las cámaras de video, esto es imágenes en tiempo real. Las principales funciones del servidor de video es almacenar las imágenes recibidas, así también como para proporcionar a usuarios remotos o aplicaciones de red (servicio Web por ejemplo) las imágenes de video recolectadas.

- Servidor de gestión de red: Los equipos administrables de la red necesitan ser monitoreadas constantemente ante una posible falla o comportamiento anómalo, estos son los servidores de gestión de red, los cuales generalmente utilizan el protocolo SNMP.

- Otros servidores: No se descarta la posibilidad de ofrecer servicios para redes externas, tal como puede ser la Internet. Uno de los servicios que frecuentemente se encuentra en un Sistema de Transporte Inteligente es la diseminación de información de tránsito, lo cual no se analizará en este documento. Sin embargo, esta red será capaz de soportar y converger a servicios futuros tales como servicio Web, de archivos, o de correo.

3. Estaciones de Trabajo
Los operadores de tránsito necesitan de una herramienta que les permita acceder a toda la información que es proporcionado por el Sistema de Transporte Inteligente, en un formato entendible para ellos (interfase Web por ejemplo), así también como controlar los equipos de campo que la componen. Para ello existen las estaciones de trabajo, los cuales son simplemente computadores de escritorio con recursos mínimos, que les permiten acceder a los servidores para monitorear y control todo el sistema que la compone.

3.3 ANÁLISIS DE DATOS

3.3.1 ANÁLISIS DE ESTÁNDARES DE COMUNICACIÓN

A lo largo de la evolución de las tecnologías en el Sistema de Transporte Inteligente es que han surgido una variedad de estándares, por lo que es difícil determinar cual es la más eficiente. Sin embargo, en los últimos años el conjunto de normas NTCIP fundada por el FHWA (*Federal Highway of America*) y elaborada en conjunto por el AASHTO, ITE y NEMA, es la más difundida y aceptada por la mayoría de fabricantes en los Estados Unidos.

NTCIP no es un protocolo propietario sino una familia de estándares que definen protocolos que son abiertos y públicos. Este proyecto ha sido elaborado para garantizar la interoperabilidad entre equipos de distintos fabricantes en un Sistema de Transporte Inteligente.

Se tiene a continuación el diagrama que un operador de tránsito utilizaría para diseñar los protocolos de comunicación entre la central y los equipos de campo:

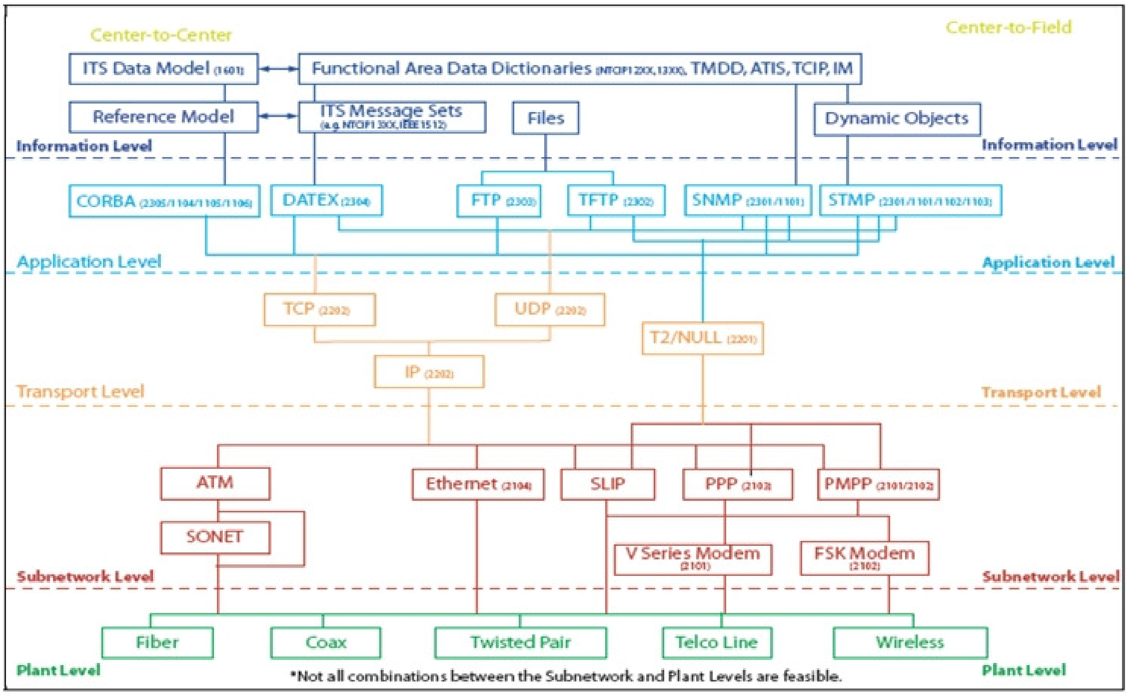

Figura 3.5 Diagrama de Estándares para el Sistema de Transporte Inteligente (Guía NTCIP 2003)

Téngase en cuenta que el presente proyecto solo involucra la comunicación entre central y los equipos de campo (C2F); sin embargo las normas NTCIP incluyen también estándares de comunicación entre central y central (C2C).

Conociendo ya los diferentes estándares de comunicación que se pueden aplicar en el diseño del Sistema de Transporte Inteligente, se puede analizar las principales características que debe de cumplir la red a implementar, pero antes se debe de aclarar que las normas NTCIP son elaboradas en base a un modelo de comunicación distinto al modelo OSI o al TCP/IP:

1. Nivel físico

Como se analizó anteriormente, existe un sistema de canalización subterráneo que permitiría el tendido de cableado para una futura implementación de una red de comunicación. Teniendo en cuenta esto, un medio alámbrico como alternativa es la más correcta. Existen distintos tipos de medios alámbricos: coaxial, par de cobre, fibra óptica. En este caso por tratarse de una red de área metropolitana lo más ideal es usar fibra óptica, además del par de cobre para el acceso a la red por parte de los equipos de campo y de la central de tráfico. El uso de cable coaxial queda descartado por ser un medio físico desplazado por la fibra óptica y el par de cobre, básicamente por costos y por la capacidad para transportar información, ya que la red debe ser capaz de soportar grandes cantidades de información que incluye video, datos y en futuro llegar a transferir voz.

2. Nivel de subred

Como se puede apreciar, las normas NTCIP cuentan con una variedad de protocolos abiertos. Una de las características que debe cumplir la red a diseñar es que los equipos de campo deben de compartir una sola infraestructura y tener acceso simultáneo. Dicho esto las alternativas más acertadas son el uso de una red ATM o Ethernet. La mejor opción es la tecnología Ethernet, las razones son principalmente por su sencillez, capacidad de transporte y costos. La tecnología ATM ha demostrado ser muy complejo y costoso; y que durante los últimos años ha sido desplazado por la tecnología Ethernet en el campo de Internet.

3. Nivel de Transporte

Una de las redes más grandes a nivel mundial es la Internet, que se basa en la pila de protocolos TCP/IP. Son las características de este modelo de comunicación la que ha proporcionado el éxito que actualmente tiene. Es por eso que las normas NTCIP ha establecido incluirlo en su pila de protocolos, cabe resaltar que para el modelo NTCIP el nivel de transporte lo conforman los protocolos de red IP y protocolos de transporte TCP y UDP del modelo TCP/IP. Esto va a permitir establecer diferentes grupos de trabajo, y de esa manera ofrecer seguridad y confiabilidad en el transporte de datos.

4. Nivel de Aplicación

Hasta ahora se ha determinado la manera de cómo transportar la información en forma confiable y segura, pero no se ha determinado como las aplicaciones van a interpretar y construir la información que se recibirá y enviará respectivamente. Existen muchos protocolos de aplicación que permiten que dos elementos de red puedan compartir información a nivel de aplicación. Por ejemplo un aplicativo de correo cuenta con un protocolo de comunicación que permite a dos usuarios de red intercambiar información, para ello se implementó los protocolos de aplicación SMPT, POP e IMAP los cuales desempeñan diferentes tareas para la correcta interpretación de datos. Así mismo, los Sistemas de Transporte Inteligente cuentan con protocolos de aplicación estándares que permiten a los operadores de tránsito conocer la información que los equipos de campo envían a nivel de aplicación. Uno de los más usados y de amplia difusión es el protocolo SNMP y SMTP, el último es una versión del SNMP desarrollada por el NTCIP aplicado a los equipos de campo de un Sistema de Transporte Inteligente, y cuya ventaja es el de usar menor cantidad de información de cabecera para el transporte de datos. Sin embargo el diseño del sistema no exige el uso de un solo protocolo a nivel de aplicación para todo el sistema, en la realidad son varios protocolos que conviven en un solo Sistema de Transporte Inteligente ya que los protocolos de nivel inferior lo permiten.

Después de este análisis el posible diagrama de flujo que tendrá la red de datos es el siguiente:

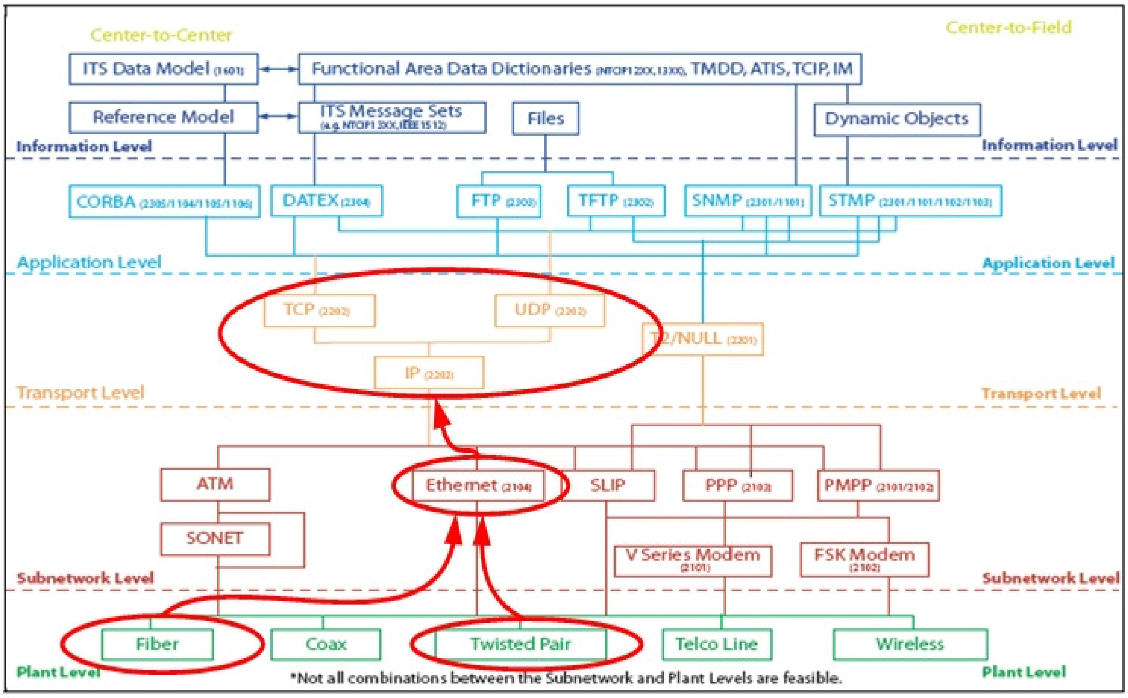

Figura 3.6 Diagrama de flujo de comunicaciones de un Sistema de Transporte Inteligente (Guía NTCIP 2003)

Como se puede apreciar el análisis y diseño de la red solo se dará hasta el nivel de transporte, no mencionando la capa de aplicación el cual es un tema que involucra en principio el desarrollo de sistemas informáticos sofisticados. El objetivo de este proyecto es de poder transferir datos, video y hasta voz de la mejor manera posible.

3.3.2 ANÁLISIS DE ANCHO DE BANDA

Una etapa importante en el diseño de la red es el cálculo del ancho de banda que consumirían los equipos de campo durante la transferencia de información. Solo se realizará el cálculo para el caso de los controladores de semáforo y los sensores de tráfico; los resultados son solo para demostrar que la red a diseñar soportará los requerimientos de ancho de banda de estos equipos. Para ello el cálculo se debe basar en un estándar de comunicación ya definido, tal como es el estándar NTCIP. Además se supondrá que el intercambio de información entre los equipos de campo y la central de tráfico se basa en el protocolo de aplicación SNMP, y que para ello se necesita conocer los objetos definidos para cada tipo de equipo, es decir su MIB, los cuales están especificados en los siguientes documentos (véase Anexo 3):

- NTCIP 1202: *Object Definitions for Actuated Traffic Signal Controller (ASC) Units*
- NTCIP 1209: *Data Element Definitions for Transportation Sensor Systems*
- NTCIP 1201: *Global Object Definition*

Para el caso de las cámaras de video se supondrá que se usa un formato de compresión relativamente sofisticado y bueno que pueda ofrecer una buena resolución de imagen usando un reducido ancho de banda, tal como puede ser el estándar MPEG-4, usado con mayor frecuencia en los *encoders* y cuya velocidad de transferencia exigida es de aproximadamente 2 Mbps en el peor de los casos.

1. Controlador de semáforo

Antes de realizar el análisis del ancho de banda requerido, se procederá a definir los objetos o parámetros que deben de intercambiar la central con el controlador de tráfico, los cuales son los más básicos.

Para poder mostrar el estado de las señales de tráfico se usará los siguientes elementos extraídos del documento NTCIP 1202:

phaseStatusGroupGreens	*- Section 2.2.4.4*
phaseStatusGroupYellows	*- Section 2.2.4.3*
phaseStatusGroupWalks	*- Section 2.2.4.7*
phaseStatusGroupPedClrs	*- Section 2.2.4.6*
overlapStatusGroupGreens	*- Section 2.10.4.4*
overlapStatusGroupYellows	*- Section 2.10.4.3*
cordPatternStatus	*- Section 2.5.10*

Estos elementos proveen las indicaciones de amarillo o verde de hasta 8 fases de vehículo, indicaciones da hasta 8 movimientos peatonales, y el patrón de coordinación (ciclo, fases y offset) aplicado. Se trata de que esta información se muestre en tiempo real y que normalmente se obtiene de cada intersección al menos una vez cada segundo.

Para poder realizar ajustes en los parámetros de los controladores de las señales de tráfico en cada intersección se usará los siguientes elementos básicos del documento NTCIP 1202, el cual permite configurar una fase y un patrón de tiempo:

phaseWalk	*- Section 2.2.2.2*
phaseMinumumGreen	*- Section 2.2.2.4*
phasePassage	*- Section 2.2.2.5*
patternCycleTime	*- Section 2.5.7.2*
patternOffsetTime	*- Section 2.5.7.3*
splitTime	*- Section 2.5.9.2*

Según datos de los operadores de tránsito, los controladores están programados para actuar como mínimo en tres fases y como máximo hasta en cinco fases, según el patrón establecido por los estudios de campo. Además en la configuración se puede establecer hasta seis patrones de tiempo. En este caso se asume que los operadores de tránsito cambian los parámetros aplicados a 5 fases y a 6 patrones de tiempo cada media hora, esto en el peor de los casos.

Además se tendrá en cuenta el parámetro global de tiempo, aplicado a cualquier dispositivo y que se encuentra en el NTCIP 1201:

globalTime *- Section 2.4.1*

Este objeto permite configurar la hora y fecha en cada dispositivo de campo, el cual se realiza por lo menos una vez al día. Para analizar la cantidad de información que debe de intercambiarse entre el equipo y la central es necesario calcular el número de bytes de toda la trama Ethernet que transporta el objeto o parámetro SNMP. En este caso se tomará como ejemplo al objeto *globalTime,* cuyas parámetros básicos son su OID = 1.3.6.1.4.1.1206.4.2.6.3.1.0 y tipo de variable = Entero de 4 bytes. Con estos datos se llega a establecer la estructura de la trama, como se aprecia en la figura 3.7.

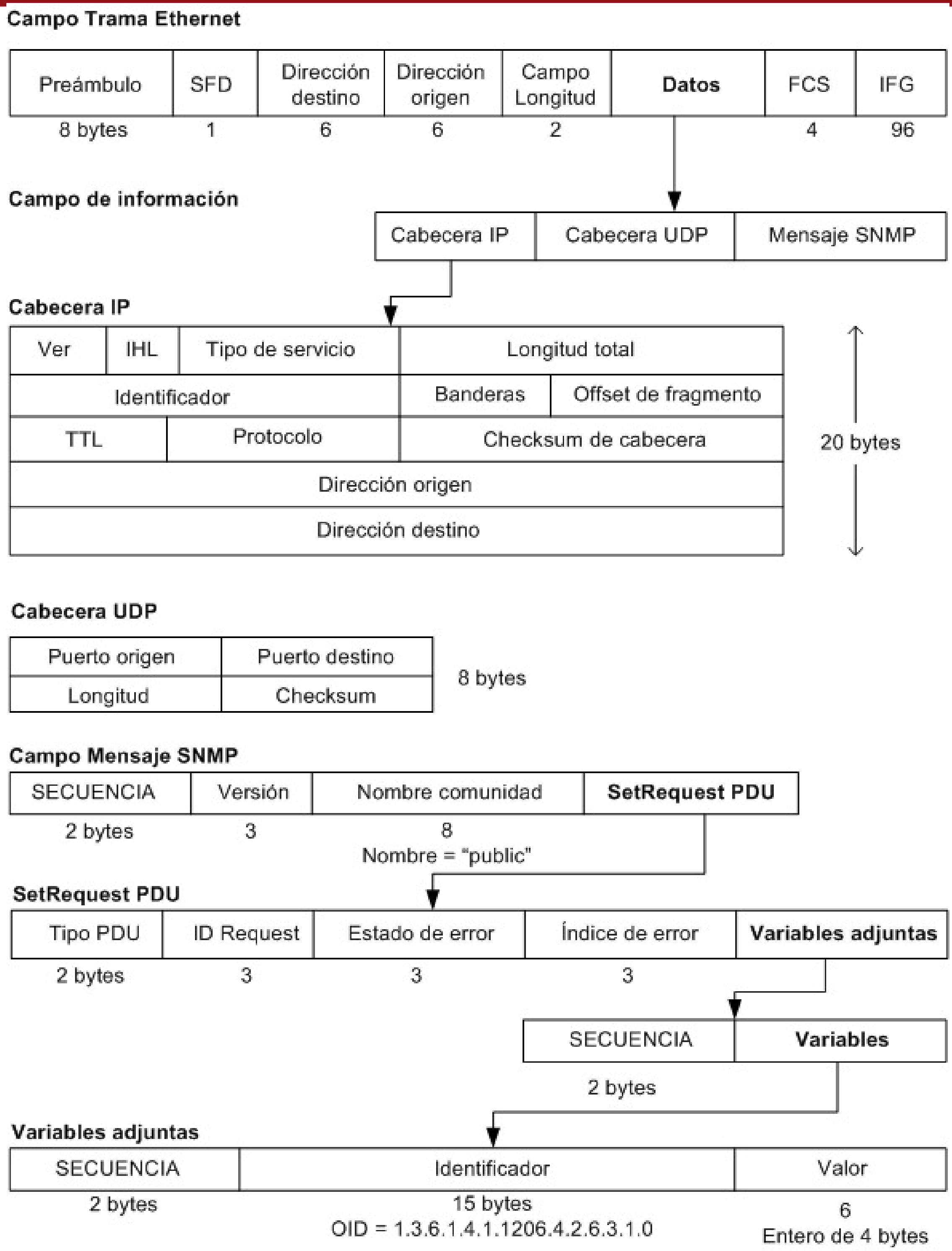

Figura 3.7 Análisis del tamaño de datagrama SNMP

Como se puede apreciar, la trama contiene información acerca de las capas superiores, los cuales son el paquete IP, el segmente UDP y el mensaje SNMP. Esto es la información enviada desde la central al dispositivo para configurar la fecha y hora del equipo. Hay que tener en cuenta que en SNMP los comandos típicos y las respuestas a ellos tienen el mismo tamaño. En un mensaje de tipo SetRequest, los valores de los elementos que deben ser configurados están contenidos en él. Correspondientemente con un mensaje SNMP de tipo *SetResponse*, los mismos valores podrían estar incluidos para indicar que los elementos han sido configurados. Por lo tanto el total de ancho de banda que resulte del análisis será válido tanto para *uplink* (del dispositivo a la central) como *downlink* (de la central al dispositivo).

Según la figura, podemos calcular el número de bytes que se necesita para transportar una variable. En los mensajes SNMP, puede transportarse más de una variable, y que formarían parte de un mismo grupo o tabla. En este caso, el objeto *globalTime* no pertenece a ninguna tabla, por lo que se transporta individualmente. En el caso de los objetos *overlapStatusGroupGreens y overlapStatusGroupYellows*, estos pertenecen a un mismo grupo por lo que serán enviados junto a la variable *overlapStatusGroupNumber*, el cual indica a que grupo pertenecen. Entonces tenemos que:

Tamaño de mensaje SNMP = 175 bytes de cabecera + 23 bytes por elemento

Para nuestro ejemplo, el número de elementos es solo el objeto *globalTime*, por lo tanto el tamaño del mensaje será de 198 bytes. Esta aproximación en el cálculo obtenido se aplicará a todos los elementos que intercambiarán la central y los controladores de tráfico. Luego, se tiene en la tabla 3.2 el resumen de las características de los parámetros a intercambiar:

Normalizando los bytes por día a bits por segundo, nos da el total de tráfico:

63426870 bytes por día x 8 bits por byte / 86400 segundos por día = 5872.86 bps

Tipo de Mensaje	Frecuencia	Tamaño de mensajes intercambiados (en bytes)	Bytes por día
Fecha y Hora	1 vez cada día	198	198
Estado de intersección	1 vez cada segundo	732	63244800
Ajuste de configuración	1 vez cada media hora	3789	181872
Total por día			63426870

Tabla 3.2 Parámetros en la transferencia de información desde los controladores de semáforos a la central de control

2. Sensor de Tráfico

Al igual que el controlador de semáforos, los sensores de tráfico serán analizados teniendo en cuenta los elementos que se intercambiarán, pero antes de ello se definirán los parámetros básicos que se aplicarían a cada uno de estos dispositivos en el transporte urbano.

Básicamente los parámetros que se recolectarán de los sensores de tráfico, cual fuese la tecnología, son los siguientes y que se encuentran en el NTCIP 1209:

VolumeData -*Sección 3.4.1.2*
percentOccupancy -*Sección 3.4.1.3*
speedData -*Sección 3.4.1.4*

Estos elementos se encuentran en la tabla *Data Collection –Sección 3.4.1*, en donde el elemento *sensorZoneNumber* índica a que zona pertenece. En el caso de la ciudad de Lima, se tiene en las calles más importantes, una vía de 8 carriles y la otra vía que cruza de 4 carriles, esto en el peor de los casos; por lo tanto en una intersección, por medio de 4 sensores de tráfico, se cubrirá como máximo 12 zonas. Esta operación se realizará cada segundo, exagerando el caso.

Teniendo todos los datos y con la fórmula aproximada que se aplicó con los controladores, se puede hallar la cantidad de bits que se intercambian en un segundo:

Tamaño de mensajes SNMP = 12 zonas x [175 bytes de cabecera + 4 elementos x (23 bytes por elemento)]

Tamaño de mensajes SNMP = 3204 bytes

Entonces la velocidad necesaria para transferir esta cantidad de información en un segundo es:

3204 bytes / 1 segundo = 25640 bps

Se puede concluir entonces que el tráfico producido por los controladores de semáforos y los sensores de tráfico es despreciable en comparación al tráfico producido por las cámaras de video. Sin embargo los resultados pueden ser útiles para dimensionar otra clase de equipos, tales como los servidores o dispositivos de almacenamiento; o también como método para analizar otra clase de equipos.

3.3.3 DISPOSITIVOS DE ADAPTACIÓN A RED

El modelo NTCIP permite que diferentes fabricantes utilicen el protocolo más eficiente para el diseño de los equipos de campo y diversos equipos que participan en un Sistema de Transporte inteligente. Sin embargo son pocos los que utilizan los protocolos TCP/IP para el desarrollo de la comunicación entre sus equipos.

Además, muchos de los fabricantes no utilizan la tecnología Ethernet como método para la transferencia de datos, es decir que sus equipos cuentan con otro tipo de interfases, y que en nuestro caso sucede con los sensores de tráfico, controladores de señales de tránsito y cámaras de video. Aunque también muchos expertos aseguran que el futuro del Sistema de Transporte Inteligente está sobre el protocolo TCP/IP, y el uso de la tecnología Ethernet, pero en nuestro caso se debe de asegurar que exista alguna forma de adaptar estos equipos a una red conmutada.

Para los sensores de tráfico y controladores de señales de tránsito, por lo general cuentan con interfases seriales RS232, los cuales son interfases para la comunicación punto - punto o punto - multipunto. En el caso de las cámaras de video, sucede que podría adquirirse cámaras analógicas, los cuales de ninguna manera funcionarían directamente en una red digital.

1. Interfases seriales

En el mercado emergieron soluciones a este tipo de problemas, no solo para el uso de equipos en el ITS, sino para las aplicaciones industriales en general. Se trata de equipos que permiten el acceso de diversos dispositivos con interfase serial RS232, RS422 y RS482, a través de una red de acceso múltiple, como por ejemplo una red Ethernet, hacia uno o varios computadores. Estos equipos son los denominados servidores de dispositivos seriales, y permiten que más de un computador tenga conectados virtualmente equipos seriales a través de un software que se comunican con los servidores de estos dispositivos.

En el mercado las soluciones se basan en redes TCP/IP, en el cual el servidor de dispositivos seriales le es asignada una dirección IP de manera dinámica (DHCP) o estática (configurando el equipo servidor) a cada puerto COM el cual está conectado el dispositivo serial de tal manera que pueda transferir información a través de un red IP.

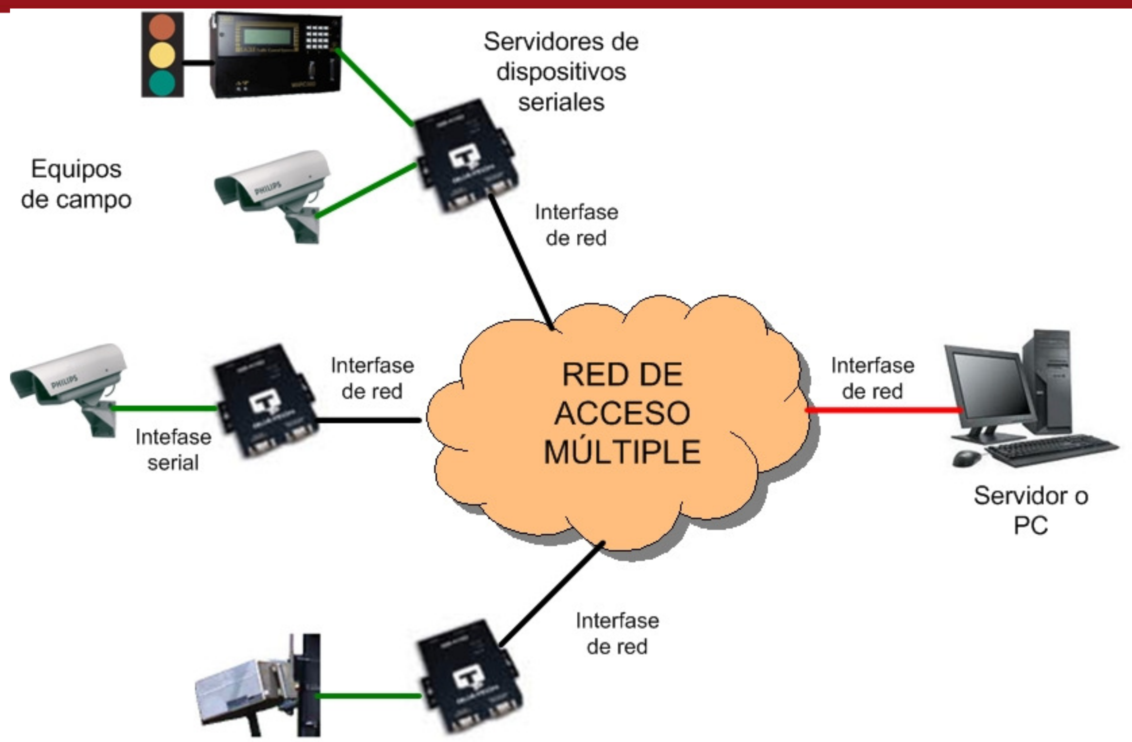

Figura 3.8 Diagrama de acceso a dispositivos seriales a través de una red conmutada

2. Codificadores de video

Actualmente los sistemas de vigilancia a través de Circuito Cerrado de TV están basados en cámaras digitales, ya que los medios por la cual envían la información son digitales. Sin embargo todavía existen en el mercado cámaras analógicas, los cuales por su bajo costo son ampliamente adquiridas y usadas. En el caso de un Sistema de Transporte Inteligente con una red Ethernet es recomendable el uso de cámaras digitales, pero eso no descarta la posibilidad de usar cámaras analógicas.

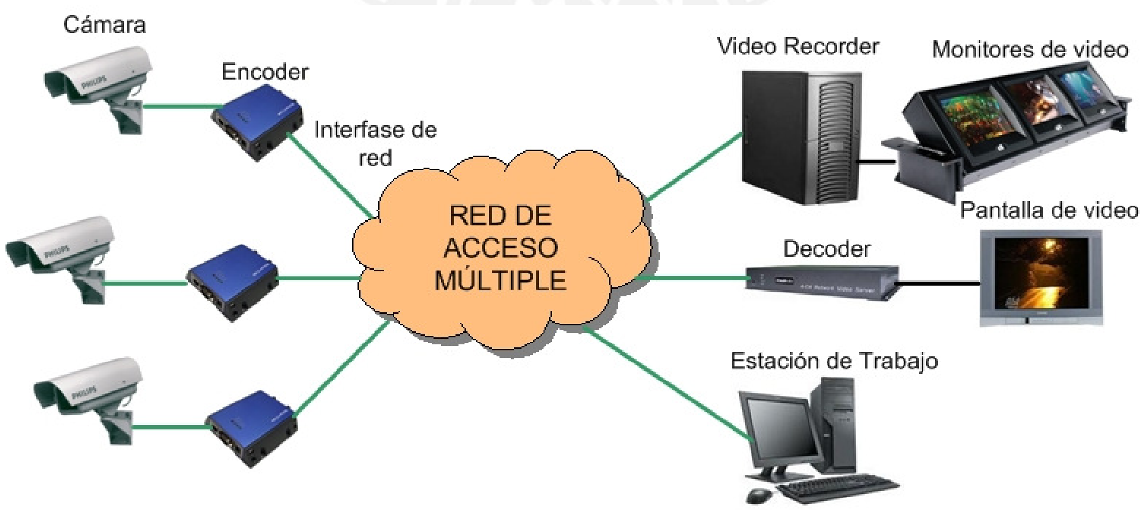

Figura 3.9 Diagrama de transferencia de video analógico a través de una red conmutada

Para ello es que se usan dispositivos que permiten, a través de un algoritmo de compresión, la transferencia de video por un medio digital y a tasas de transferencia bajas, dependiendo del tipo de compresión que se use.

Como se puede apreciar en la figura 3.9, existen diversas maneras de proporcionar video en un sistema de vigilancia. Entre estos tenemos el uso de un servidor de video, el cual proporciona grabación en tiempo real de imágenes a través de bancos de memoria, además de proporcionar visualización a través de monitores de pared, y la posibilidad de desarrollar aplicaciones servidor/cliente de tal manera que brinde servicios de video a clientes en lugares remotos; otra manera es usar directamente dispositivos que funcionan como decodificadores de video de tal manera que se muestren en los monitores, muchos de estos decodificadores tienen incorporado bancos de memoria para la grabación de video; por último se tiene también que una estación de trabajo pueda acceder directamente a las imágenes en tiempo real, esto debido a que los codificadores tienen incluido aplicaciones de red.

3.3.4 ANÁLISIS DE TOPOLOGÍA

Por tratarse de un solo local que funciona como central de operaciones, la topología mas recomendada es la centralizada. Existen muchas ventajas que puede ofrecer una topología de tales características, pero lo mas importante es la condición de los dispositivos, tal como se había mencionado la central de operaciones funciona como un dispositivo maestro, el cual gobierna todos los elementos que componen el sistema, y estos elementos que son gobernados vienen a ser los dispositivos esclavos, los cuales reciben ordenes del elemento maestro, estos últimos son los equipos de campo. Luego, la topología de la red tendrá que ser centralizada:

Además, la topología concuerda con las características de la tecnología que se utilizará, esto es *Ethernet*. Este análisis es solo a nivel de sistema, sin embargo se verá en el diseño que las subredes que lo conformarán tendrán una topología física distinta al del sistema global.

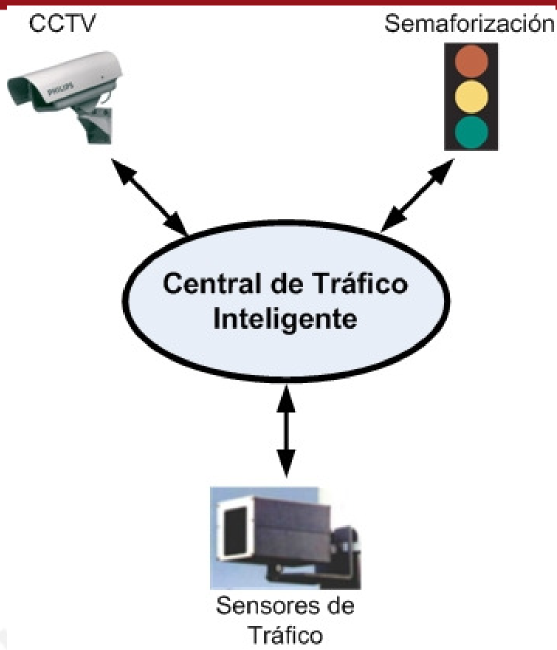

Figura 3.10 Sistema Centralizado ITS

CAPÍTULO IV
DISEÑO DE LA RED DE DATOS

Los Sistemas de Transporte Inteligentes son plataformas muy complejas ya que se distribuye en áreas realmente grandes, tales como una ciudad, y logran requerir muchos recursos debido a la variedad de servicios que se pueden implementar. Instalar una infraestructura de red centralizada en un único punto para administrar todo los equipos que intervienen en el control de tráfico de toda una ciudad metropolitana, tal como puede ser Lima, es una tarea complicada tanto para los ingenieros como para los operadores de tránsito.

Lo que facilita el control de todo el tráfico que se suscita en una ciudad es a través de la división de tareas, los operadores de tránsito se dividen en zonas, logrando así controlar mejor el tránsito. Este criterio ha sido recogido del plan de semaforización de la ciudad de Lima, en la cual se instalarán diversas centrales de tal manera que cada central administre y controle el tráfico de una determinada zona. Es por ello que en este capítulo se considera el diseño de la red para la zona centro (por decirlo de alguna manera), que vendría ha cubrir todo el Centro Histórico de Lima y alrededores. La intención de este capítulo no es el de diseñar a detalle la red que cubrirá todo el Sistema de Transporte Inteligente es esta zona, ya que es un Sistema que no existe en la ciudad y que necesita de mayor evaluación por parte de las autoridades competentes e Ingenieros experimentados. Lo que se dará a continuación es un diseño que cubre solo la muestra que se determinó en el capítulo anterior, es decir la Av. Abancay y sus alrededores, todo ello en base a la información proporcionada por los operadores de tránsito y del criterio del autor de este documento; todo ello con la finalidad de mostrar una solución basada en el uso de una tecnología ampliamente usada con una topología poco común en ella. No obstante, este diseño sirve como iniciativa para analizar mejor la situación actual del Transporte y las tecnologías que pueden ser usadas para su mejoramiento.

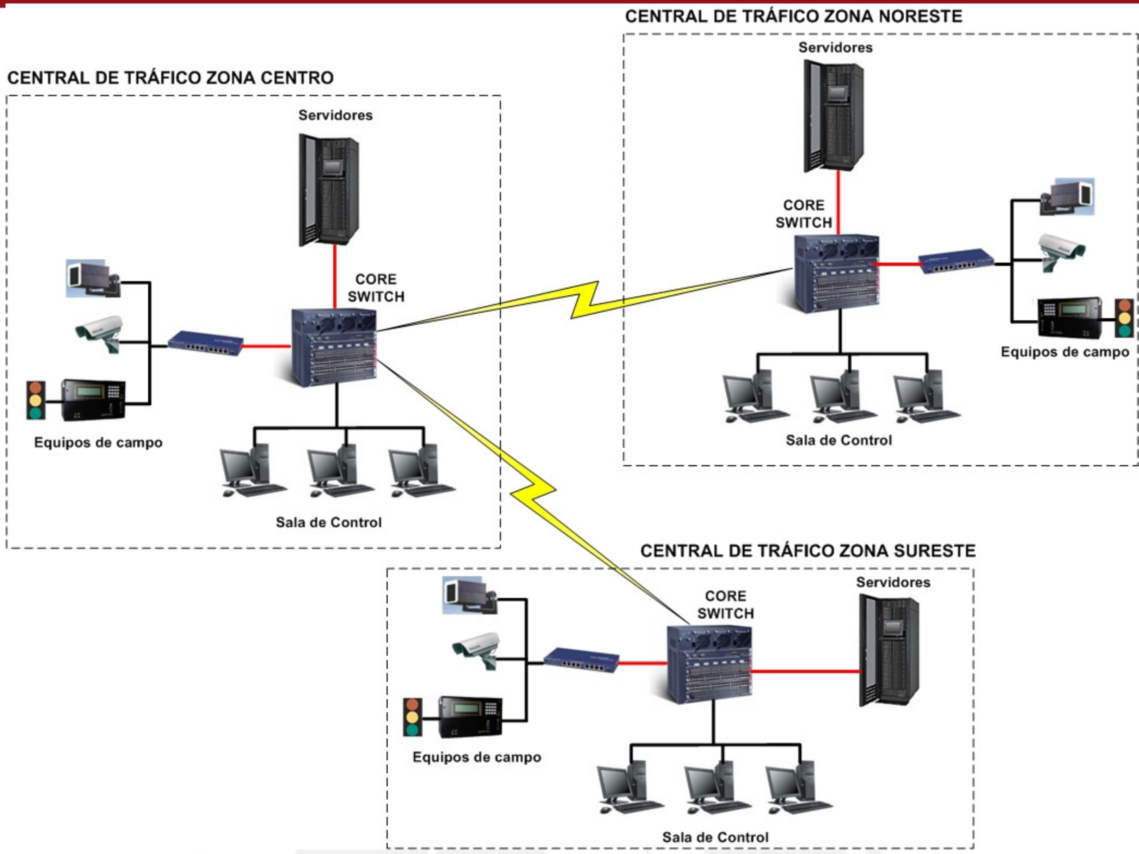

Figura 4.1 Diagrama de red del Sistema de Transporte Inteligente en Lima Metropolitana

Como se muestra en el gráfico, el control del transporte urbano puede dividirse en varias zonas, todas ellas entrelazadas a través de una topología en malla o redundante; se debe aclarar que la figura representa un bosquejo de lo que podría ser el Sistema de Transporte Inteligente en Lima, esto puede incluir muchas más zonas y enlaces. Las zonas no necesariamente se refieren a las vías urbanas, sino también incluyen por ejemplo las autopistas, en las que se implementan cámaras de video, sistemas de cobro de peaje y señales de mensaje variable. Cada zona está soportada por un dispositivo central o backbone, que en este caso es un *core switch,* ya que el diseño se basa en tecnología Ethernet. No se discutirá la intercomunicación entre zonas, sino más bien como estará estructurada cada zona, en particular la zona del Centro Histórico de Lima.

Como se puede apreciar en la figura, se tiene a grandes rasgos las características que debe tener la zona Centro o la red del Centro Histórico de Lima.

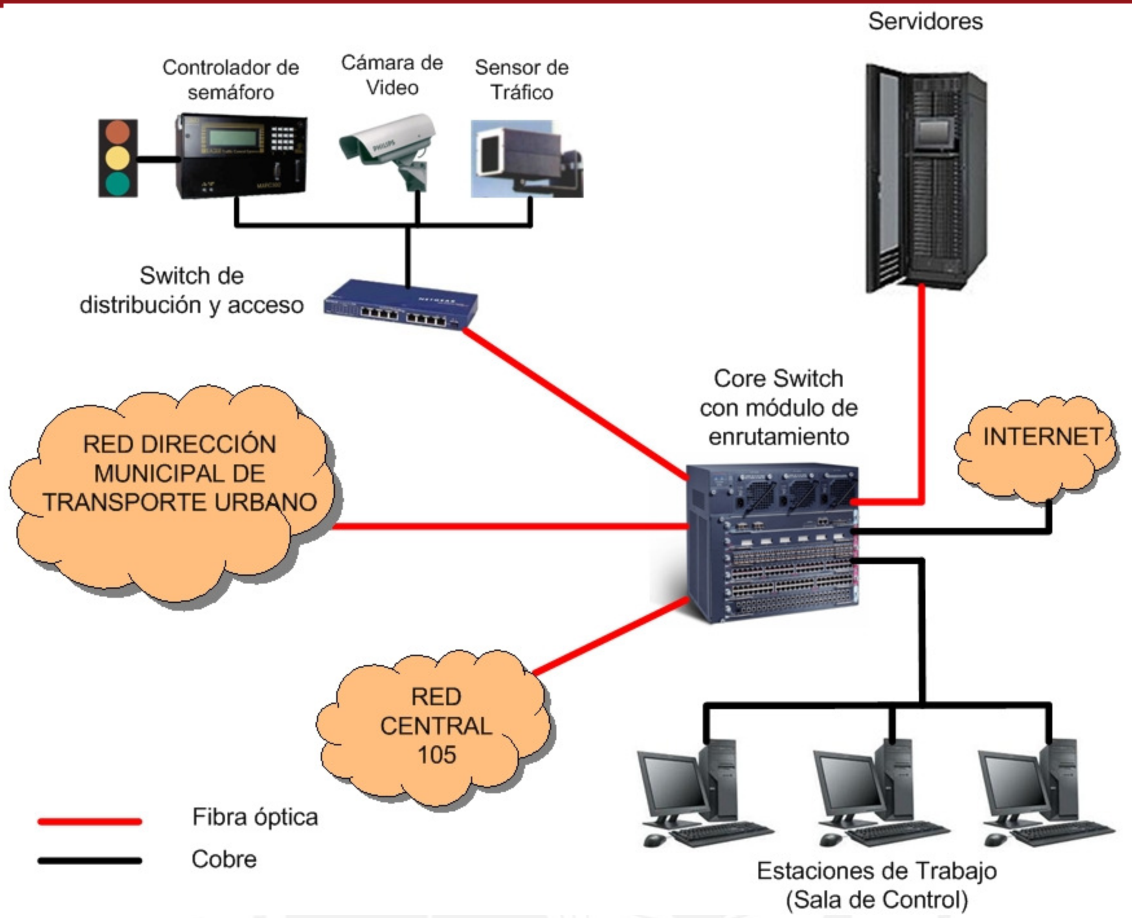

Figura 4.2 Diagrama de red del Sistema de Transporte Inteligente en el Centro Histórico de Lima

Se divide la red en tres subredes importantes: subred de equipos de campo, subred de servidores y subred de estaciones de trabajo (o sala de control). Además el *core switch* será capaz de dar servicio a dos redes que se encuentran en la zona: la red del GTU, ubicada en la Av. Nicolás de Piérola #617; y la red de la Central 105 de la PNP, ubicada en la cuadra 4 de la Av. España. Estas dos redes no están consideradas en el diseño, pero si los enlaces de estos al backbone, aquellos son dos locales correspondientes a los principales operadores de tránsito que de alguna manera requerirán de información correspondiente al tráfico y de algún otro servicio que se ofrezca por medio de los servidores. Se ha agregado un enlace a Internet como tema opcional y que no será tratado en este capitulo, esto es solo para mostrar las opciones que se pueden ofrecer al Sistema, y no necesariamente debe estar ubicado junto al *backbone*.

4.1 SUBRED DE EQUIPOS DE CAMPO

4.1.1 CARACTERÍSTICAS

Por ser nuestra muestra la Av. Abancay, se procederá a realizar el diseño de un tramo de la red en esta zona y las partes involucradas, cuyos resultados serán aplicables a nuestro universo, es decir el Centro Histórico de Lima.

Como se mostró en el diagrama de red, se diferencian tres tipos de switches: el *core switch*, que funciona como backbone; el *switch* de distribución, que permite distribuir la red a diferentes lugares de la ciudad, además de dar acceso a los equipos cerca de la zona; y el *switch* de acceso, que dará acceso a la red. En el caso del *core switch*, éste se ubicaría en la central de control. En cuanto al *switch* de distribución, se cree conveniente ubicarlos en las zonas más cercanas a los puntos donde se instalarán las cámaras de video; por las siguientes razones:

- Las cámaras de video son equipos por lo general *multicast* y cuyo flujo de paquetes son considerados *broadcast* para una red de nivel 2, por lo tanto es necesario instalar *switches* que puedan limitar el flujo de paquetes *multicast* solo a quienes deseen recibir tales datos; para ello el *switch* debe contar con *IGMP snooping*, el cual le permite "escuchar la conversación" de los *hosts* que desean formar parte del grupo *multicast*. El *switch* entonces podrá reconocer a los miembros del grupo y determinar a que puertos debe de enviar el flujo multicast.

- Los paquetes de video son muy sensibles a los retardos, en consecuencia los *switches* deben dar mayor prioridad a este tipo de información para no perder la calidad de video (y de voz si en un futuro se instala VoIP); para ello el *switch* debe tener incluido en sus características lo que se conoce como CoS (Class of Service). En el caso de video, el retardo máximo permitido para no perder la calidad de imagen es de aproximadamente 100 ms; y para el flujo de señales de audio, el máximo permitido es de 10 ms. Se considera que los otros equipos, es decir los controladores y sensores de tráfico, no tendrían alta prioridad en esta red a pesar de que son parte de aplicaciones en tiempo real, esto debido a que su retardo no debe ser mayor a un segundo (en el peor de los casos), algo muy improbable en esta red de alta velocidad.

- El número de cámaras de video en la ciudad es reducido y están situados en lugares estratégicos, por lo que la instalación de los *switches* de distribución solo en estos puntos reduciría costos y permitiría llegar a los demás equipos de campo a través de *switches* no administrables (que son menos costosos).

Para la topología física, la red se extenderá por medio de una topología híbrida hacia los equipos de campo. Debido a su distribución, esta subred debe tener una topología en cascada, requisito básico para no desperdiciar en cableado si se realizara una topología en estrella hacia todos los puntos. A la vez, esta "cadena" se cerrará en el mismo punto, formando así una topología en anillo, conformado por el *switch core* y los *switches* de distribución, de aquí la importancia que los switches de distribución sean administrables, ya que entre otras características tienen la posibilidad de formar una topología en anillo a través del estándar IEEE 802.1d o *Spanning Tree Protocol* (STP), permitiéndole además redundar en las conexiones, siendo capaz de tener disponibilidad completa en caso de alguna caída en un enlace del anillo.

Un punto muy importante en esta subred es la longitud de la cadena debido a la topología en cascada de los *switches*, cabe mencionar que en teoría es ilimitado, pero se tiene que considerar si la aplicación o propósito del sistema lo admite, y si los equipos de comunicación lo permiten. Para un Sistema de Transporte Inteligente se tiene en cuenta este tema, ya que las aplicaciones son consideradas en tiempo real, por lo que el retardo es un punto muy sensible en la confiabilidad de la red. Los equipos que se usarán en esta subred son de aplicaciones industriales, conocido como *Ethernet* Industrial, los cuales admiten realizar una topología en cascada o en línea, esto por las aplicaciones que se dan en la mayoría de sistemas de control en las industrias. La latencia (o retardo) puede tener varios orígenes, de las cuales los más comunes son la congestión y la cantidad de equipos que conmutan los datos desde el origen al destino.

Como se puede apreciar en la Fig. 4.3, el primer anillo está conformado por 10 *switches* administrables que dan acceso a las cámaras de video principalmente (determinado en el capítulo anterior), esto además permitirá dar acceso a los otros equipos de campo de los puntos o intersecciones aledañas. El anillo estará implementado a través de enlaces de fibra óptica. Antes de determinar la velocidad de los enlaces, se tiene que considerar los *switches* no administrables que darán acceso a los controladores y sensores de tráfico. Los enlaces que conforman la extensión de la red hacia las demás zonas se dará a través de fibra óptica, ya que las distancias superan los 100 m permitidos para una instalación en cobre o cable UTP.

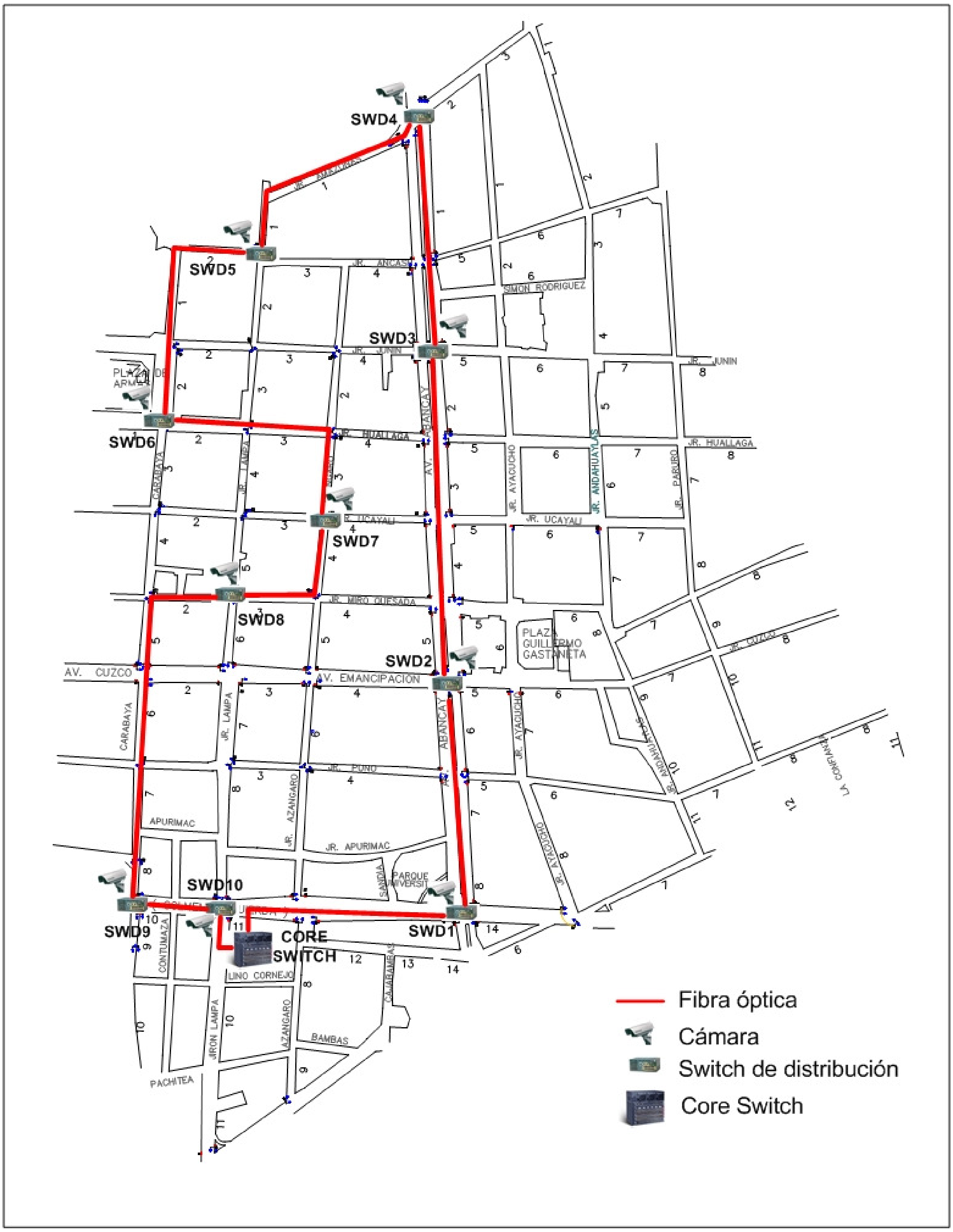

Figura 4.3 Diagrama de subred de equipos de campo en la zona de Abancay

Ahora que se tiene el número de *switches* que están en anillo, se puede determinar la velocidad de los enlaces en fibra óptica. Para ello se debe establecer un punto de ruptura, en donde el estándar IEEE 802.1d determine donde se encuentran los puertos bloqueados para el correcto funcionamiento de la red *Ethernet*. En el peor de los casos puede suceder tal que se bloquee el enlace entre el *core switch* y uno de los *switches* administrables cercanos (SWD1 o SW10 según la Fig. 4.3), dando como resultado 10 *switches* en casada hacia la central. Conociendo las tasas de transferencia por intersección (según lo establecido en el capítulo anterior), se puede determinar el ancho de banda requerido en *uplink* (equipos de campo a central) en las 31 intersecciones que servirá este anillo (ver Fig. 5.3):

21 intersecciones sin cámara	=	*21 x (50kbps) aprox.*
10 intersecciones con cámara	=	*10 x (2050 kbps)*
Total	=	*21550 kbps ó 21.55 Mbps*

Por ser una transmisión en *full duplex*, no es necesario mencionar el flujo en *downlink*, ya que la mayor carga se da en *uplink* (envío de imágenes). Con esto sin lugar a duda el ancho de banda requerido para los enlaces en fibra óptica tiene que ser 100 Mbps, según el estándar *Fast Ethernet* ó IEEE 802.3u, permitiendo además poder adicionar mayores equipos si en un futuro se requiere ofrecer servicios adicionales en el Sistema de Transporte inteligente. En cuanto al acceso de los equipos de campo por medio de cable de par trenzado, depende de la interfase que presentan los equipos, es decir si es *Ethernet* (IEEE 802.3) o Fast Ethernet (IEEE 802.3u), aunque por lo general todos los *switches* tienen la característica de auto negociar las velocidades de acceso y el modo se comunicación: *half-duplex* o *full-duplex*.

El retardo generado por un *switch* depende del método de conmutación que este tenga implementada. Los *switches* que serán usados en este sistema son del tipo *Store-and-Forward*, los cuales revisan el datagrama completo antes de conmutarla al puerto de salida, con el propósito de verificar errores en la trama. El retardo generado varía entre 1 a 2 ms, según la calidad del equipo. Analizándolo en nuestra subred, podemos deducir que en el peor de los caso el retardo puede llegar a estar entre 10 a 20 ms. No se menciona el efecto del medio de transmisión ya que la subred esta sobre fibra óptica, siendo despreciable su latencia en el envío de datos. Con este retardo las aplicaciones que se implementen pueden ser consideradas en tiempo real, y junto con la característica de CoS, se tendrá una buena calidad si se trata de envió de voz o imágenes.

En los últimos años, *Ethernet* ha evolucionado para convertirse en una tecnología de red estándar para las oficinas y los ambientes de la tecnología de información. Sin embargo esto está cambiando debido a la expansión de su uso en otro tipo de aplicaciones, tales como las redes industriales. *Ethernet* Industrial no es más que *Ethernet* aplicado a los sistemas industriales, en las que están incluidos los Sistemas de Transporte Inteligente. Los equipos que se usarán en la subred de equipos de campo son *switches* con características que superan los *switches* convencionales, pero siempre manteniendo el estándar *Ethernet*. Las características que son necesarias en esta aplicación de planta externa son básicamente la temperatura de operación, facilidad en su montaje y resistencia en lugares hostiles; la razón de ello es la locación de los *switches* en las calles, los cuales estarán en un gabinete en la intersección el cual va a servir. El equipo puede compartir el mismo gabinete que el controlador de semáforos, pero es recomendable que tenga su propio espacio, de tal manera que la administración sea más sencilla.

4.1.2 SELECCIÓN DE EQUIPOS DE COMUNICACIÓN

Existen una variedad de fabricantes que desarrollan estos productos, ideales para aplicaciones en un Sistema de Transporte Inteligente, entre algunas de estas empresas se tiene a MOXA (con distribuidor autorizado en Perú), GarrettCom (con representantes en todo el mundo) y CISCO Systems (con distribuidores autorizados en Perú). A continuación un resumen de las principales características de los *switches* para los equipos de campo:

Switch de distribución	
Características	Descripción
Interfases	Puertos 10BASE-T/100BASE-TX: conector RJ-45, cableado UTP Categoría 5 cuatro pares. Puertos 100BASE-FX: Conector SC, cableado fibra óptica multimodo de 50/125 μm.
VLAN	Dividir la red en segmentos lógicos para reducir los dominios de broadcast y dar seguridad a los equipos de campo.
IGMP	Limitar el flujo de datos multicast del tráfico de video solo a los nodos que lo soliciten.
QoS	Permitir clasificar y priorizar el tráfico de video y/o voz.
Gestión de red	El equipo debe ser monitorizado a través de SNMP.
Temperatura de Operación	El equipo debe ser capaz de soportar ambientes hostiles, tal como el interior de un controlador de semáforos, Tmax = 40°C.
Alimentación	Alimentación local: 220VAC@60Hz.

Tabla 4.1 Características de *switch* administrable

Switch de acceso	
Características	Descripción
Interfases	Puertos 10BASE-T/100BASE-TX: conector RJ-45, cableado UTP Categoría 5 cuatro pares.
Temperatura de Operación	El equipo debe ser capaz de soportar ambientes hostiles, tal como el interior de un gabinete en la vía pública, Tmax = 40°C.
Alimentación	Alimentación local: 220VAC@60Hz.

Tabla 4.2 Características de *switch* no administrable

El término “administrables” se refiere a las características adicionales que se le proporciona al *switch* de tal manera que mejore el rendimiento de la red, esto es por ejemplo el soporte de *IGMP snooping*, QoS, VLANs, seguridad en puertos, gestión SNMP, y otros. Se presentará a continuación tres *switches* que cumplen con las características mencionadas anteriormente:


Catalyst 2955
(Cisco Systems)
Serie P62F
(GarretCom)
Serie ED6008
(MOXA)

Figura 4.4 Switches administrables disponibles en el mercado

Existen otros fabricantes que ofrecen productos similares, pero los mostrados son los principales y que son accesibles al mercado peruano. Entre las características típicas de los *switches Ethernet*, cuentan con dos puertos de *uplink* que son usados para los enlaces con otros *switches,* tal que se pueda implementar topologías en cascada y/o en anillo, estos puertos pueden ser RJ45, SC, o MT-RJ, el cual solo se usará el MT-RJ por ser enlaces de fibra óptica para *Fast Ethernet*, flexible y de tamaño compacto. Debido a que se necesita una mediana cantidad de puertos, ya que la red se va a extender por medio de estos *swiches*, se prefiere el CISCO *Catalyst* 2955C (véase Hoja de Especificaciones en el Anexo 2). Para los *switches* no administrables, los productos son similares, y cuya diferencia está en su software y su bajo costo. Estos *switches* serán usados como repetidores, ya que permiten extender la red a las intersecciones que no pueden acceder directamente a los switches en anillo, ya que superan los 100 metros permitidos para un enlace en par trenzado de cobre. Además deberán contar con puertos de *uplink* para fibra óptica, ya que también pueden extenderse en una topología en cascada. Algunos modelos que pueden ser usados son los del fabricante Garrettcom, los modelos que se adaptan a la red son los Mágnum ES42P-2MTRJ y el ES42P-1MTRJ, los cuales tienen uno y dos puertos de *uplink* respectivamente, con interfases MTRJ.

Magnum ES42
(Garrettcom)

Figura 4.5 *Switches Magnum* ES42 de *Garrettcom* con diferentes puertos de *uplink*

Como se ha podido apreciar, los *switches* de distribución se expanden en topología estrella a los s*witches* de acceso, esto se realiza a través de fibra óptica ya que la distancia entre intersecciones es en promedio 150m. Sin embargo los *switches* Catalyst 2955C o cualquier otro en el mercado diseñado para este propósito, solo cuenta con uno o dos puertos de *uplink* 100BASE-FX que les permite conectarse en cascada, siendo el resto de puertos del tipo 10/100BASE-TX específicamente para el acceso a red. Por ello se necesita de un medio para poder realizar un enlace de fibra óptica entre los *switches* no administrables con los puertos de acceso de los *switches* administrables, la industria ofrece soluciones a este tipo de problemas. En este caso una solución es el uso de convertidores de medios de transmisión. Aquellos son dispositivos que permiten el cambio de la señal, a nivel físico, para que sea transferido en otro tipo de medio de transmisión. En nuestro caso, la solución sería transportar la señal de la interfase RJ45 a través de fibra óptica, el cual logra mayor alcance y menor retardo, cumpliendo así las exigencias de la transmisión para cable UTP.

Existen muchos fabricantes que desarrollan estos productos, sobre todo los que están involucrados en aplicaciones industriales y de planta externa (outdoor), a continuación los productos de fabricantes ya antes mencionados, el cual se usará el GarretCom:

Serie ME61
(MOXA)

Magnum 14EH
(GarretCom)

Figura 4.6 Convertidores de fibra a cobre en *Ethernet*

4.1.3 <u>PRUEBAS DE TRÁFICO EN TOPOLOGÍA CASCADA</u>

Como se determinó en la sección anterior, la topología para la subred de equipos de campo estará en cascada, motivo por el cual es necesario determinar si las características de tráfico en una red de este tipo son factibles para implementar aplicaciones en tiempo real, tal como es el envío de video MPEG4, y en un futuro VoIP.

Las aplicaciones en tiempo real son bastante susceptibles al *jitter* y a la pérdida de paquetes, características que deben evitarse en lo posible para lograr una calidad de servicio aceptable. Hasta ahora no se ha definido un nivel de *jitter* límite, en el cual una aplicación en tiempo real pueda considerarse de buena calidad de servicio, ya que esto depende fundamentalmente de las características del sistema, esto es el tamaño del buffer de los *decoders*, ya sea de voz o video. Solo debe considerarse que el valor del *jitter* no tenga valores picos demasiado altos, que no puedan adecuarse a las características de un sistema en particular.

En el anexo 7, se muestran una serie de pruebas realizadas en un laboratorio de redes, en la cual se usan *switches* similares a los considerados en el diseño y dispuestos en cascada. Se simula tráfico de video MPEG4 a 2 Mbps, y se incrementa el número de flujos para determinar el punto en el cual se tenga características de tráfico no deseados para aplicaciones en tiempo real, esto es un *jitter* alto.

Al término de las pruebas, se logró observar que un flujo total entre 29.76Mbps y 39.60Mbps es el rango en el que el *jitter* comienza a tener picos relativamente altos, pero no dañinos para la calidad de video. Sin embargo, un flujo superior a 39.6Mbps puede perjudicar la calidad del servicio, ya que se puede apreciar picos de *jitter* bastante altos. Si las características de la red son la de soportar un tráfico superior al mencionado, entonces se consideraría definitivamente el reemplazar los enlaces entre *switches,* de *Fast Ethernet* a *Gigabit Ethernet*. El diseño realizado no supera este límite, incluso existe ancho banda disponible para agregar más equipos usados en aplicaciones en tiempo real, tales como teléfonos IP o cámaras de video.

Además del *jitter*, se logro observar que a pesar del alto tráfico alcanzado, esto es aproximadamente 59.52Mbps, no se obtuvo pérdida de paquetes; esto es importante para la calidad de servicio de cualquier tipo de aplicación. El resto de aplicaciones en el Sistema de Transporte Inteligente, no afectarán en las características vistas en tráfico para aplicaciones en tiempo real, ya que con la característica de QoS, estos tendrán menor prioridad, y porque además consumen menor ancho de banda.

4.2 SUBRED DE SERVIDORES

Los servidores son plataformas de computación encargados de procesar información para ser entregados a pedido de los usuarios. Como se refirió en el capítulo anterior, en esta subred habrá cuatro tipos de servidores: servidor para control de tránsito, servidor para imágenes de video, servidor de gestión de red y servidor multipropósito. Además existirá adicionalmente una plataforma para realizar copia de respaldo (backup) de la información más importante de las operaciones del tráfico. Los usuarios no solo son los operadores que se encuentran en la Central de Tráfico, sino también al personal que forma parte de la operación del transporte urbano, ellos pueden ser del GTU o de la PNP. En lo posible, estos dispositivos compartirán un mismo bastidor, básicamente para ocupar menos espacio en la sala donde estarán ubicados. A continuación se verán algunos detalles de las características que tendrán cada servidor.

4.2.1 SERVIDOR DE CONTROL DE TRÁNSITO

Los controladores de semáforos y los sensores de tráfico son los encargados de operar el transporte urbano por medio de los datos obtenidos del tráfico y controlando el flujo del tránsito de vehículos. Es por ello que se necesita de un dispositivo que se encargue de procesar toda esta información y determinar, si fuera el caso, como se controlaría el tráfico. Los subsistemas que debería albergar este servidor son la aplicación de control (basado en una interfase gráfica de usuario – GUI) y la base de datos (para administrar los datos obtenidos del campo). Muchas aplicaciones existentes en el mercado sugieren el uso de un servidor dedicado a la base de datos, y otro dedicado al procesamiento de los datos para el debido control del tránsito. Así también existen aplicaciones que incluyen en un solo servidor aplicaciones que realizan las dos funciones: base de datos y control. Para evitar el uso indebido de recursos, se sugiere el uso de un solo servidor, con características que logren satisfacer los requerimientos de las aplicaciones existentes en el mercado o de otros desarrollos individuales.

1. CPU

Los requerimientos de CPU para que se albergue un programa de gestión de tráfico depende mucho del nivel de complejidad que tenga el sistema. La empresa *Econolite* (www.econolite.com) ofrece un software servidor/cliente llamado *Icon,* que es de baja complejidad, para controlar señales de tránsito y administrar la información que resulta de la vigilancia por medio de sensores de tráfico, soportando además el estándar NTCIP. En este caso el software requiere de una PC estándar (lo que se usa para aplicaciones de escritorio) que soporte el sistema operativo Windows 2000 o Windows 2003. A pesar de solo requerir un hardware de este nivel, esto no puede brindar la seguridad que ofrece un servidor para un sistema de alta disponibilidad.

Por otro lado se tienen *software* en donde se ejecutan algoritmos de alta complejidad mediante el uso de la información reunida por los sensores de tráfico, y en tiempo real ejecutar el control de las señales de tránsito, consumiendo de esa manera gran cantidad de recursos de CPU. La empresa *Fortran Traffic* ofrece la aplicación servidor/cliente *Fastracs* para un control adaptativo SCOOT de hasta 2000 dispositivos de tráfico, en el cual recomienda de manera opcional un servidor basado en un procesador Alpha de 600 MHz o superior para el control inteligente y automático de los semáforos, además recomienda el uso de otro servidor para la base de datos. Para este último, el requerimiento mínimo es un servidor con procesador Intel Pentium III de 900 MHz, tal como puede ser para un *Microsoft Database Server 2000*.

Las principales ciudades de Argentina y Chile usan sistemas SCOOT para el control del tránsito, así como muchas ciudades en todo el mundo. Esto demuestra que los sistemas tienden a ser más sofisticados y en tiempo real, por lo que es necesario que el servidor tenga una gran capacidad de procesamiento, además de ser redundante para la confiabilidad del sistema. Además, los sistemas *Windows* son cada vez más usados en estas aplicaciones, tal como sucede en los sistemas de control industrial. Actualmente los servidores que están en el mercado se basan en procesadores bastante potentes, tales como Pentium IV o Xeon, con velocidades entre 2.8 a 3.8 GHz. Es por ello que un solo servidor puede satisfacer los requerimientos de la aplicación de control y base de datos a la vez.

2. Memoria

Debe haber suficiente memoria *cache* y de acceso dinámico aleatorio (DRAM) para soportar los procesamientos de las aplicaciones de tránsito, ya que si la capacidad de memoria llega a su límite, se puede forzar al CPU a aumentar su carga de trabajo, reduciendo así el tiempo de vida del servidor. Es por ello que una buena inversión en memoria adicional puede prolongar la utilidad del equipo. Es recomendable que la capacidad sea de 1 GB, teniendo la posibilidad de expandirse en capacidad para darle escalabilidad.

3. Redundancia

Los componentes redundantes están identificados como los componentes secundarios que automáticamente toman el control del servidor cuando los componentes primarios fallan. Mientras existan más cantidad de componentes de protección secundarios, el servidor será menos vulnerable a las fallas de hardware. Entre los componentes redundantes más importantes se consideran los procesadores, las fuentes de energía, los cables de alimentación, la ventilación (*cooler*), los canales de I/O, las tarjetas de red, los adaptadores de discos y los "*backplane*". Es recomendable que el servidor cumpla con los requerimientos de redundancia ya que en ella se ejecutan procesos críticos.

4. Densidad de equipo

La cantidad de componentes por unidad de área es un atributo importante cuando se trata de servidores, no solo en cuestión de peso y tamaño, sino también en si se adapta o no a espacios tales como bastidores. Un equipo en donde el CPU, la memoria y los discos de almacenamiento ocupen el menor espacio posible es lo más deseable en los sistemas actuales.

5. Intercambiabilidad (*Swappability*)

Esto es un término usado para determinar si los componentes pueden ser remplazados y asimilados por el sistema. La "intercambiabilidad en caliente" (*hot swappable*) son aquellos que pueden ser reemplazados cuando el sistema está en operación, sin la necesidad de apagar el sistema durante la reparación. Componentes como los ventiladores, tarjetas de procesador, fuentes de energía, discos rígidos, pueden ser intercambiables en caliente.

6. Módulos de software (*drivers*)

Son módulos del sistema, provenientes de diversos fabricantes, que se utilizan como interfases entre sus productos y el sistema operativo. Es indispensable que estos módulos existan para la mayor cantidad de sistemas operativos y no se centralice en uno solo, esto debido a que el sistema de control de tráfico puede ser desarrollado en cualquier tipo de sistema operativo, tales como Windows o Linux.

7. Escalabilidad

Un aspecto muy importante en una plataforma de servidor es la capacidad para realizar mejoras sin requerir un mayor cambio o reemplazo. Esta característica es muy deseable, la posibilidad de aumentar tarjetas de circuitos, memoria, procesadores, o fuente de energía, debe de lograrse con el mínimo efecto en la plataforma base.

8. Interfase de red

Según el análisis del capítulo anterior, cada semáforo genera 5.872 kbps y cada sensor de tráfico 25.64 kbps, y que en total lo podemos asumir como 50 kbps; sabiendo además que existe 120 intersecciones aproximadamente y que todos ellos cuentan con los dos dispositivos, entonces el tráfico de *uplink* o *downlink* es de aproximadamente 6 Mbps. Además el sistema debe ser capaz de poder escalar a servicios adicionales para el transporte, extender su área de servicio (toda Lima Centro) y poder servir a los operadores del transporte mediante aplicaciones de red que les permita monitorear y controlar de manera eficiente el transporte urbano; este último basado en gráficos, lo cual consume recursos de red teniendo en cuenta la cantidad de clientes. Según lo descrito, la interfase que se adapta mejor a estos requerimientos es la de 1 Gbps, no solo porque es lo deseable para un servidor, sino porque se tiene en cuenta la escalabilidad del sistema. Como se determinó anteriormente, el sistema debe ser redundante, luego habrá otra interfase de respaldo, esto es 1 Gbps.

9. Almacenamiento

La información que se va a recolectar para la operación del transporte es valiosa, por lo que no solo se debe tener en consideración el tamaño de los discos, sino también la manera como se almacena los datos. Se necesita de un método de almacenamiento que proporcione redundancia para la tolerancia a fallos. Una de las técnicas más conocidas y que se ajusta a las necesidades de almacenamiento para los operadores y las aplicaciones en el transporte es RAID (*Redundant Array of Independent Disks*). RAID es un método de combinación de varios discos para formar una única unidad lógica en la que se almacenan los datos de forma redundante. El método consiste en desglosar la información en fragmentos para distribuirlas en varios discos, usando diversas técnicas dependiendo del nivel de RAID que se use; esto proporciona redundancia, reducción en el tiempo de acceso, y obtención de mayor ancho de banda para leer y/o escribir, así también como para recuperar datos en caso un disco se averíe.

Variable	Tamaño (bytes)	Descripción
Hora	4	Número de segundos transcurridos a partir de una fecha de referencia
Número se sensor	2	Indica el número de sensor
Número de carril	1	Indica el número de zona o carril
Volumen	1	Número de autos pasantes en un periodo de tiempo
Ocupación	1	Porcentaje de ocupación en una zona
Velocidad	1	Velocidad de un auto pasante en un instante de tiempo
Total	10	

Tabla 4.1 Descripción de las variables que se almacenarán en un Sistema de Adquisición de Datos de Tráfico

Para el dimensionamiento del disco se deberá asumir la adquisición de las variables definidas en el capítulo anterior para los sensores de tráfico. Además se asumirá el uso de una base de datos relacional, tal como puede ser SQL. La forma de almacenamiento de los datos en SQL es mediante tablas, en este caso las variables a almacenar estará dada en columnas y las muestras en filas. A continuación se muestra la descripción de las variables que se usarán en un posible Sistema de Adquisición de Datos.

Considerando además que las muestras se realizan cada segundo (exagerando el caso), y que el número de sensores bordea los 240, se tiene que cada segundo se almacena 240x10 = 2400 bytes de información. Esto complementado con las 14 horas de una jornada laboral, da un total de 115.36 MB por día. Si se considera que se usa el método de *mirroring* (RAID) para el almacenamiento, la información se duplicaría a 230.72 MB. En cuanto a la política de generación de copia de respaldo, es algo que no se puede precisar, ya que los operadores no cuentan con este tipo de sistema. Sin embargo podemos asumir que cada trimestre se realiza esta copia. Por lo tanto, el espacio necesario para tener los datos por un trimestre es de 20.28 GB. En conclusión, para un sistema de adquisición de datos se requiere espacio de almacenamiento medianamente alto. Con un disco estándar de 80 GB, ya sea SCSI o

ATA, y con la posibilidad de expandir la capacidad para ofrecer mayor escalabilidad, es suficiente para mantener toda esa cantidad de información.

4.2.2 SERVIDOR DE VIDEO

Estos servidores de video como elemento de vigilancia tienen las siguientes funciones:

- Recibir las imágenes desde todas las cámaras de video instalados en las vías en tiempo real y visualizarlas en una pantalla, y brindarlo a los usuarios a través de aplicaciones de red.

- Almacenar las imágenes de video a determinadas horas e intervalos de tiempo, dependiendo de la política del operador de transporte.

- Tener a disposición las imágenes almacenadas para un posterior análisis o visualización.

Se comenzará primero con la capacidad de recepción de imágenes. El formato de las imágenes que se envían al servidor de video esta dado en formato MPEG-4 con una calidad de imagen de aproximadamente 720x480 y a 30 fps (*frame per second* ó cuadro por segundo), esto es un flujo de 2 Mbps aproximadamente según los fabricantes de *encoders*. Teniendo en cuenta que se tendrá hasta 22 cámaras de video alrededor del Centro Histórico de Lima, el servidor tiene que tener una capacidad de recepción de aproximadamente 44 Mbps. Esto es una gran cantidad de información, sin contar la necesidad de que los usuarios consulten al servidor. Es por ello que una interfase de 1 Gbps es lo que se necesita para su funcionamiento, además de otra interfase similar para redundar.

El servidor de video debe tener una gran capacidad de almacenamiento, teniendo en cuenta que la política de la Central 105 es la de realizar una copia de los hechos más relevantes en forma diaria. La calidad de imagen no debe perderse, pero sin embargo la cantidad de imágenes puede reducirse a 1 fps, esto debido a que se necesitaría mayores recursos de almacenamiento si se realizará a 30 fps. Para hallar la cantidad de disco necesaria se procederá a realizar el cálculo de la cantidad almacenada de imágenes por una cámara en un segundo. Suponiendo que envía imágenes a 720x480 de 30 fps, entonces el flujo será de 2 Mbps como máximo, entonces lo almacenado resulta 245 kB/s aproximadamente. Pero la escritura se da a 1 fps, por lo tanto la cantidad resultante es 8 KB/s, en consecuencia para una jornada laboral de 14 horas la cantidad de disco utilizada debe ser de 393.75 MB. Como se tiene 22 cámaras, lo lógico es tener como mínimo 8.46 GB diario. Hoy en día los dispositivos de almacenamiento tienen mayor capacidad y son cada vez menos costosos.

Como se ha visto, se requiere de mediana capacidad de almacenamiento, teniendo en cuenta que la copia de respaldo se realiza diariamente y que se utiliza un formato de compresión sofisticada. Sin embargo las políticas del sistema de vigilancia pueden variar, por lo que es recomendable adquirir servidores escalables en discos. En cuanto a las copias de respaldo, se pueden realizar de diferentes maneras, mediante discos compactos o casetes. Una manera económica de realizarlo, y que es muy usado, es la grabación en DVD (*Digital Video Disk*) o en CD (*Compact Disk*), con ello se puede conseguir mayor flexibilidad en la realización de copias que en el caso de los casetes. Un ejemplo de ello es el sistema de vigilancia que la PUCP ha implementado en el Polideportivo, en el cual la arquitectura cliente/servidor se basa en protocolos TCP/IP, a pesar de que su sistema de adquisición de imágenes es analógico. Aquí, las imágenes se guardan en disco duro durante un mes, la capacidad de disco es de aproximadamente 120GB, luego de ese tiempo se realizan copias de seguridad en DVD's. Los DVD's están siendo más utilizados en copias de respaldo de video, ya que tiene una capacidad de almacenamiento superior al CD.

Software	Requerimientos mínimos
NetCam Center Professional Edition	- CPU: PIV-2.0GHz (soporta dual core y multiprocesamiento). - Memoria RAM: 32 MB + 24 MB por cámara. - HDD: 20 GB para almacenamiento. - Red: 100 Mbps.
Visual Hindsight Professional Edition	- CPU: PIII-2.0GHz (soporta multiprocesamiento). - Memoria RAM: 512 MB.
Milestone Xprotect Enterprise	- CPU: Simple o Multiprocesador Intel. - Memoria RAM: 1 GB. - Red: 1 Gbps.
Siemens NextView	- CPU: Intel PIII, PVI, o Celeron – 600MHz. - Memoria RAM: 128 MB. - HDD: 10 GB.

Tabla 4.2 Requerimientos mínimos para servidor de video

Los sistemas de vigilancia por video están surgiendo y evolucionando cada vez más, se pueden conseguir infinidad de productos relacionados a la clase de aplicación presentada. Los servidores de video ofrecidos en el mercado son computadores de alto rendimiento, alta capacidad de procesamiento y gran cantidad de almacenamiento. Las aplicaciones que se ofrecen pueden llegar a administrar hasta 64 cámaras en un mismo computador, utilizando multiprocesamiento y almacenamiento de varios *terabytes* en disco duro.

Como se puede apreciar en la tabla 4.2, la capacidad de procesamiento para el servidor de video es bastante alta, por lo que es necesario que las características sean las más robustas posibles. Un servidor ideal para un sistema de vigilancia IP debe de superar las características antes vistas, además de permitir la escalabilidad del sistema.

4.2.3 SERVIDOR MULTIPROPÓSITO O DE APLICACIONES

Actualmente son múltiples los servicios con las que debe contar una empresa o institución, tales como servicios Web, correo, almacenamiento de ficheros (NFS por ejemplo), autenticación, de impresión y otros. Existe la posibilidad de dimensionar la red de tal manera que exista espacio suficiente para adicionar un número mayor de servidores, sin embargo muchas veces estos servicios no necesitan de mayores recursos, por lo que pueden convivir en un mismo servidor. Es por ello que se sugiere tener a disposición un servidor que actúe como plataforma para cualquier servicio que se necesite en el Centro de Operaciones de Tráfico o cualquier ente encargado del Transporte Urbano. El almacenamiento debe ser escalable, ya que un servicio de correo o de almacenamiento de archivos puede originar alto requerimiento de espacio en discos rígidos. Se recomienda una velocidad de acceso a red de 1 Gbps, y otro enlace de 1 Gbps como enlace redundante.

4.2.4 SERVIDOR DE GESTIÓN DE RED

Los dispositivos de red, servidores e incluso las estaciones en la sala de control deben ser monitoreados para asegurar su correcto funcionamiento. Los elementos necesarios para el monitoreo de equipos de red son los agentes SNMP (*Simple Network Management Protocol*) con capacidades RMON (*Remote Monitoring*). Los agentes son procesos que se ejecutan en los dispositivos de red y reportan información de su estado a un servidor de gestión de red o NMS (*Network Management System*). El NMS generalmente acumula datos desde los agentes y computariza las estadísticas de la red. Estado, alarmas, e información de rendimiento es mostrado en cualquier estación de trabajo que se conecta al NMS, en donde la interfase Web es la más usada.

La información que se recolecta debe ser lo necesario para poder tener un panorama claro de lo que ocurre en la red, evitando así el uso innecesario de recursos de red al enviar gran cantidad de información de gestión. Los agentes en los equipos de red están ya definidos por los fabricantes, mientras que los agentes que se instalan en los servidores son definidos por el usuario, los cuales se pueden conseguir como software libre. La métrica típica que se obtiene de los servidores es información de I/O, sistema de memoria, utilización de CPU y latencia en la comunicación con otros dispositivos.

Para la red del Sistema de Transporte Inteligente, los equipos a monitorear son los *switches* administrables y los servidores, incluso las estaciones de trabajo. Diferentes fabricantes de dispositivos ofrecen soluciones de software para la implementación de un sistema integrado de gestión de red, por ejemplo se tiene el *CiscoWorks LAN Mangement* y el *HP OpenView*. Además de ello, se tienen aplicaciones libres que pueden ser una solución para el alto costo de las aplicaciones propietarias, e incluso puede desarrollarse aplicaciones específicamente para este propósito. Todo este sistema no necesita de mayores recursos para operar, por lo que pueden instalarse en una PC de escritorio estándar con acceso a red de 100 Mbps o un servidor que ofrece mayor seguridad para el sistema de gestión. Se recomienda implementarse en un servidor, el cual ofrece mayor seguridad para la ejecución del NMS que un computador de escritorio.

4.2.5 ALMACENAMIENTO DE RESPALDO

Existe una variedad de dispositivos de almacenamiento, entre ellos las cintas magnéticas y los discos rígidos. El espacio de disco de los servidores para almacenar información es limitada, por lo que cada cierto tiempo se ven en la necesidad de liberar espacio, ello debido a que los datos almacenados superan su capacidad máxima. Para cualquier institución o empresa, es indispensable que la información antigua quede almacenada de alguna forma, en caso necesiten revisarlo. Es por ello que se pone a disposición una plataforma que permita almacenar estos datos en dispositivos que puedan retenerlos durante largo tiempo.

Según las necesidades del sistema, el servidor de control de tráfico sería el único que necesitaría realizar copias de respaldo, además de tenerlo disponible en caso se requiera realizar análisis de datos pasados. Es por ello que no se requiere un medio para copia de seguridad externa, sino interna, es decir instalado en el mismo servidor, reduciendo también el costo del dispositivo.

4.2.6 SELECCIÓN DE SERVIDORES

Existe una variedad de fabricantes de servidores, entre los más populares y usados en el Perú son IBM y HP, por ser las computadoras de mayor rendimiento conocidos localmente. Lo recomendable es que los servidores sean del mismo fabricante, ya que se simplifica la adquisición y soporte. Son muchos factores los que influyen en la selección de la plataforma de software, en este caso IBM y HP tienen una tendencia de desarrollo similar, son servidores de alto rendimiento y que siguen los lineamientos industriales, tal como el ser compatible con sistemas operativos estándar, entre ellas Windows y Linux. Para la aplicación establecida, los servidores que se adaptan a las necesidades son los IBM *xSeries* y los HP *Proliant*, los cuales son similares en características, estandarizados en la industria de la tecnología de la información, y basados en procesadores Intel x86. Sin embargo el criterio para discriminar el uso de estos servidores es el rendimiento, para ello se consulto a dos organizaciones encargadas de realizar pruebas de rendimiento, ellos son el TPC (Transaction Procession Performance Council) y el SPEC (Standard Performance Evaluation Corporation). Los resultados muestran una leve superioridad de los IBM *eServer* en comparación con los HP *Proliant*, no solo en rendimiento de CPU y costo/beneficio, sino también en su comportamiento con aplicaciones Web y transacciones de red, necesario en las aplicaciones antes vistas, que son del tipo cliente/servidor. Por lo tanto se trabajará con los servidores IBM, seleccionando los modelos que se muestran en la tabla para el uso de los servicios del Sistema de Transporte Inteligente según las características antes descritas.

Los rasgos más importantes en la selección de los equipos fue la capacidad de CPU. Para las aplicaciones de control de tráfico y vigilancia IP, la capacidad de procesamiento son los mejores, ya que sus requerimientos de procesamiento son altos. Se optó por elegir servidores de doble procesador y basados en Intel Xeon con doble núcleo, tecnología que permita elevar el rendimiento y capacidad de procesamiento, sin aumentar el consumo de energía. Para las otras aplicaciones, se eligió servidores con un solo procesador Pentium IV, pero de alta velocidad. Para la memoria RAM, se dejó con su capacidad estándar, 1 GB para los servidores de control de tráfico y vigilancia; y 512 MB para los otros servidores.

Una característica en común de los servidores es la capacidad de disco duro, todos ellos usan Ultra 320 SCSI, de alta velocidad, y con característica de intercambiabilidad en caliente, a excepción del servidor de gestión, en el cual los discos son serial ATA e internos. Pero todos ellos se les dejó con su capacidad estándar, esto es 73 GB para los SCSI y 80 GB para los Serial ATA, tal como se requirió. Para el servidor de control de tráfico, se le agregó un dispositivo interno para back-up DDS Gen 5 de 36/72 GB de capacidad. Para el servidor de vigilancia, se le agregó un dispositivo de lectura/escritura de DVD y CD, usado en el back-up de video.

Las características de red son similares, es decir todos los servidores usan interfase de red 10/100/1000 BASETx, el cual es uno de los últimos estándares Ethernet y que permite reducir costos y alcanzar altas velocidades, necesarias para cualquier servidor. Los enlaces son redundantes ya que se desea la más alta disponibilidad por tratarse de un sistema crítico. Solo tres de los servidores pueden montarse en un gabinete estándar de 19'', esto para ocupar el menor espacio posible, mientras que el otro tiene un chasis para escritorio, no obstante se puede posicionar en un gabinete, pero ocupando mayor espacio.

Función	Modelo del producto	Características
Control de tráfico	eServer xSeries 346	- Procesador Intel Xeon 3.8 Ghz y doble núcleo (max. 2 unidades). - 2MB de memoria Cache L2. - 1 GB de memoria RAM DDRII (Hasta 16 GB de capacidad). - 73 GB HDD Ultra 320 SCSI (Hasta 1.8 TB de capacidad) . - Interfase dual 10/100/1000BASE-TX integrado. - Dispositivo back-up DDS Gen 5 36/72 GB.
Vigilancia en video	eServer xSeries 336	- Procesador Intel Xeon 3.8 Ghz y doble núcleo (max. 2 unidades). - 2MB de memoria Cache L2. - 1 GB de memoria RAM DDRII (Hasta 16 GB). - 73 GB HDD Ultra 320 SCSI (Hasta 600GB de capacidad). - Interfase dual 10/100/1000BASE-TX integrado. - Dispositivo lectura/escritura de CD-ROM/DVD.
Multipróposito	eServer xSeries 306m	- Procesador Intel Pentium IV 3 GHz. - 512 MB de memoria RAM DDRII (Hasta 8 GB de capacidad). - 73 GB HDD Ultra 320 SCSI (Hasta 600 GB de capacidad). - Interfase dual 10/100/1000BASE-TX integrado.
Gestión de red	eServer xSeries 100	- Procesador Intel Pentium IV 2.8 GHz.. - 512 MB de memoria RAM DDRII (Hasta 8 GB de capacidad). - 80 GB HDD Serial ATA (Hasta 500 GB de capacidad). - Interfase 10/100/1000BASE-TX integrado.

Tabla 4.3 Servidores del Sistema de Transporte Inteligente

4.3 SUBRED DE ESTACIONES DE TRABAJO

4.3.1 CARACTERÍSTICAS

Esta subred está conformada por todos los equipos que permiten a los operadores del transporte controlar, monitorear y administrar el tráfico en las vías. Estos equipos pueden ser de múltiples variedades y tecnologías, entre ellas, y que conforman el elemento principal, son las estaciones de trabajo. Estos son computadores personales en donde se ejecutan aplicaciones que permite a los operadores tener un panorama de lo que sucede en el tránsito y así poder controlarlo y analizarlo. Estas aplicaciones muchas veces trabajan como clientes de servicios brindados por los servidores de control de tráfico o de video ya antes vistos, y que se basan en protocolos TCP/IP, en el cual el estándar Web es el preferido para realizar el acceso a los servicios.

Las estaciones de trabajo están ubicadas en una sala de control, el cual funciona como una Central de Operaciones, y que muchas veces está conformada por más que estaciones de trabajo. En este ambiente se puede encontrar proyectores, servidores de multipantallas, impresoras, teléfonos IP (futura implementación); los cuales mayormente necesitan estar conectados a red.

Debido a que en este espacio se procesan y ejecutan aplicaciones de alta demanda, es recomendable que tengan acceso a la red directamente del *backbone*, aprovechando la ubicación de todos los equipos en un solo local. Como objetivo de esta red, deberá de soportarse en un futuro la implementación de VoIP, ya que se necesitará de comunicación entre la sala de control y las dos redes de los operadores del transporte: el GTU y la Central 105.

Las características que debe tener una estación de trabajo son las más simples, no tiene que compararse a los recursos que puede proporcionar un servidor. Por ejemplo, una computadora estándar de escritorio tiene las siguientes características: procesador Pentium IV, memoria RAM de 512 MB, disco duro de 40 GB, lectora de CD-ROM, teclado, ratón, tarjeta de red 10/100 Ethernet, disquetera y monitor de 15" a color; lo suficiente para poder desarrollar el trabajo en una central de tráfico. No se precisa el número de operadores que puede haber en la sala de control, esto debido a que no existe un sistema tal como se ha planteado, sin embargo se puede presumir asumiendo que cantidad de área puede ocupar cada persona que labora en la central. Lo razonable es que una persona ocupe un área de 10 metros cuadrados (BICSI), lo cual daría un total de hasta 4 operadores en un área de aproximadamente 40 m^2, que es la medida de la sala de control de la Central. Sin embargo, esta cantidad puede aumentar hasta 6, debido a la cantidad de personal que existe laborando en el lugar.

Con la descripción de las características de los servidores y de la los equipos de la sala de control, se puede obtener el diagrama de red que habrá en el local donde estará ubicado la Central de Control de Tráfico.

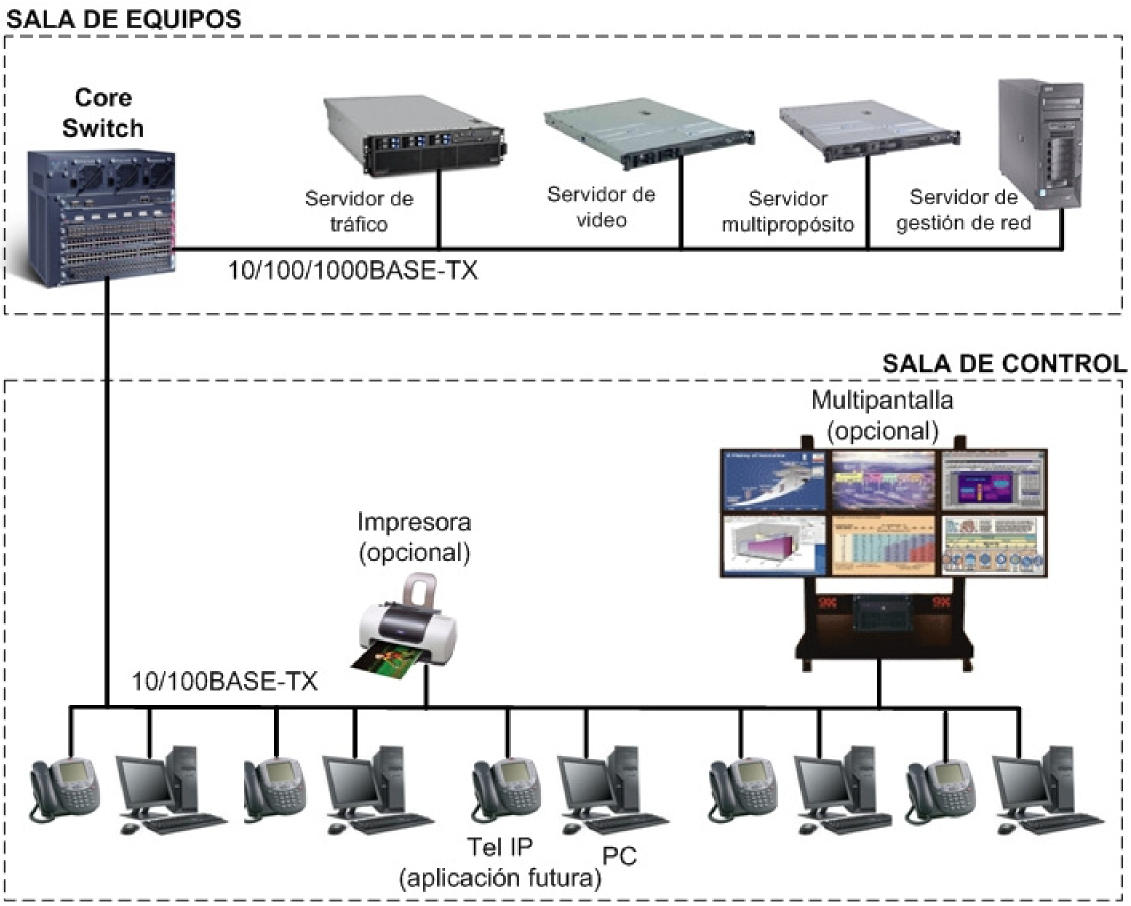

Figura 4.7 Diagrama de subred de servidores y estaciones de trabajo (sala de control)

4.3.2 <u>SELECCIÓN DEL CORE SWITCH</u>

Conociendo mejor las necesidades de la red, se puede saber que dimensiones tendrá el *core switch*. En este caso, no es necesario que sea un equipo adaptado a los ambientes industriales, sino un equipo comercial. Podemos saber aproximadamente cuantos puertos se necesita para cada subred y de que tipo.

- Subred de equipos de campo: Se necesita de puertos 100BASE-FX, en el cual cada anillo que sirve aproximadamente 30 intersecciones, consume 2 de estos puertos.

Entonces si son aproximadamente 120 intersecciones, se puede presumir que puede haber hasta 4 anillos de este tipo, dando como resultado 8 puertos 100BASE-FX necesarios como mínimo. No obstante se recomienda tener a disposición mayor cantidad de puertos en caso de expansión de la red.

- Subred de servidores: Se necesita de puertos 10/100/1000BASE-T, al tener 4 servidores que requieren estos puertos, se estima que es necesario al menos 4 puertos de este tipo. Sin embargo se debe contar con el doble de puertos en caso se requiera que el sistema sea redundante, es decir dos puertos *Gigabit Ethernet* para cada servidor. Además debe existir puertos extras en caso de un aumento de servidores.

- Subred de estaciones de trabajo: Se necesita de puertos 10/100BASE-T con PoE para el soporte de VoIP en un futuro u otro equipo que lo necesite, no se sabe con exactitud el numero del personal que estará en la sala de control, pero se presume que puede haber hasta 6 operadores, dando como resultado 12 puertos necesarios, tanto para la estación de trabajo como para los futuros teléfonos IP. Además se recomienda dejar a disposición más puertos en caso de adicionamiento de elementos de red.

- Enlaces a redes del GTU y Central 105: En este caso los enlaces se dan a través de puertos 1000BASE-X, por lo que es necesario 2 puertos de este tipo. Solo se considerarán los enlaces, y no las redes de estas instituciones.

Existe infinidad de fabricantes de *core switches* comerciales, por mencionar algunos están *CISCO Systems*, *Nortel Network*, *Alcatel*, *Foundry Network*. Sin embargo es recomendable que el *core switch* sea del mismo fabricante que los *switches* administrables con las cuales forma la topología en anillo, ya que así se podrá aprovechar todas las ventajas que pueda proporcionar el fabricante en sus productos, fuera de los estándares *Ethernet*, tales como facilidad en la administración de los equipos de red. Es por ello que se escoge los productos CISCO, que en este caso ha mostrado interés en las aplicaciones del Sistema de Transporte Inteligente, y que además proporciona flexibilidad en la administración de sus equipos.

El *switch* que más se adapta a las necesidades antes mencionadas es el *Catalyst* 4503, un *core switch* provisto de 3 ranuras, en el cual la primera ranura esta destinada al motor del *switch* y las dos restantes para módulos de diferentes características, y que en este caso los que se usarán son los que se muestran en la Fig. 4.8. Para mayor detalle, puede verse las hojas de especificaciones en el Anexo 2.

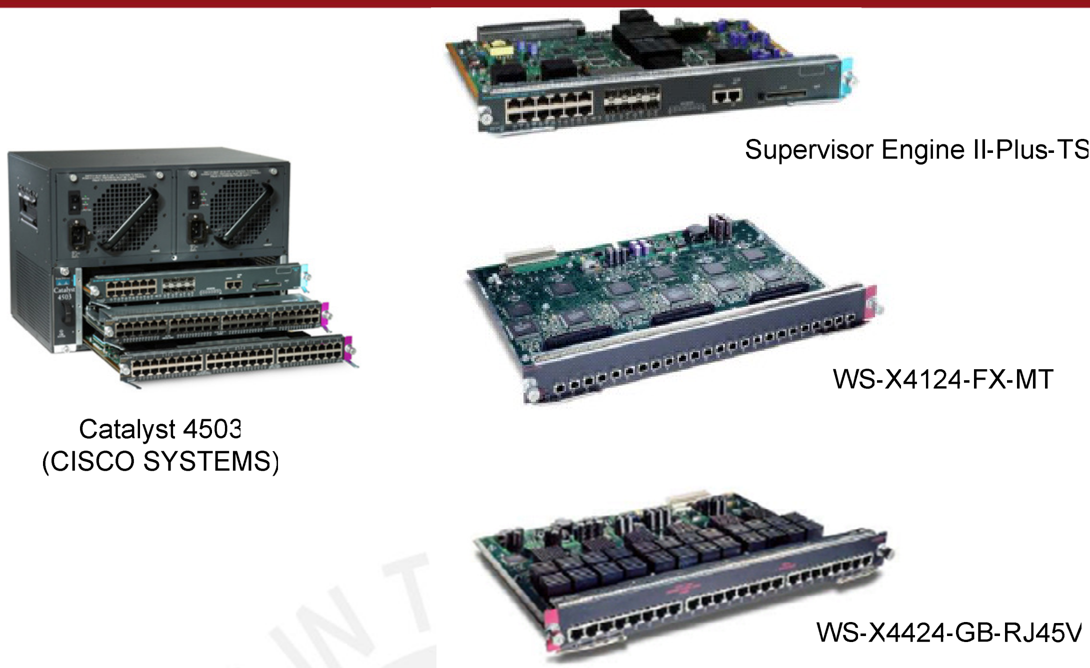

Figura 4.8 CISCO Switch Catalyst 4503 con los respectivos módulos que serán usados

Modelo	Características
Catalyst 4503	- Conmutación multicapa a nivel 2 (MAC), nivel 3 (IP) y nivel 4 (TCP/UDP). - Conmutación multicast. - QoS para nivel 2 (CoS) y nivel 3 (ToS). - VLANs. - IEEE 802.1D Spanning Tree Protocol. - IEEE 802.1Q Virtual Trunking Protocol.
WS-X4124-FX-MT	- 24 puertos 100BASE-FX fibra óptica multimodo con interfases MT-RJ.
WS-X4424-GB-RJ45	- 24 puertos 10/100/1000BASE-T PoE con interfases RJ-45.
Supervisor Engine II-Plus-TS	- Motor de switch capa 2 a 4, de 64 Gbps y 48 Mpps. - 12 puertos 10/100/1000BASE-T PoE con interfases RJ-45. - 8 puertos SFP (Small Form-Factor Pluggable) para mini-GBIC.

Tabla 4.4 Características del Switch Catalyst 4503 y módulos respectivos

Según la tabla 4.4, se eligió un módulo para los enlaces *Fast Ethernet* en fibra, y un módulo para enlaces *Gigabit Ethernet* en cobre, el último requerido para los servidores y estaciones de trabajo, esto para darle mayor escalabilidad.

4.4 DIRECCIONAMIENTO IP

Uno de los aspectos importantes en el diseño de la red a nivel de protocolo IP es la asignación de direcciones IP a las subredes que la conforman. En este caso se considerará solo al protocolo IPv4, ya que IPv6 está en pleno desarrollo y los fabricantes no ven la necesidad de migrar a esta versión.

Existen dos tipos de direcciones IP, las públicas y las privadas. Las direcciones públicas tienen carácter legal y son válidas solo para uso en la Internet, por lo tanto es necesario solicitarlos a una autoridad de Internet como son el *American Registry for Internet Numbers* (ARIN) o *Réseaux IP Européennes* (RIPE). En cambio las direcciones privadas son aquellas que fueron separadas de las direcciones IP por la norma RFC 1918, para que sea de uso exclusivamente privada, es decir que no son reconocidos en Internet y por lo tanto su uso es libre para cualquier red privada.

El Sistema de Transporte Inteligente para la ciudad de Lima es un proyecto de gran envergadura, el cual no contempla solo el Centro Histórico, sino toda la ciudad, y hasta todo el Perú. Por lo tanto, es necesario obtener una dirección de red que pueda soportar las necesidades de direccionamiento de dicho sistema. El uso de direcciones privadas seria lo ideal para el ITS del Centro Histórico de Lima debido a las siguientes razones:

- La red ITS es totalmente privada.
- La red comprende un alto volumen de elementos.
- Escasez de direcciones públicas.
- Necesidad de escalabilidad para proyectos futuros.

Existen tres tipos de direcciones privadas

- Direcciones de Clase A: 10.0.0.0 hasta 10.255.255.255
- Direcciones de Clase B: 172.16.0.0 hasta 172.31.255.255
- Direcciones de Clase C: 192.168.0.0 hasta 192.168.255.255

Teniendo en cuenta el tamaño de la red para el Centro Histórico de Lima, la dirección de clase A es la que mejor se adapta a las necesidades acceso, por lo tanto la dirección de red del sistema será el 10.0.0.0, de donde se desprenderá las subredes que conforman la red completa. La asignación de direcciones para cada subred se puede realizar en forma estática o dinámica. Para realizarlo en forma dinámica se necesita de un servidor DHCP, los cuales por lo general vienen embebidos en los *switches* administrables, así también como en el *core switch*.

Grupo	Número de elementos	Dirección de subred/mascara de subred	Direcciones IP disponibles
Equipos de control de tráfico	<120 controladores de semáforos <240 sensores de tráfico	10 1 0 0 / 255 255 0 0	65534
Cámaras de video	Hasta 22 unidades	10 2 1 0 / 255 255 255 0	254
Servidores	Hasta 8 interfases incluyendo redundancia	10 2 2 0 / 255 255 255 0	254
Estaciones de trabajo	Hasta 6 unidades	10 2 3 0 / 255 255 255 0	254

Tabla 4.5 Tabla de asignación de direcciones IP para los equipos del Sistema de Transporte Inteligente en el Centro Histórico de Lima

La manera como se distribuye las direcciones puede variar en cuanto al criterio del administrador de red, es por ello que se dará como ejemplo la asignación de direcciones en la red del Sistema de Transporte Inteligente. En este caso se dividirá la red 10.0.0.0 en pequeñas subredes, convirtiéndola así en direccionamiento sin clase (deja de ser dirección de clase A). En la actualidad todos los equipos de enrutamiento tienen capacidad para enrutar redes con dirección sin clase, por lo que no existe ningún problema en ese aspecto. Luego, el direccionamiento para los equipos se resume en la siguiente tabla.

Como se puede apreciar, no existe problema si se desperdicia direcciones IP, esto debido a la naturaleza de la dirección privada. Asimismo no es necesario que el *core switch* utilice protocolos de enrutamiento, ya que es el único dispositivo que enruta, no obstante se puede utilizar. Esto obliga a implementar direccionamiento estático, dando como resultado un enrutamiento más consistente y seguro.

4.5 CONSIDERACIONES EN CABLEADO ESTRUCTURADO

Un elemento importante para la integridad de una red es el cableado estructurado. Muchos administradores de red lo ven como algo efímero, sin importancia para la operación del sistema. Sin embargo, mucho de los problemas que a menudo son irreparables se debe a la inadecuada instalación y planeamiento del cableado. Además, los problemas de cableado son los mas difíciles de determinar y resolver, y muchas veces no tienen solución. Es por ello que una buena estructura en el cableado es de vital importancia para aplicaciones críticas como la de un Sistema de Transporte Inteligente.

Un Sistema de Cableado Estructurado provee un plan de cableado flexible que pueda soportar múltiples computadores y otros dispositivos adquiridos de diferentes vendedores. Esto involucra una jerarquía de cableado que transporta la señal desde el backbone hasta los gabinetes de telecomunicación en varios pisos de una edificación, y un cableado horizontal que transporta los servicios desde los gabinetes hasta las zonas de trabajo. La facilidad con la que estos sistemas pueden expandirse y reorganizarse, ayuda a administrar los constantes movimientos, cambios y aumentos que ocurren en una red. Un Sistema para el transporte de datos en la red basado en una estructura de cableado da como resultado una red confiable, y que a la vez facilita la detección de problemas.

Algunas de las organizaciones que regulan la estructura de un cableado estructurado son ANSI/EIA/TIA y el ISO/IEC, de los cuales se tomará en cuenta las especificaciones de ANSI/EIA/TIA debido a que es el más usado en el Perú, siendo los más importantes los siguientes:

- ANSI/EIA/TIA 568-A *Commercial Building Telecommunication Cabling Standard*
- ANSI/TIA/EIA 569-A *Commercial Building Standard for Telecommunication Pathways and Spaces*
- ANSI/TIA/EIA 606 *Administration Standard for the Telecommunication Infrastructure of Commercial Buildings*
- ANSI/TIA/EIA 607 *Grounding and Bonding Requirements for Telecommunication in Commercial Buildings*

Además los elementos a considerar en la red en la Central de Tráfico son el cableado Horizontal, Cableado *Backbone*, Área de Trabajo y el Cuarto de Equipos. Considerando esto se puede ofrecer las consideraciones necesarias para el Sistema de Cableado que tendrá la red. Sin embargo estos estándares no serán validos para la subred de equipos de campo, debido a que no está orientado a aplicaciones como un Sistema de Transporte Inteligente, considerado una aplicación industrial y de planta externa.

4.5.1 CABLEADO PARA ETHERNET INDUSTRIAL

Las aplicaciones de los Sistemas de Transporte Inteligentes tienen carácter industrial, es decir que las especificaciones de cableado en la subred de equipos de campo deben de exceder las recomendaciones que especifica el EIA/TIA 568, que ha sido elaborado para edificaciones comerciales. El cableado estructurado que se desprende del *backbone* a las intersecciones viales debe de ser lo suficientemente robustos para soportar las condiciones que se dan en esta área.

La tecnología Ethernet se ha vuelto muy popular en las redes empresariales y de *campus*, en donde las especificaciones para el cableado estructurado solo se consideran las condiciones del ambiente de oficina. En esta última década, *Ethernet* ha expandido su aplicación hacia las redes industriales, debido básicamente a su simplicidad y bajos costos, el cual se incluye los Sistemas de Transporte Inteligente. Es por ello que se están dando esfuerzos de parte de las principales organizaciones, entre ellas el EIA/TIA y el IEC, para elaborar un estándar para el cableado estructurado e interfases de red en aplicaciones industriales. El *Internacional Telecommunicaction Industry* (TIA) ha conformado la comisión TR-42.9 *Industrial Telecommunications Infrastructure* a finales del año 1999, cuyo objetivo es la de desarrollar y mantener estándares para la infraestructura de telecomunicaciones en edificaciones, estructuras, y *campuses* que escapan del alcance de los estándares para edificaciones comerciales. Se han logrado grandes avances, los cuales se usarán en el diseño de la red, además de otros estándares que concuerdan con el ambiente en donde se implementará la red.

Los enlaces de fibra óptica que se requieren deben ser de tipo multimodo de 50/125 um, el cual tiene un ancho de banda mínima de 500Mhz*km, permitiendo alcanzar una distancia de 2 km a una velocidad de 100 Mbps. En la figura se muestra la disposición de los enlaces de fibra óptica, y cuyas distancias no sobrepasan los 500 metros, pudiéndose entonces también usar cable multimodo de 62.5/125 um, logrando alcanzar una distancia máxima de 500m a una velocidad de 100 Mbps, pero para futuros escalamientos se recomienda el primero. Para el acceso de los equipos de campo, se usará cable UTP Categoría 5e o Categoría 6, el cual es ideal para ambientes de alto ruido electromagnético (EMI) generado por la cercanía de las líneas de alimentación y para conexión de dispositivos de planta externa. Como se puede apreciar en el diagrama, se ha calculado que se necesitará aproximadamente 6500 metros de fibra óptica para los enlaces en el anillo y la expansión en estrella hacia el resto de puntos.

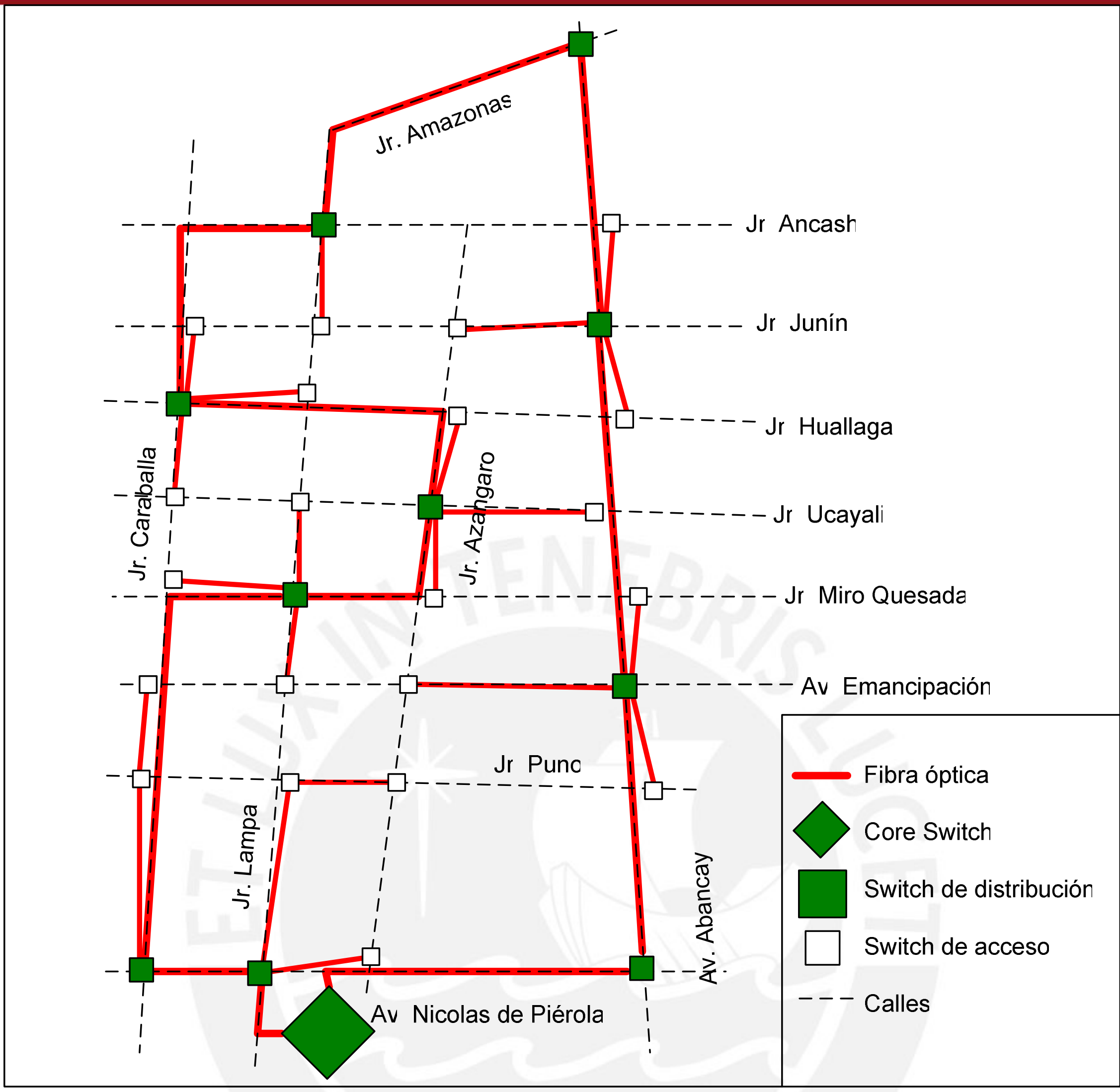

Figura 4.9 Diagrama que muestra la disposición de los nodos en la subred de equipos de campo

La subred de equipos de campo está dispuesta en forma de anillo, muy usado en los equipos de *backbone*, en este caso los enlaces de fibra óptica se adaptarán a los estándares y requerimientos de los enlaces de fibra óptica en planta externa, los cuales son el ANSI/ICEA-S-83-640 y el ANSI/TIA/EIA 568-B. Pero en general, esta parte de la red debe cumplir los requerimientos del estándar ANSI/TIA/EIA 758 *Customer Owned Outside Plant.*

Para las conexiones de los equipos que están fuera del gabinete, los requerimientos de transmisión de los dispositivos de conexión debe cumplir el estándar ANSI/TIA/EIA 568-B, el cual es básicamente cableado horizontal. Los componentes necesarios para esta distribución son como se muestra en el gráfico, se tiene el *patch panel*, el cual es usado como bloque de conexión cruzada o panel de distribución, y donde se distribuye el acceso a los equipos que estarán conectados a la red.

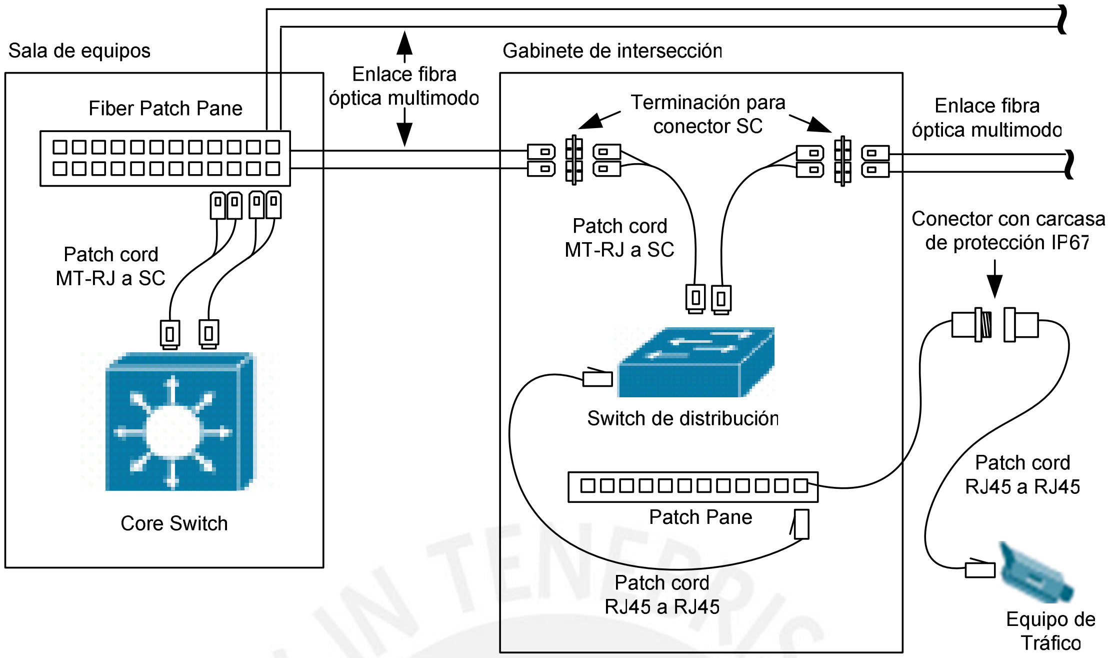

Figura 4.10 Diagrama de enlace entre la sala de equipos y los gabinetes de intersección

El canal consiste en el cable de equipo, cableado horizontal y el cable de dispositivo de red; los cuales en total no deben de sobrepasar los 100 m. Como toda aplicación de planta externa, estos equipos de conexión deben cumplir ciertos requerimientos. En el panel de distribución o *patch panel*, debe estar diseñado para permitir un ajuste seguro en el gabinete de intersección. En cuanto a los terminales y cables expuestos a la intemperie, deben de soportar temperaturas en el rango de -40℃ a 70℃, además de resistir la corrosión provocada por la humedad, la degradación UV, y el contacto con el agua (en caso de lluvias).

Para que se cumplan estos requerimientos, existen cables UTP categoría 5e y 6 especialmente diseñados para estas aplicaciones. Además existen carcasas de protección para las terminaciones, el cual cumple con el estándar IEC IP67. El estándar IP (*Ingress Protection* o “Protección de Ingreso”) especifica la protección ambiental en gabinetes y aplicaciones de planta externa, en donde el primer número indica el nivel de protección contra materiales sólidos y el segundo contra materiales líquidos.

Figura 4.11 A la derecha un extremo del *patch cord* del equipo de campo (conector macho), a la izquierda un extremo del cableado horizontal (conector hembra), muestra de la protección IP67 para cable UTP. (SIEMON's Industrial Plug)

Como se muestra en la Fig. 4.11, se asegura una protección total contra factores externos en una conexión de planta externa. El primer número que es "6", indica total protección contra cualquier tipo de polvo, y el segundo número "7", indica protección contra los efectos de inmersión en líquido entre los 15 cm y 1 m.

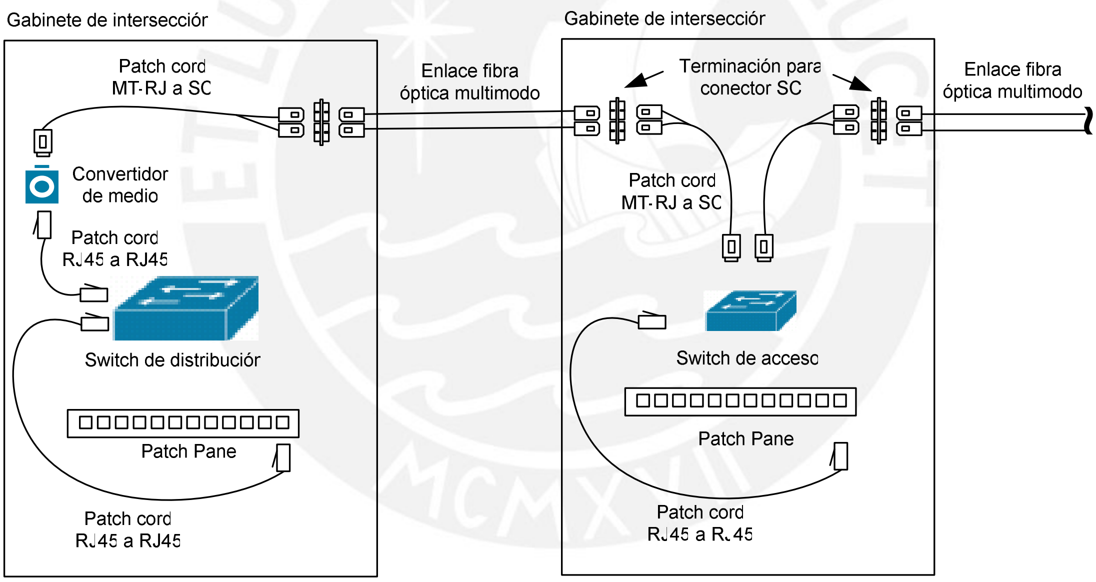

Figura 4.12 Diagrama de enlace entre el switch de distribución y switch de acceso

Para extender la red se usará los convertidores de medio, los cuales ya se determinó anteriormente. En este caso el enlace se realizará como un cableado *backbone* o vertical, según los estándares ya mencionados. Se puede apreciar en el gráfico siguiente como es que se realiza los enlaces de "*switches* de acceso" a los "*switches* administrables", y el uso del convertidor de medio de transmisión.

4.5.2 CABLEADO HORIZONTAL

El cableado horizontal es aquel que se extiende de un conector en el área de trabajo hasta el gabinete de comunicaciones por medio de un panel de distribución. Estos enlaces se aplican a lo que será la sala de control. Los componentes de este tipo de cableado son los siguientes:

1. Cableado horizontal

Existen tres tipos de cables para el cableado horizontal según el estándar EIA/TIA 568-B, de los cuales solo se usarán dos:

- Cuatro pares de cable UTP de 100 ohmios de impedancia balanceado (conductor sólido AWG-24), de Categoría 5e o superior, esto para permitir la estabilidad y alto rendimiento de aplicaciones que requieran alta calidad tales como VoIP y PoE (*Power over Ethernet*), se recomienda sin embargo cable UTP Categoría 6 por exceder las especificaciones de sus antecesores. El tipo de conector es el RJ45 con terminación modular de 8 cables o cuatro pares de cables.

- Dos cables de fibra óptica multimodo de 62.5/125 o 50/125 um. Las especificaciones para el tipo de conector se le conoce como conector *duplex* SCFOC/2.5, o más conocido como conector SC, que viene de las siglas "*Subscriber Connector*" (conector de suscriptor), y FOC de "*Fiber Optic Conector*" (Conector de fibra óptica). Existen varios tipos de conectores más para fibra óptica, sin embargo eso es lo que se usa en la mayoría de *switches* con interfase *Gigabit Ethernet*.

2. Conector de pared

Un mínimo de dos conectores de pared (outlets) es la especificada para cada área de trabajo, y cada área está conectada directamente al gabinete de telecomunicaciones. Un conector debe estar enlazado a un cable UTP (8 hilos), y el otro a cualquier tipo de cable horizontal ya sea cable UTP, cable STP, o fibra óptica multimodo, esto según la necesidad del usuario. En el caso de la sala de control, los dos conectores deben ser cable UTP, uno para la estación de trabajo y el otro para un teléfono IP como aplicación futura. La longitud no debe exceder de los 5 metros. En el caso de los servidores, la conexión puede ser directa, debido a la cercanía del switch y porque son equipos que no requiere mayor movilidad o cambio.

3. *Patch Cord* de conexión cruzada

Los cables de equipo y los *patch cord* usados en los gabinetes de telecomunicación no deben exceder los 5 m de distancia. Se permite 5 m para el *patch cord* del conector de pared a la estación de trabajo. Esto da un total de 10 m para el cableado de equipo de telecomunicación y estación de trabajo en todo el trayecto, por lo que combinado con los 90 metros permitidos para el cableado horizontal, da un total de 100m desde el *core switch* al equipo del usuario.

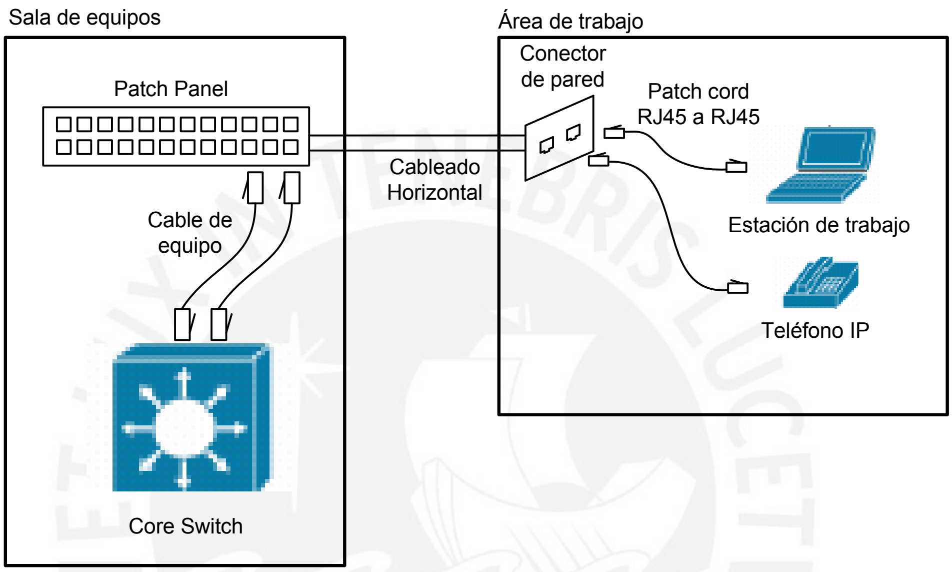

Figura 4.13 Cableado Horizontal en la Central de Tráfico

4.5.3 CABLEADO BACKBONE

Los aspectos que se consideran en cuanto al cableado vertical o de *backbone* son la topología y el medio de transmisión. En nuestro caso, los enlaces que se necesitan son hacia los equipos de campo y a las redes del GTU y la Central 105. Se supondrá que estas redes existen o serán implementadas en un futuro, aunque no necesariamente sea válido, ya que de alguna manera la Central de Tráfico necesitará de enlaces hacia otras redes, ya sea a otras centrales o redes de instituciones que estén involucradas directamente con el Sistema de Transporte Inteligente.

La topología comúnmente usada y la más recomendada es la estrella, aspecto que no se cumpliría para la conexión con los *switches* de administración, sin embargo es válido realizarlo en el caso de la tecnología *Ethernet,* y por tratarse de una aplicación de planta externa. Para la selección del medio de transmisión, se determinó que para el enlace en anillo entre el *core switch* y los *switches* administrables se usará fibra óptica multimodo de

50/125 µm, el cual logra distancias de hasta 2 Km. usando 100BASE-FX. En el caso de los enlaces a las redes de los operadores de tránsito, se usaría fibra óptica monomodo, con el cual se lograría alcanzar distancias de hasta 5 km, según el estándar de cableado estructurado, usando 1000BASE-LX. Todo este cableado saldrá por la ruta de acceso que se encuentra en la sala de control, tal como se apreció en el capitulo anterior, el cual consta de dos tubos PVC de 3" que salen directamente hacia los ductos que existe en el exterior por dos rutas diferentes.

4.5.4 SALA DE EQUIPOS

Este cuarto estará conformado por el *core switch*, los servidores y los paneles de distribución de telecomunicaciones o de conexión cruzada. En cuando a su ubicación, se ha elegido el primer piso de la central de tráfico, siguiendo las siguientes recomendaciones (BICSI):

- Espacio requerido: Según la regla, si existe menos de 200 áreas de trabajo, entonces el cuarto de equipos no debe ser menor a 14 m^2. Como se sabe, el sistema tiene hasta 120 intersecciones bajo control, adicionalmente a las áreas de trabajo en la sala de control, el cual no supera las 6 unidades.

- Acceso a ruta de comunicación externa: La salida hacia los ductos de comunicación existentes se encuentra en la sala de control, a una altura de 1 metro, haciéndolo más cercano a la sala de equipos.

- Acceso a suministro eléctrico: En el primer piso existen mayores facilidades al acceso de energía eléctrica, en términos de reubicación o cambios.

En cuanto a la disposición de los equipos, por tratarse de un ambiente pequeño, se trata en lo posible de reducir el espacio que ocuparán los equipos. Es por ello que los chasis de los equipos seleccionados fueron escogidos para que puedan montarse en un gabinete de telecomunicaciones. Por lo tanto se usarán dos gabinetes de 19'' de ancho, uno para los servidores y el otro para el *core switch* con el panel de distribución de telecomunicaciones. Estos gabinetes deben cumplir con el estándar EIA-310D, el cual fija las dimensiones y mecánica de los gabinetes para equipos de telecomunicaciones.

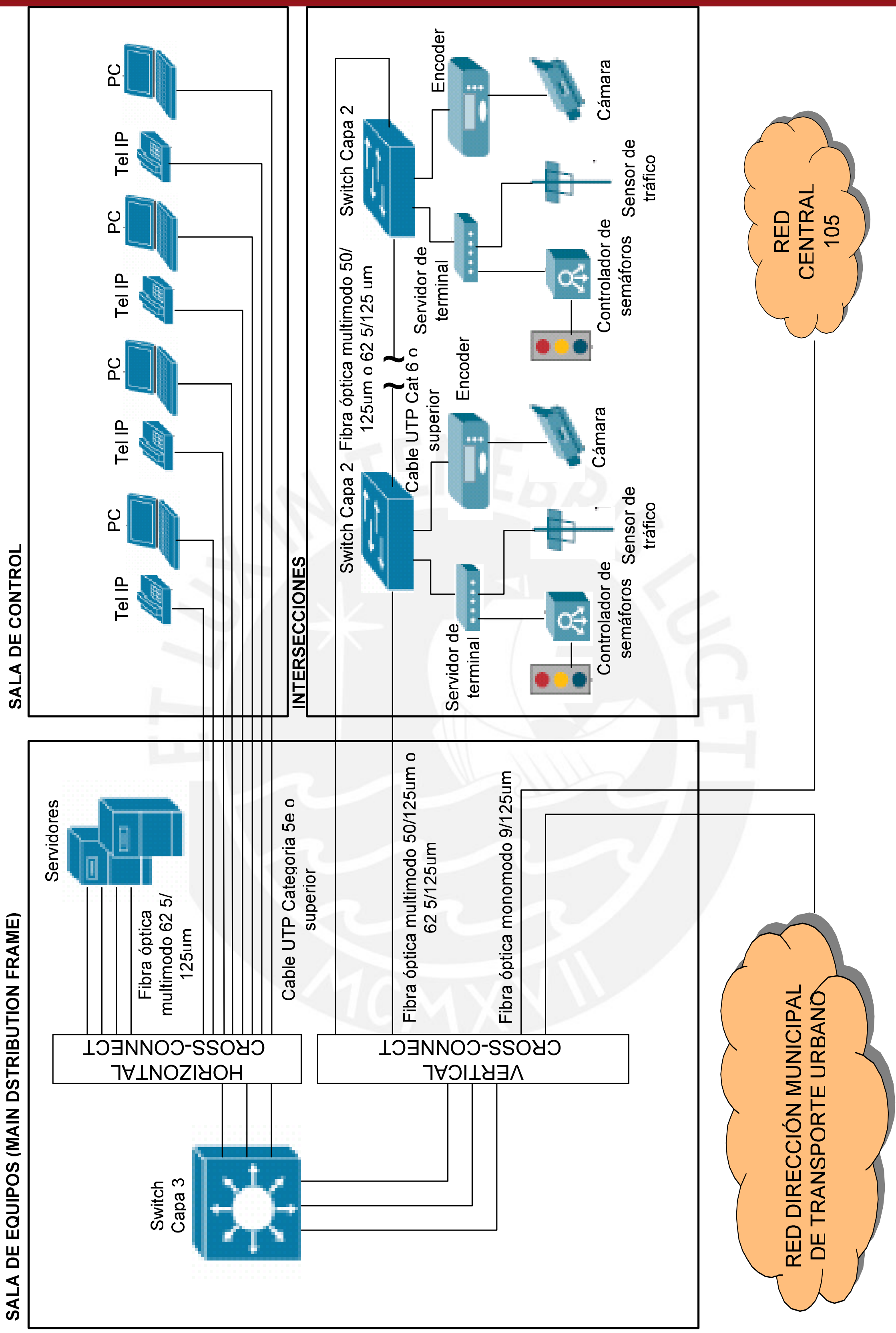

Figura 4.14 Cableado Estructurado de la red para el Sistema de Transporte Inteligente en el Centro Histórico de Lima

4.5.5 CERTIFICACIÓN DE CABLEADO ESTRUCTURADO

Son muchos los problemas que se pueden presentar en un sistema de cableado, uno de ellos es el ruido producido, tanto por agentes externos como por señales provenientes del mismo cable. Pero el ruido no es lo único que se puede suscitar en un cable UTP, esto produce una alta tasa de error (CRC) durante la transferencia de datos, provocando que se realicen retransmisiones y a la vez la saturación de la red. El boletín TIA/EIA, Telecommunication System Bulletin 67 (TSB-67), detalla los requerimientos para el testeo y certificación del cableado horizontal UTP instalado. TSB-67 define un enlace básico y un canal para propósitos de prueba. Este enlace consiste en un cable que viaja entre el conector de pared del área de trabajo y el punto de terminación en el panel de distribución de cableado. El enlace básico está limitado a una distancia de 90 metros. Un instalador debe realizar está instalación y luego testear para certificar el cableado según las especificaciones del TSB-67.

El segmento de cable horizontal, incluyendo el cable *patch* y el cable de equipo se le conoce como canal, y debe tener como máximo 100 m, todo ello es considerado en las pruebas del TSB-67. Esta red debe ser certificada utilizando un equipo diseñado especialmente para este propósito, tal como puede ser el LAN CAT V de *Datacom Technologies Inc*, de acuerdo a las normas EIA/TIA 568, y los parámetros que se miden son típicamente la atenuación, NEXT, longitud de cable y mapa de cableado.

Asimismo se debe realizar pruebas a los enlaces de fibra óptica, utilizando equipos tales como el OTDR (Optical Time Domain Reflectometer). En este caso, los parámetros son diferentes a los realizados en cable UTP, y que básicamente permite detectar anomalías en los conectores, las junturas y el mismo cable. Entre alguno de ellos están las pérdidas en fibra, reflectancia (similar a las pérdidas de retorno), punto de pérdida, y ancho de banda.

4.6 CONSIDERACIONES EN LA PLANTA DE ENERGÍA

Uno de los problemas que afectan el servicio de red y que generalmente pasa inadvertido, es el de disturbios en la energía eléctrica. Las variaciones o los fuera de servicio de la energía eléctrica son las causas más comunes de la interrupción del sistema. Por otro lado, muchos de los apagones duran menos de 5 minutos, ocurren frecuentemente y pueden ser indetectables; diversos estudios demostraron que un tercio de los datos perdidos se debe a esta causa. Estos disturbios en la energía eléctrica no dañan instantáneamente el sistema, pero puede degradar los componentes de diversas plataformas, reduciendo así el tiempo de vida de éstos.

4.6.1 IRREGULARIDADES EN LA ENERGÍA ELÉCTRICA

La electricidad viaja en ondas que pueden variar en tamaño, frecuencia, y en forma. La frecuencia, medida en Hertzios (Hz), es un parámetro crítico en las especificaciones de potencia, una frecuencia incorrecta puede dañar el equipo que alimenta. Idealmente la energía AC que se entrega debe ser regular en cuanto al flujo, pero esto difícilmente se cumple debido a las circunstancias que se dan en la realidad.

A medida que la tecnología avanza, los equipos son más sensibles a las irregularidades de la energía eléctrica, resultando en interrupciones más frecuentes debido a las impurezas en la señal eléctrica. Esto causa que los equipos reinicialicen su sistema en pleno proceso de servicio de red, y además el daño de algunos dispositivos tales como discos rígidos o cintas magnéticas. Pero estos disturbios no se deben únicamente al sistema de energía eléctrica, sino también a errores humanos tales como reparaciones eléctricas, mantenimiento, accidentes de construcción y otros errores causados localmente. Es por ello que se tiene cuidado en la estructura del sistema eléctrico, más aún cuando se trata de un sistema crítico.

4.6.2 CONSUMO DE ENERGÍA EN LA RED DE COMUNICACIÓN

Como parte del diseño, se mostrará el consumo de energía de los equipos que actuarán en el sistema de telecomunicaciones, el cual se puede extraer de las respectivas hojas de especificaciones. Como se puede apreciar en la tabla, los *switches* que trabajan fuera de la central consumen poca energía, por lo que comparado con la energía consumida por el sistema semafórico (sobre todo las luces de semáforos), no representa gran carga. En cuanto al consumo en la sala de equipos, conformado por los servidores y el *core switch*, se debe asegurar que el sistema de distribución eléctrica permita como mínimo la entrega de hasta 3 kW, según lo establecido en los cálculos. Debe señalarse que el cuarto de equipos necesariamente debe tener su propia caja de distribución eléctrica con la finalidad de darle mayor autonomía, esto según las recomendaciones en el diseño de la sala de equipos (BICSI). En los cálculos se ha especificado el consumo del *core switch* solo cuando realiza transmisión de datos y no cuando ofrece energía por cable (PoE), requerido por dispositivos con esas características tales como teléfonos o cámaras IP. Estos resultados servirán para el dimensionamiento del sistema de energía de respaldo.

	Cantidad	Consumo eléctrico por unidad	
Servidores			
eServer xSeries 346	1	625 W	
eServer xSeries 336	1	385 W	
eServer xSeries 306m	1	350 W	
eServer xSeries 100	1	310 W	
Consumo en Servidores			1670 W
Estaciones de trabajo			
PC Estándar	6	150 W	
Monitor Estándar 15"	6	50 W	
Consumo en Estaciones de Trabajo			1200 W
Core Switch			
Catalyst 4503	1	(solo datos) 1400 W	
Consumo en Core Switch			1400 W
Switches de campo (Solo zona analizada 31 intersecciones)			
Cisco Catalyst 2955C	10	23 W	
Garrettcom ES42	21	9 W	
Garrettcom 14E	19	3 5 W	
Consumo en Switches de campo			485 5 W

Tabla 4.6 Consumo eléctrico de equipos en la red

4.6.3 <u>CONSUMO DE ENERGÍA EN EL SISTEMA DE TRANSPORTE INTELIGENTE</u>

Debido a que el sistema de energía depende de una subestación eléctrica instalada por Edelnor para el Sistema de Tráfico, se debe realizar un cálculo aproximado del consumo por parte de todos los equipos involucrados, para determinar si se requiere de un aumento en la capacidad o si con el sistema eléctrico actual se satisface los requerimientos del Sistema de Transporte Inteligente planteado. En la siguiente tabla se muestra el consumo por parte de los equipos de tráfico, considerando que todas las intersecciones están instaladas en promedio un controlador de semáforo, 2 sensores de tráfico, y una cámara, esto en el peor de los casos.

Equipo de tráfico	Cantidad	Consumo Eléctrico por unidad	Consumo por equipos	
Controlador de semáforo	1	120 W	120 W	
Semáforos Vehiculares	4	100 W	400 W	
Semáforos Peatonales	2	100 W	200 W	
Cámara de Video con módulo de compresión	1	25 W	25 W	
Sensores de tráfico	2	7.5 W	15 W	
Consumo total por intersección				760 W

Tabla 4.7 Consumo de los equipos de tráfico por intersección

En este caso, cada intersección consumiría aproximadamente 760 W, por lo que para las casi 120 intersecciones controladas en el Centro Histórico de Lima, daría un total de 91.2 kW. Considerando además el consumo en la Central de Tráfico y los equipos de comunicación, superaría el límite de la subestación instalada. Es por ello que muchos de los semáforos dentro de esta área se conectan a otras subestaciones, dejando así a muchas intersecciones sin energía de respaldo, es decir sin acceso a los generadores eléctricos. En el cálculo realizado se considera que se usan semáforos basados en focos incandescentes, los cuales consumen gran cantidad de energía. Actualmente existen los semáforos basados en diodos emisores de luz (LED), los cuales consumen como máximo 15 W. Considerando su uso se puede obtener, al reemplazarlo en los cálculos, un total de 250 W por intersección, y por lo tanto 30 kW para todas las intersecciones en el Centro Histórico de Lima. Es por ello que se recomienda su uso en un Sistema de Transporte Inteligente.

4.6.4 FUENTES DE ENERGÍA

La disponibilidad de energía comercial AC está en el rango de 99.9% a 99.98%. Si en cada disrupción de energía se requiere una reinicialización de la energía, entonces la disponibilidad del sistema se reduce significativamente. Un local debe ser provisto con suficiente energía para soportar los requerimientos de operación actuales y futuras. Se requiere un inventario de todos los equipos con los consumos de energía de cada uno de ellos, ello para conocer la energía requerida por el sistema. Todos los fabricantes especifican los Voltios y Amperios que consumen sus equipos, además de los valores máximos que pueden consumir, el cual deben ser considerados más que los valores nominales ya que estos reflejan el consumo que se realiza durante el encendido del sistema, y que normalmente superan en 30% los valores normales.

El Sistema actual de los operadores del transporte en el Centro Histórico de Lima obtiene la energía eléctrica de la combinación de dos fuentes principales: energía pública y local. La energía pública es la obtenida de la red pública, en este caso proviene de la empresa Edelnor. Se tiene en el mismo local donde funciona la Central de Semáforos, un transformador especialmente orientado a alimentar todos los semáforos del Centro Histórico de Lima y los equipos de la Central, con una potencia de aproximadamente 150 KVA y con salida trifásica. La energía local es la producida internamente, y que en este caso son dos generadores eléctricos diesel, con una potencia de 150 KVA cada uno y con salida trifásica.

4.6.5 FUENTES DE RESPALDO

Para sistemas críticos no es suficiente con tener una sola fuente de energía, en el caso de nuestro sistema se tiene la energía pública y los generadores diesel; sin embargo la conmutación entre una y otra fuente durante una falla toma mucho tiempo, tomando como referencia la velocidad de trabajo de los equipos de cómputo, sobre todo para los servidores, cuyos procesos trabajan a una alta frecuencia. Este sistema debe ser diseñado de tal manera que mantenga la operación del equipamiento ante disturbios específicos. Debido a que el costo es un factor limitante, se debe de entender a profundidad las condiciones que causarán el detenimiento de la operación del sistema.

1. Fuente de Poder Ininterrumpido (UPS o *Uninterruptible Power Supply*)
Un UPS es un dispositivo usado para proporcionar energía limpia temporalmente cuando ocurre una disrupción en la fuente de energía principal. Este se inserta entre la fuente de poder y el sistema que se quiere proteger. El UPS trabaja con baterías para mantener el sistema activo por un periodo de tiempo corto. Esto permite la activación de una segunda fuente de energía o tiempo para que el sistema se apague apropiadamente si la disrupción es por largo tiempo. Es importante decidir la selección de los sistemas que se desean proteger por un UPS, preferible los equipos críticos. Un UPS puede ser usado para proteger cualquier tipo de equipo, desde un a PC hasta una central de datos completa.

Para el Sistema de Transporte Inteligente, el equipamiento crítico es lo que se encuentra en la sala de equipos y servidores, ya que son los que sostienen el servicio para el transporte urbano. Los UPS existen de todas las formas y tamaños, y pueden ser usados de diferentes maneras. Las especificaciones mínimas que deben cumplir los UPS en el sistema son básicamente que proporcionen suficiente energía por un corto tiempo a los equipos críticos, mientras se realiza la conmutación de fuente de energía, esto es de energía pública al generador eléctrico, y que sea lo más rápido en cuanto a una falla o corte en la energía eléctrica. Es por ello que los UPS que serán usados deben servir a los servidores, el *core switch* y las estaciones de trabajo, es decir toda la central de tráfico, mientras se conmuta la fuente de energía, esto debido a que no se toleraría una reinicialización de estos sistemas durante una disrupción eléctrica.

Equipo	Potencia consumida	Modelo de UPS	Tiempo de trabajo a plena carga
Core Switch	1400 W	Smart UPS APC / 3000 VA - 2100 W	14 1 minutos
Servidores	1670 W	Smart UPS APC / 3000 VA - 2100 W	14 1 minutos
PC y Monitor	200 W	UPS APC / 350 VA - 210 W	4 7 minutos

Tabla 4.8 UPS seleccionados y características

Los UPS para el *core switch* y los servidores deben de ofrecer facilidad para ser instalados en gabinetes, de tal manera de ocupar el menor espacio posible. Es por ello que el chasis de estos equipos está diseñado para montarse en un gabinete estándar de 19’’ de ancho.

2. Interruptor o llave de transferencia

Un interruptor de transferencia automático (*Automatic Transfer Switch* o ATS) es un dispositivo que sensa la irregularidad de energía e inicializa un generador eléctrico para proveer energía de respaldo. Durante este tiempo, un sistema UPS puede proveer de energía auxiliar.

Se desconoce si la Central de Tráfico cuenta con una ATS o un interruptor manual, lo cierto es que para este sistema es necesario que el cambio de energía sea automático. Entonces el ATS debe de cumplir con las condiciones de trabajo del sistema de energía.

3. Generadores eléctricos

Es una máquina que funciona a combustible y que es usado como fuente de energía de respaldo. Como se mencionó anteriormente, el Sistema cuenta con dos generadores diesel 2 de 125KW/150 KVA cada uno, esto para darle redundancia y alta disponibilidad por tratarse de un servicio crítico. Este generador es activado por un ATS, el cual sensa irregularidades en la energía. Este equipo siempre está en constante mantenimiento para confirmar su operabilidad. Los generadores pueden proveer de energía indefinidamente, siempre y cuando tenga lleno el tanque de combustible. Es recomendable que se cambien los generadores, no solo por su antigüedad, sino también porque el uso de petróleo lleva consigo un alto costo, además de estar en un país con abundancia en gas natural.

4.6.7 DISTRIBUCIÓN DE ENERGÍA

La distribución de la energía tendrá como núcleo la Central de Tráfico, en donde existe una subestación eléctrica capaz de alimentar el sistema en todo el perímetro del Centro Histórico de Lima. Actualmente se cuenta con varias subestaciones, las cuales sirven al sistema, debido básicamente al alto consumo de los semáforos usados. Las características del Sistema Eléctrico debe tener la arquitectura mostrada en la figura.

Como se podrá apreciar en el figura 4.15, se obtiene del transformador y generador una salida trifásica de 220VAC por fase. La derivación a la central es bifásica, sin embargo la derivación a las intersecciones es trifásica, ya que se necesita las tres líneas para obtener un balanceo de cargas. Se muestra además los tableros de distribución con el respectivo consumo en cada grupo de equipos, además de su respectiva protección. La protección eléctrica se basa en interruptores termomagnéticos, ideal para las sobrecargas causadas por fallas eléctricas. Se considera también las cargas por energía luminaria, todo ello en la Central de Tráfico. Nótese que en la subestación eléctrica se usa un solo transformador y un solo generador eléctrico. En cuanto a las especificaciones de cableado eléctrico y protección eléctrica, deben seguirse las recomendaciones del NEC (National Electrical Code), tal como lo estipula la IEEE.

La caída de voltaje permitido en las instalaciones eléctricas es del 5%, es decir de los 220VAC que ofrece una subestación, debe llegar a la carga como mínimo 209VAC. Esto se debe tener en cuenta en el Sistema de Transporte Inteligente, ya que la distancia máxima que debe cubrir para alimentar a una carga es de 1.5 Km aproximadamente.

Para que la caída de voltaje no supere lo permitido, se debe tener instalado cableado eléctrico con un calibre lo suficientemente alto como para reducir la resistencia total en el tramo que se desea cubrir. Considérese el tramo de la Av. Abancay, y parte de la Av. Colmena, que es aproximadamente 1.5 Km y en donde salen las líneas eléctricas desde la Central de Tráfico, alimentando 12 intersecciones.

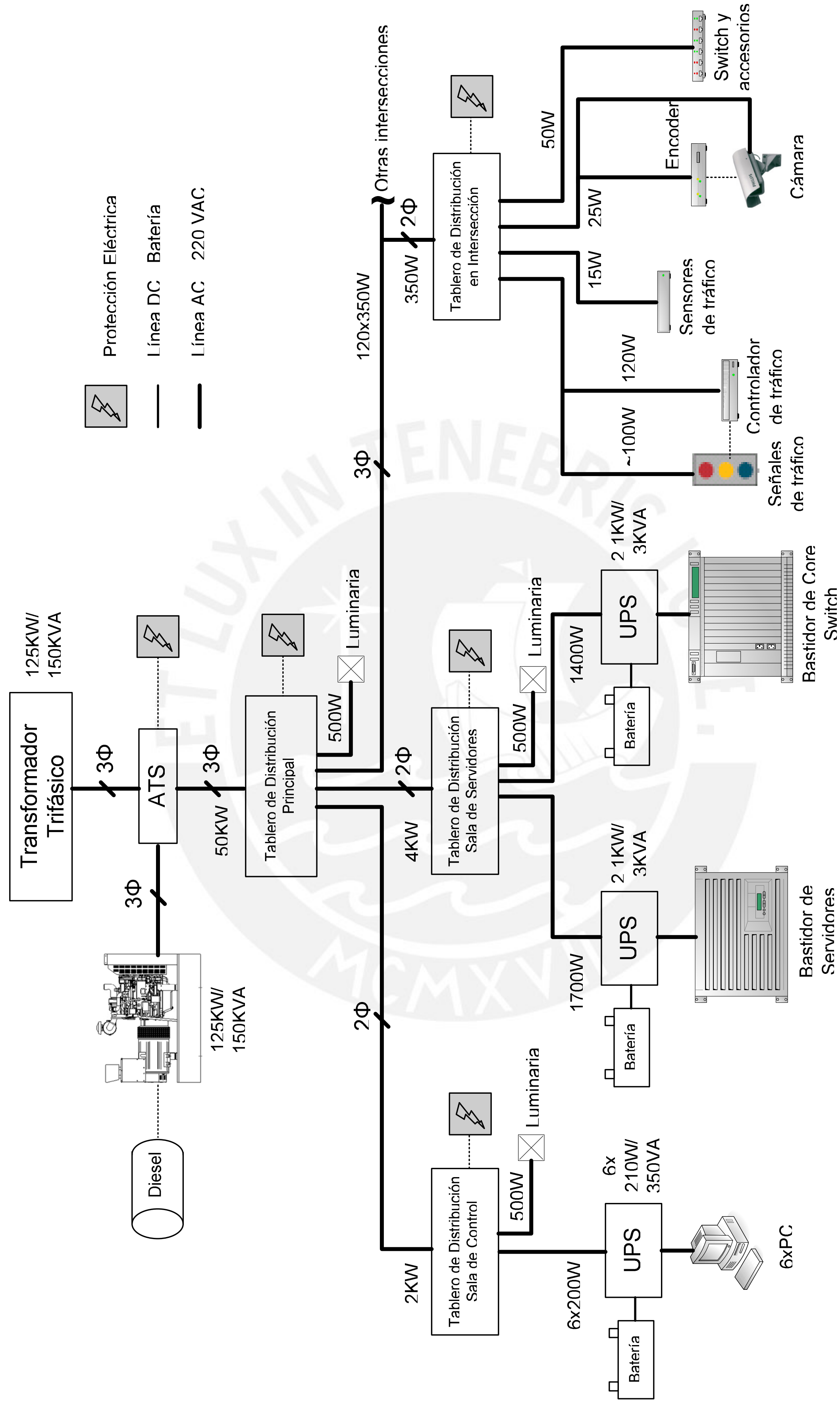

Figura 4.15 Distribución Eléctrica en el Sistema de Transporte Inteligente

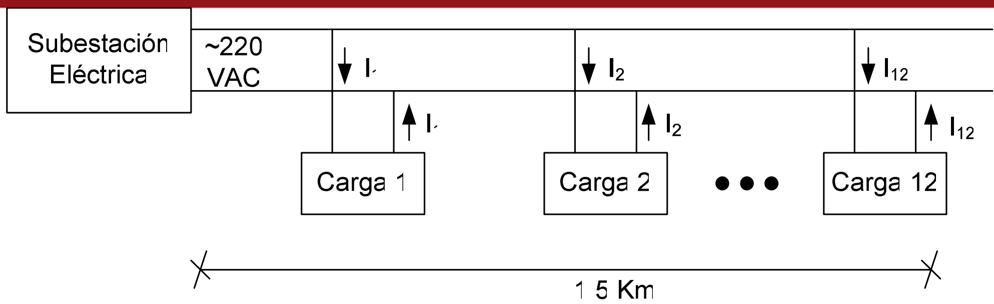

Figura 4.16 Diagrama de servicio de energía a cargas en el tramo Av. Abancay y Av. Colmena

Para realizar el cálculo de la manera más simple, se supondrá una línea bifásica que alimenta a cargas que consumen igual potencia (P=350W por intersección), es decir que las corrientes de las cargas sean iguales (I=1.6A), asimismo que las distancias entre cargas sean iguales. Entonces usando la fórmula $\Delta V = \frac{\rho \times L \times I}{S}$, y sabiendo que la variación de voltaje se da en las dos líneas de energía, se tiene:

$$\Delta V = 2 \times \frac{\rho}{S} \times [L \times (I_1 + I_2 + ... + I_{12}) + L \times (I_2 + I_3 + ... + I_{12}) + ... + L \times (I_{12})] = \frac{2 \times \rho \times L \times (78I)}{S}$$

$\Delta V = \frac{156 \times \rho \times L \times I}{S} = 5\% V$; donde V=220VAC (voltaje de línea), ρ=0.018 Ωxmm^2/m (resistividad de cobre), I=1.6A (corriente de carga), L=(1.5/12) Km.

Entonces S=51.05mm^2, y según la medida de cable normalizado, se deduce que el cable debe tener como mínimo un diámetro de 8.4mm. Este cálculo no es exacto, ni considera los factores reales que intervienen en el sistema eléctrico, sin embargo nos da una idea aproximada del tipo de cable de energía que se debe usar.

4.6.6 CALIDAD DE ENERGÍA

1. Supresor de sobre voltaje

Son dispositivos diseñados para limitar el exceso de voltaje generado en las líneas de energía. Este equipo provee protección, supresión y filtración en las variaciones de voltaje para evitar transiciones bruscas en la energía. Pueden ser usados para proteger sistemas individuales, tales como computadores o *switches*, o también para cables. Adicionalmente a la supresión de voltaje, el dispositivo puede ser evaluado por otros parámetros, que incluyen el tiempo de respuesta, o la cantidad de tiempo requerido para suprimir, y la cantidad de voltaje que es permitido llegar al equipo protegido.

Por lo general, los supresores de sobre voltaje están ubicados en los conectores de energía AC, cerca de los computadores. En este caso los equipos de la central de tráfico están protegidos por los UPS, los cuales incluyen un sistema de protección contra variaciones en la energía eléctrica.

2. Puesta a tierra

Un apropiado pozo de tierra protege tanto al equipo como al personal. Como se mencionó en el capítulo anterior, existen instalaciones de puesta a tierra adecuados para el sistema de semaforización, sin embargo no se tiene conocimiento si cumple con los estándares para una red de comunicación. No solo debe cumplir los códigos locales, sino también debe estar acorde con las especificaciones internacionales para sistemas de comunicación, tales como el ANSI/TIA/EIA 607 *Commercial Building Grounding and Bonding Requirements for Telecommunications*, sobre todo si se cuenta con equipos de telecomunicaciones. Se dará algunas pautas de cómo debe ser una instalación de puesta a tierra para este sistema, además de algunas recomendaciones para el correcto funcionamiento de la protección.

En la figura se muestra la manera como se realiza una puesta a tierra en una subestación eléctrica, con un generador como fuente de respaldo, esto según lo establecido por el NEC, en la sección 250. Se puede apreciar que existen dos tipos de pozos de tierra, uno para el neutro del transformador trifásico y del generador; y el otro de la protección a tierra, los cuales cumplen roles diferentes. La puesta a tierra del neutro ayuda a equilibrar las cargas en una conexión trifásica, de tal manera que no exista variación en el voltaje de línea.

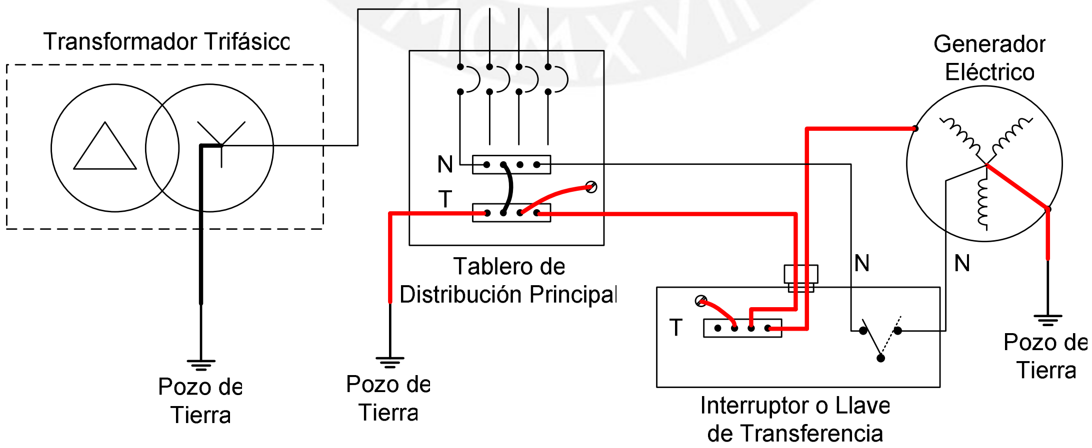

Figura 4.17 Diagrama de puesta a tierra para la subestación eléctrica

La puesta a tierra de conexión equipotencial permite dar continuidad eléctrica a las corrientes de falla, para proteger los equipos y los usuarios, conectando toda parte metálica hacia el barraje equipotencial de tierra. Por lo tanto, una correcta instalación de puesta a tierra debe asegurar que en los conductores de tierra no circule corriente. El máximo valor de la resistencia de los pozos de tierra en una subestación interna es de 10Ω.

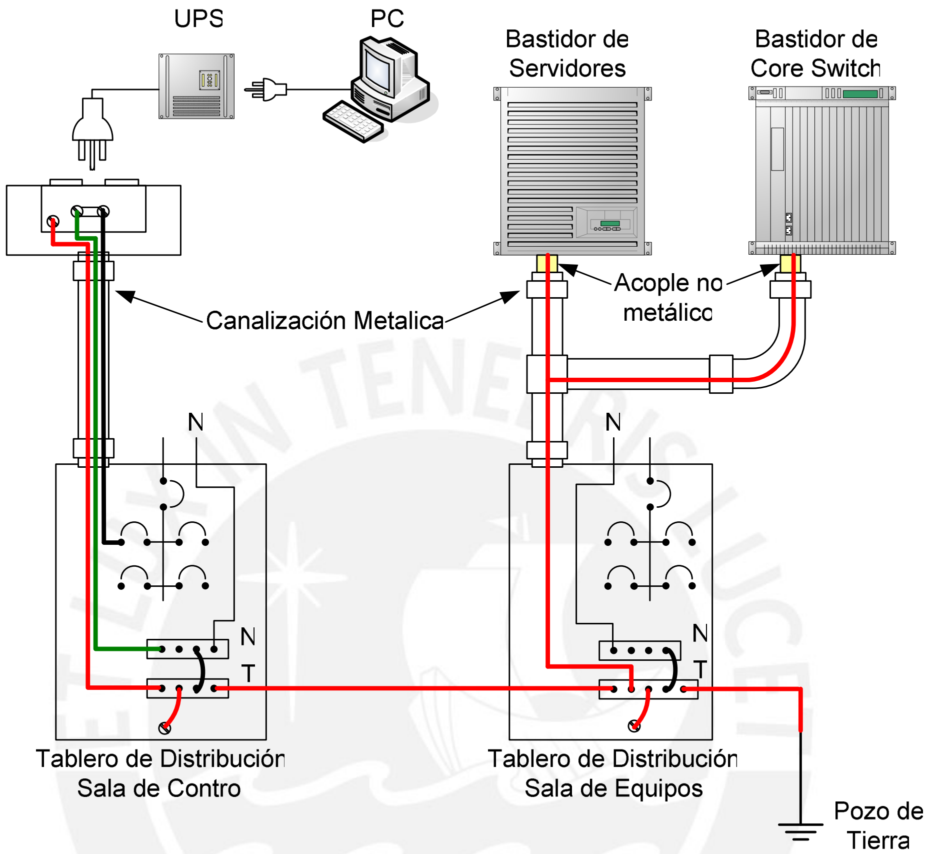

Figura 4.18 Diagrama de puesta a tierra para los equipos de la Central de Tráfico

En el caso de los equipos de cómputo, se tiene dos áreas con una distribución eléctrica independiente, sin embargo compartirán la misma instalación de puesta a tierra. Como se aprecia en la figura, se diferencia las conexiones de la línea de neutro y las conexiones equipotenciales de tierra. En el caso de las estaciones de trabajo, el neutro es parte de la línea de energía, sin embargo en el tablero de distribución se realiza la puesta a tierra. Asimismo, toda parte metálica está conectada al barraje equipotencial de tierra, y esto se hará a través de los polos de tierra de los tomacorrientes. Los conductores de tierra se guiarán por una canalización metálica, tal como lo estipula el NEC, conectados también a un punto equipotencial. En el caso de los servidores y *switches*, la conexión de tierra se realiza directamente al chasis del bastidor, según se muestra en la figura. La resistencia del pozo de tierra para la protección de estos equipos debe ser bastante bajo, permitiéndose un máximo de 4Ω.

Para las conexiones de puesta a tierra en las intersecciones, las especificaciones son similares a aquellos que se usan en los interiores de las edificaciones. Sin embargo se debe considerar que los equipos están alojados en gabinetes, montados en postes metálicos, por lo que la protección para los transeúntes es vital. Los elementos que deben estar puestos a tierra en todas las intersecciones son los siguientes:

- Servicio de energía eléctrica o tableros de distribución
- Los postes con servicio de energía instalado.
- Los postes con semáforos vehiculares y peatonales.
- Las cabinas con equipos de tránsito y de comunicaciones.

Cada uno de estos elementos debe tener un pozo de tierra lo más cercano posible, asegurándose de que todos los pozos estén conectados a una distancia mayor que el doble del electrodo más grande de todos ellos, formando así una red o arreglo de pozos de tierra, el cual ayuda a reducir la resistencia total. Para la medición de resistencia del suelo, se usa un telurómetro, mediante el método de Wenner. Los electrodos deben ser de cobre y los empalmes se deben de realizar con soldadura exotérmica, todo ello con la finalidad de reducir la resistencia total al pozo de tierra.

4.7 <u>COSTO DE EQUIPOS</u>

En el Anexo 5 se presenta un archivo Excel en el cual están los costos de los equipos que serán usados en las diferentes subredes determinadas y analizadas. Como se apreciará, solo se toma en cuenta los elementos más importantes de la red, asimismo se consideran solo los equipos que actuarán en la zona estudiada, es decir la Av. Abancay y alrededores. Se presenta el resumen de los costos:

	COSTO PARCIAL
Sala de equipos	$ 36957.06
Sala de control	$ 4815.12
Equipos de campo	$ 59969.41
COSTO TOTAL	$ 101741.59

Tabla 4.9 Costos finales, considerando solo la zona de la Av. Abancay

La implementación de la red no tiene finalidades lucrativas, sino más bien tiene como objetivo el uso de sistemas modernos para el control del tráfico. Los recursos para desarrollar estos sistemas provienen de los impuestos por arbitrios que los contribuyentes realizan. Es el deber de las autoridades locales el de incentivar el uso de las tecnologías de la información para mejorar el estilo de vida de los ciudadanos.

CONCLUSIONES

1. Una red de comunicaciones para la implementación de un Sistema de Transporte Inteligente ayudaría a mejorar el sistema de monitoreo y control del transporte urbano, no solo en el Centro Histórico de Lima, sino también en toda la ciudad de Lima. Esto debido a que permitiría transportar la información obtenida del campo, por medio de los equipos de adquisición o sensores, hacia la Central de Tráfico, de tal manera que los operadores de transporte ejecuten las medidas de corrección necesarias para el ordenamiento del tránsito.

2. La implementación de una red *Ethernet* para el Sistema de Transporte Inteligente por medio de fibra óptica en todo el Centro Histórico de Lima es factible, ya que se tiene la infraestructura adecuada, el cual permitiría transportar gran cantidad de información para una infinidad de servicios en el transporte urbano. Mucho se dice acerca del costo elevado de la fibra óptica, sin embargo con el tiempo ha ido decreciendo, convirtiéndolo en una solución rentable y escalable.

3. Una red *Ethernet* permitiría la integración de varios servicios que pueden existir en un Sistema de Transporte Inteligente, ya que puede transportar datos, voz, y video en una sola infraestructura de red, ahorrando costos en otras implementaciones. No solo es posible instalar controladores de semáforos, sensores y cámaras de video, sino también equipos que permitan ofrecer otros servicios que son fundamentales en el control y difusión de información del transporte urbano. Se tiene los rompe muelles electrónicos, los cuales bloquean una vía de manera remota; los paneles de mensaje variable, que muestran información en la vía pública; casetas de información, que son computadores instalados en la vía pública para ofrecer información local a los turistas por medio de la Web; los hot spot o acceso a Internet inalámbrico, un servicio que se puede ofrecer a los turistas; teléfonos públicos de emergencia; y así una infinidad de servicios brindados en el Sistema de Transporte Inteligente.

4. La tecnología *Ethernet* está creciendo como estándar, ya que no solo se utiliza en oficinas y *campus*, sino también en zonas industriales y aplicaciones de planta externa, tal como ocurre con el Sistema de Transporte Inteligente, en la cual muchas empresas y fabricantes de equipos involucrados en esto muestran interés en que sus productos cumplan con el estándar *Ethernet*. Es por ello que los *switches* convencionales no pueden ser usados en aplicaciones del Sistema de Transporte Inteligente, sino más bien *switches* para aplicaciones industriales y de planta externa.

5. Una red *Ethernet* convencional es diseñada teniendo en cuenta una topología en estrella, lo cual es muy recomendado para redes corporativas. Sin embargo, existen casos en que esta topología no se acomoda a las necesidades de acceso de un sistema en particular, tal como puede suceder en un Sistema de Transporte Inteligente. La topología en cascada para una red *Ethernet* está siendo aplicado hoy en día para estos sistemas, debido básicamente a la distribución de los nodos del sistema. En las pruebas de tráfico realizadas en esta investigación, se ha determinado que las características de tráfico en una red *Ethernet*, con topología en cascada y con enlaces *Fast Ethernet* entre *switches*, son óptimas para el correcto desempeño de aplicaciones de video MPEG4 en tiempo real. Sin embargo, existe un límite en la cantidad de tráfico para que esto ocurra. Es por ello que se considera reemplazar los enlaces entre *switches* de *Fast Ethernet* a *Gigabit Ethernet* si es que el tráfico requerido supera este límite, logrando así un mejor desempeño.

6. El protocolo TCP/IP está siendo cada vez más utilizados en los Sistemas de Transporte Inteligentes, prueba de ello es el surgimiento de las normas NTCIP, los cuales incluye la pila de protocolos TCP/IP como método para el transporte de datos, voz y video. La generalización de esta pila de protocolos no es ajena a los fabricantes de equipos y desarrolladores de aplicaciones para este sistema, llegando así dejar de lado sus protocolos propietarios.

RECOMENDACIONES

1. El diseño presentado en este documento solo es referencial, el cual fue realizada en base al criterio del autor y datos recogidos de las instituciones operadoras del Transporte Urbano, pero es un paso para la aceptación de las aplicaciones TCP/IP y tecnología Ethernet en la implementación de los Sistemas de Transporte Inteligentes. Un diseño real involucra la participación no solo de los profesionales de Ingeniería, sino también de las autoridades del transporte, los desarrolladores de equipos y aplicaciones para el control del tráfico, universidades, y gremios o instituciones que aporten en el ordenamiento del tráfico.

2. Los servicios presentados en el documento son los más importantes y necesarios para cualquier Sistema de Transporte Inteligente, y sobre todo para el transporte urbano en Lima. Sin embargo pueden surgir nuevas necesidades que solo pueden ser planteadas por los operadores del transporte.

3. Solo se ha visto el diseño en la zona de Abancay y alrededores, dejando de lado el resto del Centro Histórico de Lima. Es necesario estudiar a fondo el resto de puntos que no han sido considerados, ya que las condiciones podrían cambiar e incluso poder encontrar una mejor solución o diseño para la implementación de la red.

4. La tecnología Ethernet no solo contemple el uso de fibra óptica, sino también el uso de medios inalámbricos, tal como puede ser el estándar IEEE 802.11. A simple vista de la zona estudiada, se descarta la posibilidad de implementar una red inalámbrica, debido a la gran densidad urbana y edificios altos. Sin embargo, se debería realizar el estudio para descartar posibilidades.

5. El Sistema de Transporte Inteligente es un campo de estudio muy grande, el cual involucra tecnologías de control, de telecomunicaciones y de la información. Se deja un campo abierto para continuar el estudio de este tema ya que puede ofrecer posibilidades

para infinidad de investigaciones. Por ejemplo el desarrollo de equipos de control de tráfico, software de control de tráfico, sistemas y aplicaciones servidor/cliente, etcétera.

6. Los ductos de comunicación existentes no son suficientes para el diseño de los enlaces en fibra óptica de la red presentada, esto debido a que fue construida para otro tipo de sistema, y por lo tanto existen tramos que no cuentan con canalización. Sin embargo esto se solucionaría completando los tramos que faltan, siguiendo las mismas especificaciones de los ductos existentes.

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ANEXOS

Esta página contiene un CD con todos los anexos del documento.

ANEXO 1 - FOTOS

ANEXO 2 - HOJA DE DATOS DE EQUIPOS

ANEXO 3 - ESTÁNDARES

ANEXO 4 - PLANOS

ANEXO 5 - COSTOS

ANEXO 6 - RESUMEN DE ENTREVISTAS

ANEXO 7 - PRUEBAS DE TRÁFICO

RESUMEN DE ENTREVISTA E INSPECCIÓN OCULAR EN CENTRAL DE EMERGENCIA 105 DE LA POLICIA NACIONAL DEL PERÚ

Se logró acceder a las instalaciones de la Central de Emergencia 105 ubicada en la cuadra 4 de la Av. España, local de la VII Región de la PNP. Gracias a la gentileza del Jefe de esta dirección, el Coronel Roberto Luján, se obtuvo los siguientes datos que resumimos a continuación:

Origenes
La Central de Emergencia entró en funcionamiento en Diciembre de 1996. El objetivo de su creación es el de ser un intermediario entre la ciudadanía y la PNP, a través de la recepción de llamadas. Para ello esta dirección cuenta con varios sistemas tecnológicos, entre ellos el Sistema de Circuito Cerrado de TV (CCTV).

Descripción del Sistema de CCTV
La PNP cuenta con aproximadamente 84 cámaras, ubicados en las zonas más transitadas y los puntos críticos de la ciudad de Lima, con el único objetivo de tener un panorama de lo que está ocurriendo en las calles. La finalidad de tener rastreado la ciudad a través de cámaras es para resguardar la seguridad ciudadana, controlar el orden público y observar el tránsito vehicular. 15 cámaras del total están instaladas en el Centro Histórico de Lima, ubicándose en las avenidas más congestionadas y en los puntos en donde se encuentran las instituciones gubernamentales más importantes.

Elementos del Sistema de CCTV
Las cámaras de video con que cuenta la policía son para aplicaciones outdoor, especial para vigilancia. Estas cámaras envían las imágenes sin ningún formato de compresión digital, es decir con un formato de video analógico, esto es el PAL. La transmisión se realiza a través de enlaces micro-ondas con el local de la Central de Emergencia 105. Muchos de estos enlaces no se realizan directamente, sobre todo en el Centro de Lima, en donde existe una alta densidad de edificios altos, por lo que en esos casos hacen uso de repetidores.

En la Sala de Operaciones de la Central de Emergencia 105, existen 5 módulos de control, el cual está conformado por un monitor de TV, un joystick para el control PTZ y un teclado para la selección de las cámaras que se desean controlar y visualizar. Adicionalmente, se cuenta con varios monitores de TV de aproximadamente 15" ubicados a un lado de la habitación. Este sistema tiene aproximadamente 10 años de antigüedad, el cual por su tecnología necesita de una serie de switches o conmutadores de video analógicos, estos ubicados en un cuarto contiguo a la sala de operaciones. En cuanto a la grabación de video, también cuentan con un equipo encargado de realizar grabaciones múltiples en cintas de video de los hechos más importantes que ocurrieron.

Difusión de imágenes
Canal N consiguió el permiso de la PNP para transmitir sus imágenes en un programa matutino de esta televisora. Para ello, envían personal técnico para realizar la instalación de sus equipo satelitales en la Central de Emergencia 105, y de esta manera enviarlo al local del canal. El objetivo principal es el de difundir información relacionado al tránsito vehicular en las calles más importantes de la ciudad, donde se encuentran ubicados las cámaras.

Futuras implementaciones

La PNP planea aumentar el número de cámaras en la ciudad de Lima, sobre todo en el Centro Histórico de Lima. Es por ello que se consiguió las posiciones de las cámaras que se encuentran instaladas actualmente y las que desean instalarse.

Cámara	Ubicación	Motivo
1	Jr. Lampa y Av. Colmena	Vigilancia de zona de alto tráfico y de JNE (Jurado Nacional de Elecciones).
2	Jr. Carabaya y Av. Colmena	Vigilancia de zona de tráfico moderado y de la Plaza San Martín
3	Av. Nicolas de Piérola y Av. Abancay	Vigilancia de zona de alto tráfico y del Parque Universitario
4	Jr. Montevideo y Av. Abancay	Vigilancia de zona de alto tráfico (centro de agencias de transporte interprovincial).
5	Av. Emancipación y Av. Abancay	Vigilancia de zona de alto tráfico, del Ministerio Público y de alta tasa delincuencial.
6	Jr. Junín y Av. Abancay	Vigilancia de zona de alto tráfico y del Congreso de la República.
7	Jr. Amazonas y Av. Abancay	Vigilancia de zona de tráfico moderado y parte del límite entre el Cercado y el Rimac.
8	Jr. Ucayali y Jr. Azángaro	Vigilancia de entrada a Palacio de Gobierno.
9	Jr. Miro Quesada y Jr. Lampa	Vigilancia de zona de tráfico moderado y centro financiero.
10	Jr. Carabaya y Jr. Junín	Vigilancia de la Plaza de Armas, Palacio Municipal y Palacio de Gobierno.
11	Jr. Ancash y Jr. Lampa	Vigilancia de zona de alta tasa delincuencial.
12	Jr Carabaya y Av. Emancipación	Vigilancia de zona de tráfico moderado.
13	Jr. Cailloma y Av. Cusco	Vigilancia de zona de alta tasa delincuencial.
14	Jr. Rufino Torrico y Jr. Ica	Vigilancia de zona de alta tasa delincuencial.
15	Jr. Conde de Superunda y Av. Tacna	Vigilancia de zona de tráfico moderado y parte del límite entre el Cercado y el Rimac.
16	Av. Colmena y Av. Tacna	Vigilancia de zona de alto tráfico y alta tasa delincuencial.
17	Av. Roosevelt y Av. Paseo de la República	Vigilancia de zona de alto tráfico y Palacio de Justicia.
18	Av. 09 de Diciembre y Av. Paseo de la República	Vigilancia de zona de alto tráfico en Av. Grau y Av. Paseo de la República, y Palacio de Justicia.
19	Av. Roosevelt y Av. Inca Garcilazo de la Vega	Vigilancia de zona de alto tráfico.
20	Plaza Bolognesi	Vigilancia de zona de alto tráfico en intersección de varias avenidas.
21	Av. Uruguay y Av. Alfonso Ugarte	Vigilancia de zona de alto tráfico y alta tasa delincuencial.
22	Jr. Andahuaylas y Jr. Puno	Vigilancia de zona de alto tráfico y alta tasa delincuencial.

Tabla 1. Lista de cámaras para el Centro Histórico de Lima


PLAYA
971

Data Sheet

Cisco Catalyst 2955 Series Switches

Product Overview

Cisco Catalyst® 2955 Series switches are industrial-grade switching products that provide wire-speed Fast Ethernet and Gigabit Ethernet connectivity for deployment in harsh environments. The Cisco Catalyst 2955 Series operates in environments such as industrial networking solutions (industrial Ethernet deployments), intelligent transportation systems (ITS), and transportation network solutions. It integrates into military equipment, Supervisory Control and Data Acquisition (SCADA) systems, power generation systems, waste water treatment facilities, building automation systems, warehouses, and any other facilities or applications where the environmental conditions or suspended solid concentrations exceed the specifications of other commercial switching products. The Cisco Catalyst 2955 Series uses industrial-grade components, a compact form factor, convection cooling, and relay output signaling to extend intelligent services such as enhanced security, high availability, and advanced quality of service (QoS) to areas that cannot be served by traditional commercial-grade Ethernet switches.

Embedded in Cisco Catalyst 2955 Series switches is Cisco Cluster Management Suite (CMS) Software. This network management solution allows administrators to easily configure features, monitor performance, and troubleshoot multiple Cisco Catalyst switches using a standard Web browser. For larger deployments, Cisco Catalyst 2955 Series switches support Simple Network Management Protocol (SNMP)-based network management platforms such as CiscoWorks.

This product line offers Cisco IOS® Software functionality for traditional data, video, and voice services, with enhanced intelligent services features for additional security, advanced QoS, and high availability. Intelligent services are critical in supporting the reliability and determinism of proprietary Layer 2 solutions typical of industrial Ethernet deployments, while providing the advantages (standardization, open connectivity, bandwidth, integration, etc.) of an advanced Ethernet switching architecture. These intelligent services include Layers 2-4 traffic prioritization, rate limiting, and security filtering, helping to ensure the high uptime, low latency, deterministic performance, and data integrity critical for industrial automation control networks.

Cisco Catalyst 2955 Series switches consist of the following devices:

- Cisco Catalyst 2955T-12—Twelve 10/100 ports and two fixed 10/100/1000BASE-T uplink ports
- Cisco Catalyst 2955C-12—Twelve 10/100 ports and two fixed 100BASE-FX multimode uplink ports
- Cisco Catalyst 2955S-12—Twelve 10/100 ports and two fixed 100BASE-LX single-mode uplink ports

Intelligence in the New Ethernet Networks

Currently, non-Ethernet Layer 2 networks are evolving from traditional fieldbuses or proprietary technologies to standards-based Ethernet networks. The progression to Ethernet is driven by a multitude of factors, including:

- Standardization—There are hundreds of millions of Ethernet devices around the world; Ethernet has become the prevalent Layer 2 technology based on widely adopted standards.
- IP Connectivity—Ethernet is the most ubiquitous Layer 2 technology for Internet connectivity, in turn providing unprecedented communications potential to networks that have been traditionally isolated.
- Bandwidth—Orders of magnitude above other existing technologies, Ethernet takes advantage of the increased computational power of the new network hosts (I/O devices, motion machinery, sensors, intelligent electronic devices, etc.) being deployed today. This allows for real-time control and data gathering for a multitude of applications that were not previously feasible, including preventive maintenance, total quality control monitoring, remote monitoring, and asset management and optimization.
- Multiple services on a single infrastructure—Intelligent Ethernet allows a single network to carry multiple vendor implementations of control [Ethernet/IP, Modbus TCP, Foundation Fieldbus High Speed Ethernet (HSE) and various Advanced Traffic Management Systems (ATMS)], and to use the same investment to also deliver traditional voice (telephony), data (e-mail, technical support, and browsing), and video services (video monitoring).
- Multilayer integration—All of the elements described above allow for the integration of higher-level applications such as enterprise resource planning (ERP), manufacturing execution systems (MES), and advanced traffic management systems to the floor control layer (programmable logic controllers [PLCs], PC-based control systems, traffic control equipment, and human-machine interfaces [HMIs]). This allows for a true flow of data and automation from the demand side (customer placing and order) to the factory floor (assembly line) or from the monitoring devices in a freeway all the way to the emergency response systems, as well as real-time control in SCADA applications. As organizations increasingly rely on Ethernet networks, it is important to ensure high availability, security, scalability, and control. By adding Cisco IOS Software functionality to new network applications, users can now deploy network-wide intelligent services that address these requirements in a consistent way—from the I/O or monitoring device to the core and through the WAN.

Network Security through Advanced Security Features

Cisco Catalyst 2955 Series switches offer enhanced data security through numerous security features. These features allow customers to enhance network security with capabilities to secure traffic through the protection of passwords and configuration information; to provide options for network security based on users, ports, and Media Access Control (MAC) addresses; and to enable more immediate reactions to intruder and hacker detection.

Secure Shell (SSH) Protocol and SNMPv3 protect information from tampering or eavesdropping by encrypting information being passed along the network, thereby guarding administrative information. Private VLAN Edge isolates ports on a switch, ensuring that traffic travels directly from the entry point to the aggregation device through a virtual path and cannot be directed to another port.

Port-based access control parameters (ACPs) restrict sensitive portions of the network by denying packets based on source and destination MAC addresses, IP addresses, or Transmission Control Protocol/User Datagram Protocol (TCP/UDP) ports. ACP lookups are done in hardware, so forwarding performance is not compromised when implementing this type of security in the network. In addition, time-based ACPs allow configuration of differentiated services based on time periods. ACPs can also be applied to filter traffic based on differentiated services code point (DSCP) values. Port security provides another means to ensure that appropriate users are on the network, by limiting access based on MAC addresses.

For authentication of users with a Terminal Access Controller Access Control System (TACACS+) or RADIUS server, 802.1x provides port-level security. 802.1x in conjunction with a RADIUS server allows for dynamic port-based user authentication. 802.1x-based user authentication can be extended to dynamically assign a virtual LAN (VLAN) based on a specific user, regardless of where that user connects on the network. This intelligent adaptability provides greater flexibility and mobility to the network's stratified user populations. By combining access control and user profiles with secure network connectivity, services, and applications, customers can more effectively manage user mobility and drastically reduce the overhead associated with granting and managing access to network resources.

With multilayer Cisco Catalyst 2955 Series switches, network managers can implement high levels of console security. Multilevel access security on the switch console and a Web-based management interface prevent unauthorized users from accessing or altering switch configurations. TACACS+ or RADIUS authentication enable centralized access control of the switch and restrict unauthorized users from altering the configuration. Deploying security can be done through Cisco CMS Software Security Wizards, which ease the deployment of security features that restrict user access to a server, a portion of the network, or the entire network.

Network Control through Advanced QoS and Rate Limiting

Cisco Catalyst 2955 Series switches offer superior and highly granular QoS based on Layers 2-4 information, to help ensure that network traffic is classified and prioritized, and that congestion is avoided in the best possible manner. These switches can classify, reclassify, police (determine if the packet is in or out of predetermined profiles and affect actions on the packet), and mark or drop the incoming packets before the packet is placed in the shared buffer. Packet classification allows the network elements to discriminate between various traffic flows and to enforce rate-limiting policies based on Layer 2 and Layer 3 QoS fields.

To implement QoS, these switches first identify traffic flows or packet groups. They classify or reclassify these groups using the DSCP field in the IP packet and/or the 802.1p class of service (CoS) field in the Ethernet packet. Classification and reclassification can also be based on criteria as specific as the source or destination IP address, source or destination MAC address, or the Layer 4 TCP/UDP ports. At the ingress (incoming port) level, Cisco Catalyst 2955 Series switches can also perform policing and marking of the packet.

After the packet goes through classification, policing, and marking, it is assigned to the appropriate queue before exiting the switch. Cisco Catalyst 2955 Series switches support four egress (outgoing port) queues per port, allowing the network administrator to be more discriminating and specific in assigning priorities for the various applications on the network. At the egress level, the switch performs scheduling—an algorithm that determines the order in which the queues are processed. The switches support Weighted Round Robin (WRR) scheduling, strict priority queuing or strict priority scheduling. The WRR scheduling algorithm ensures that lower-priority packets are not entirely starved for bandwidth and are serviced without compromising the priority settings administered by the network manager. Strict priority scheduling ensures that higher-priority packets will always get serviced first, ahead of other traffic in lower-priority queues.

These features allow for prioritization of mission-critical, such as motion-control traffic, critical I/O or sensor data, video monitoring of security areas over voice (IP telephony traffic), ERP (Oracle, SAP, etc.), and CAD/CAM, which, in turn, would be scheduled to have precedence over less time-sensitive applications such as FTP or e-mail (SMTP).

For example, it would be highly undesirable to have a large file download destined to one port on a switch and have quality implications, such as increased latency in industrial control traffic, destined to another port on the switch. This condition is avoided by ensuring that the control traffic is properly classified and prioritized throughout the network. Other applications, such as Web browsing, can be treated as low priority and handled on a best-efforts basis.

Cisco Catalyst 2955 Series switches allocate bandwidth based on several criteria, including MAC source address, MAC destination address, IP source address, IP destination address, and TCP/UDP port number. Bandwidth allocation is essential in network environments that require service-level agreements, or when it is necessary for the network manager to control the bandwidth given to certain users. Cisco Catalyst 2955 Series switches support up to six policers per Fast Ethernet port and up to 60 policers on a Gigabit Ethernet port. This gives the network administrator granular control of the network bandwidth.

Network Availability

To provide efficient use of resources for bandwidth-hungry applications like multicasts (common in producer-consumer data distribution models), Cisco Catalyst 2955 Series intelligent switches support Internet Group Management Protocol (IGMP) snooping in hardware. Through the support and configuration of IGMP snooping via Cisco CMS Software, Cisco Catalyst 2955 Series switches deliver outstanding performance and ease of use in administering and managing multicast applications on the LAN.

The IGMP snooping feature allows the switch to "listen in on" the IGMP conversation between hosts. When a switch hears an "IGMP join" request from a host for a given multicast group, the switch adds the host's port number to the group destination address (GDA) list for that group. When the switch hears an "IGMP leave" request, it removes the host's port from the Content Addressable Memory (CAM) table entry.

Per VLAN Spanning Tree Plus (PVST+) allows users to implement redundant uplinks while distributing traffic loads across multiple links. This is not possible with standard Spanning-Tree Protocol implementations. Cisco UplinkFast technology ensures immediate transfer to the secondary uplink, a vast improvement over the traditional 30-to-60-second convergence time.

Network Management

Cisco CMS Software is Web-based and embedded in Cisco Catalyst 2955, 2950, 3550, 3500 XL, 2900 XL, and 2900 LRE XL switches. Through Cisco switch clustering technology, users can access Cisco CMS Software with any standard Web browser to manage up to 16 of these switches at once, regardless of their geographic proximity—with the option of using a single IP address for the entire cluster if desired. Cisco CMS provides an integrated management interface for delivering intelligent services, such as multilayer switching, QoS, multicast, and security access control lists (ACLs). Cisco CMS allows administrators to take advantage of benefits formerly reserved for only the most advanced networks—without having to learn the command-line interface (CLI) or even the details of the technology.

Cisco CMS Software supports standards-based connectivity options such as Ethernet, Fast Ethernet, Fast EtherChannel, Gigabit Ethernet, and Gigabit EtherChannel™ connectivity. Because Cisco switch clustering technology is not limited to a single stack of switches, Cisco CMS Software expands the traditional cluster domain beyond a single wiring closet, saving time and effort for network administrators.

Cisco Catalyst 2955 switches can be configured either as “command” or “member” switches in a Cisco switch cluster. Cisco CMS also allows users to designate a switch as a standby or redundant command, which takes the commander duties if the primary command switch fails. Other key features include the ability to configure multiple ports and switches simultaneously, to perform software updates across the entire cluster at once, and to clone configurations to other clustered switches for rapid network deployments. Bandwidth graphs and link reports provide useful diagnostic information, and the topology map gives network administrators a quick view of the network status.

In addition to Cisco CMS, Cisco Catalyst 2955 Series switches provide extensive management tools using SNMP platforms such as CiscoWorks for Switched Internetworks.

Cisco Catalyst 2955 Series switches deliver a comprehensive set of management tools to provide the required visibility and control in the network. Managed with CiscoWorks, Cisco Catalyst switches can be configured and managed to deliver end-to-end device, VLAN, traffic, and policy management. Coupled with CiscoWorks, Cisco Resource Manager Essentials, a Web-based management tool, offers automated inventory collection, software deployment, easy tracking of network changes, views into device availability, and quick isolation of error conditions.

Enhanced Hardware Features

The Cisco Catalyst 2955 Switch has been designed for deployment in harsh environments. Through the use of special thermal design techniques and industrial-rated components, the Cisco Catalyst 2955 is rated to operate at extreme temperatures (–40 to 60 C; –40 to 140 F). Robust mechanical specifications allow for its deployment as a mobile platform and under extreme vibration and shock environments (50G trapezoidal shock pulse). The compact form factor, DIN rail mounting, and dual cabling orientations facilitate its deployment into industrial enclosures, traffic control cabinets, and transportation vehicles. Two normally open relays can be associated with the different port alarms, power alarms, and high temperature conditions to send an output signal to other external mechanisms (visible or audible alarms, for example), HMIs, or PLCs for a controlled shutdown. Dual power inputs provide for optional redundant power supplies, guaranteeing an even higher level of resiliency and reliability.

Figure 1
Cisco Catalyst 2955 Series Switches

Table 1 Product Features and Benefits

Feature	Benefit
Availability	
Superior redundancy for fault backup	• IEEE 802.1D Spanning-Tree Protocol support for redundant backbone connections and loop-free networks simplifies network configuration and improves fault tolerance. • Support for Cisco Spanning-Tree Protocol enhancements such as UplinkFast, BackboneFast, and PortFast technologies ensures quick failover recovery, enhancing overall network stability and availability. • IEEE 802.1w Rapid Spanning-Tree Protocol (RSTP) provides rapid convergence of the spanning tree, independent of spanning tree timers. • The command switch redundancy enabled in Cisco CMS Software allows customers to designate a backup command switch that takes over cluster management functions if the primary command switch fails. • Provides unidirectional link detection (UDLD) and Aggressive UDLD for detecting and disabling unidirectional links on fiber-optic interfaces caused by incorrect fiber-optic wiring or port faults.
Integrated Cisco IOS Software features for bandwidth optimization	• Bandwidth aggregation of up to 4 Gbps (two ports full duplex) through Cisco Gigabit EtherChannel technology and up to 16 Gbps (eight ports full duplex) through Fast EtherChannel technology enhances fault tolerance and offers higher-speed aggregated bandwidth between switches, to routers and individual servers. Port Aggregation Protocol (PAgP) is available to simplify configuration. • Per-port broadcast, multicast, and unicast storm control prevents faulty end stations from degrading overall system performance. • PVST+ and IEEE 802.1s Multiple Spanning-Tree Protocol (MSTP) allow for Layer 2 load sharing on redundant links to efficiently use the extra capacity inherent in a redundant design. • VLAN Trunking Protocol (VTP) pruning limits bandwidth consumption on VTP trunks by flooding broadcast traffic only on trunk links required to reach the destination devices. Dynamic Trunking Protocol (DTP) enables dynamic trunk configuration across all ports on the switch. • IGMP snooping provides for fast client joins and leaves of multicast streams and limits bandwidth-intensive video traffic to only the requestors. Multicast VLAN Registration (MVR), IGMP filtering, fast-join, and immediate leave are available as enhancements. • MVR continuously sends multicast streams in a multicast VLAN while isolating the streams from subscriber VLANs for bandwidth and security reasons. • Supports additional frame formats: Ethernet II (tagged and untagged), 802.3 (SNAP encapsulated, tagged and untagged frames).
Security	
Network-wide security features	• Filtering of incoming traffic flows based on Layer 2, Layer 3, or Layer 4 ACPs prevents unauthorized data flows. – The following Layer 2 ACPs or a combination can be used for security classification of incoming packets: source MAC address, destination MAC address, and 16-bit Ethertype. – The following Layer 3 and Layer 4 fields or a combination can be used for security classification of incoming packets: source IP address, destination IP address, TCP source or destination port number, UDP source, or destination port number. ACPs can also be used] to filter based on DSCP values. – Time-based ACPs allow configuration of differentiated services based on time periods.

Table 1 Product Features and Benefits

Feature	Benefit
	• A private VLAN edge provides security and isolation between ports on a switch, ensuring that voice traffic travels directly from its entry point to the aggregation device through a virtual path and cannot be directed to a different port. • Support for the 802.1x standard allows users to be authenticated, regardless of which LAN port they are accessing, and provides unique benefits to customers who have a large base of mobile (wireless) users accessing the network. • 802.1x with VLAN assignment allows a dynamic VLAN assignment for a specific user, regardless of where the user is connected. • 802.1x with voice VLAN gives an IP phone access to the voice VLAN, regardless of the authorized or unauthorized state of the port. • 802.1x with port security authenticates the port and manages network access for all MAC addresses, including the clients'. • SSH and SNMPv3 provide network security by encrypting administrator traffic during Telnet and SNMP sessions. • Port security secures the access to a port based on the MAC address of a user's device. The aging feature removes the MAC address from the switch after a specific timeframe to allow another device to connect to the same port. • MAC address notification allows administrators to be notified of new users added or removed from the network. • Spanning-tree root guard (STRG) prevents edge devices not in the network administrator's control from becoming Spanning-Tree Protocol root nodes. • The Spanning-Tree Protocol PortFast/bridge protocol data unit (BPDU) guard feature disables access ports with Spanning-Tree Protocol PortFast enabled upon reception of a BPDU, and increases network reliability, manageability, and security. • Multilevel console access security prevents unauthorized users from altering the switch configuration. • TACACS+ and RADIUS authentication enables centralized control of the switch and restricts unauthorized users from altering the configuration. • The user-selectable address-learning mode simplifies configuration and enhances security. • Trusted Boundary provides the ability to trust the QoS priority settings if a Cisco IP phone is present and to disable the trust setting if the IP phone is removed, preventing a rogue user from overriding prioritization policies in the network. • IGMP Filtering provides multicast authentication by filtering out nonsubscribers and limits the number of concurrent multicast streams available per port. • Support for dynamic VLAN assignment through implementation of VLAN Membership Policy Server (VMPS) client functionality provides flexibility in assigning ports to VLANs. Dynamic VLAN enables fast assignment of IP addresses. • Cisco CMS Software Security Wizards ease the deployment of security features for restricting user access to a server, a portion of the network, or the entire network.
QoS	
Overview	• The switches support the aggregate QoS model by enabling classification, policing/metering, and marking functions on a per-port basis at ingress and queuing/scheduling functions at egress. • The switches support configuring QoS ACPs on all ports, using ACPs to ensure proper policing and marking on a per-packet basis. Up to four ACPs per switch are supported in configuring either QoS ACPs or security filters. • Automatic QoS (Auto-QoS) greatly simplifies the configuration of QoS in voice-over-IP (VoIP) networks by issuing interface and global switch commands that allow the detection of Cisco IP phones, the classification of traffic, and egress queue configuration.

Table 1 Product Features and Benefits

Feature	Benefit
QoS metering/ policing at ingress	• Support for metering/policing of incoming packets restricts incoming traffic flows to a certain rate. • The switches support up to six policers per Fast Ethernet port, and 60 policers on a Gigabit Ethernet port. • The switches offer granularity of traffic flows at 1 Mbps on Fast Ethernet ports, and 8 Mbps on Gigabit Ethernet ports.
QoS marking at ingress	• The switches support marking and remarking packets based on the state of policers/ meters. • The switches support marking and remarking based on the following mappings: from DSCP to 802.1p, and from 802.1p to DSCP. • The switches support 14 well-known and widely used DSCP values. • The switches support classifying or reclassifying packets based on the default DSCP per port, and support classification based on DSCP values in the ACL. • The switches support classifying or reclassifying frames based on the default 802.1p value per port. • The switches support 802.1p override at ingress.
QoS scheduling support at egress	• Four queues per egress port are supported in hardware. • The WRR queuing algorithm ensures that low-priority queues are not starved. • Strict Priority Scheduling ensures that time-sensitive applications such as voice always follow an expedited path through the switch fabric.
Sophisticated traffic management	• The switch supports up to six policers per Fast Ethernet port and up to 60 policers on a Gigabit Ethernet port. • The switch offers granularity of traffic flows at 1 Mbps on Fast Ethernet ports and 8 Mbps on Gigabit Ethernet ports. • The switch offers the ability to limit data flows based on MAC source or destination address, IP source or destination address, TCP/UDP port numbers, or any combination of these fields. • The switch offers the ability to manage data flows asynchronously upstream and downstream from the end station or on the uplink.
Management	
Superior manageability	• An embedded Remote Monitoring (RMON) software agent supports four RMON groups (history, statistics, alarms, and events) for enhanced traffic management, monitoring, and analysis. • The switch supports all nine RMON groups through the use of a Cisco SwitchProbe® Analyzer Switched Port Analyzer (SPAN) port, permitting traffic monitoring of a single port, a group of ports, or the entire switch from a single network analyzer or RMON probe. • A SPAN port monitors traffic of a single port from a single network analyzer or RMON probe. • Remote SPAN (RSPAN) allows network administrators to locally monitor ports in a Layer 2 switch network from any other switch in the same network. • The Domain Name System (DNS) provides IP address resolution with user-defined device names. • Trivial File Transfer Protocol (TFTP) reduces the cost of administering software upgrades by downloading from a centralized location. • Network Timing Protocol (NTP) provides an accurate and consistent timestamp to all switches within the intranet.

Table 1 Product Features and Benefits

Feature	Benefit
	• Layer 2 traceroute eases troubleshooting by identifying the physical path that a packet takes from the source device to a destination device. • Crash Information Support enables the switch to generate a crash file for improved troubleshooting. • Show Interface Capabilities provides information on the configuration capabilities of any interface. • RTTMON-MIB allows users to monitor network performance between a Cisco Catalyst switch and a remote device. • Multifunction LEDs per port for port status, half-duplex/full-duplex, 10BASE-T/100BASE-TX/1000BASE-T indication and switch-level status LEDs for system, redundant power supply, and bandwidth usage provide a comprehensive and convenient visual management system.
Cisco CMS	• Cisco CMS Software allows the user to manage up to 16 interconnected Cisco Catalyst 3550, 2950, 2950ST-LRE, 2955, 3500 XL, 2900 XL, and 2900 LRE XL switches without the limitation of being physically located in the same wiring closet, and with the option of using a single IP address for the entire cluster if desired. Full backward compatibility ensures that any combination of the above switches can be managed with a Cisco Catalyst 2955 Series Switch. • Cisco AVVID (Architecture for Voice, Video and Integrated Data) wizards use just a few user inputs to automatically configure the switch to optimally handle different types of traffic—voice, video, multicast, or high-priority data. • A security wizard is provided to restrict unauthorized access to servers and networks, and to restrict certain applications on the network. • One-click software upgrades can be performed across the entire cluster simultaneously, and configuration cloning enables rapid deployment of networks. • Cisco CMS Software has been extended to include multilayer feature configurations such as ACPs and QoS parameters. • Cisco CMS Guide Mode assists users in the configuration of powerful advanced features by providing step-by-step instructions. • Cisco CMS provides enhanced online help for context-sensitive assistance. • An easy-to-use graphical user interface provides both a topology map and a front-panel view of the cluster. • Multidevice and multiport configuration capabilities allow network administrators to save time by configuring features across multiple switches and ports simultaneously. • Cisco CMS offers the ability to launch the Web-based management for a Cisco Aironet™ Wireless Access Point by simply clicking on its icon in the topology map. • A user-personalized interface allows users to modify polling intervals, table views, and other settings within Cisco CMS and to retain these settings the next time they use Cisco CMS. • Alarm notification provides automated e-mail notification of network errors and alarm thresholds.
Support for CiscoWorks	• Manageable through CiscoWorks network management software on a per-port and per-switch basis, providing a common management interface for Cisco routers, switches, and hubs. • SNMPv1, v2, and v3 (non-crypto) and Telnet interface support deliver comprehensive in-band management, and a CLI-based management console provides detailed out-of-band management. • Cisco Discovery Protocol versions 1 and 2 enable a CiscoWorks network management station to automatically discover the switch in a network topology. • CiscoWorks is supported by the CiscoWorks 2000 LAN Management Solution.

Table 1 Product Features and Benefits

Feature	Benefit
Ease of use and ease of deployment	• Autoconfiguration eases the deployment of switches in the network by automatically configuring multiple switches across a network via a boot server. • Autosensing on each Ethernet port] detects the speed of the attached device and automatically configures the port for 10-, 100-, or 1000-Mbps operation, easing the deployment of the switch in mixed 10, 100, and 1000BASE-T environments. • Autonegotiating on all ports automatically selects half- or full-duplex transmission mode to optimize bandwidth. • Cisco VTP supports dynamic VLANs and dynamic trunk configuration across all switches. • DTP enables dynamic trunk configuration across all ports in the switch. • PAgP automates the creation of Cisco Fast EtherChannel or Gigabit EtherChannel groups, enabling linking to another switch, router, or server. • Link Aggregation Control Protocol (LACP) allows the creation of Ethernet channeling with devices that conform to IEEE 802.3ad. This is similar to Cisco EtherChannel and PAgP. • The default configuration stored in Flash ensures that the switch can be quickly connected to the network and can pass traffic with minimal user intervention.

Table 2 Product Specifications

Feature	Description
Performance	• 13.6 Gbps switching fabric • Cisco Catalyst 2955T-12: 6.4 Gbps maximum forwarding bandwidth • Cisco Catalyst 2955C-12: 2.8 Gbps maximum forwarding bandwidth • Cisco Catalyst 2955S-12: 2.8 Gbps maximum forwarding bandwidth (Forwarding rates based on 64-byte packets) • Cisco Catalyst 2955T-12: 4.8 Mpps wire speed forwarding rate • Cisco Catalyst 2955C-12: 2.0 Mpps wire speed forwarding rate • Cisco Catalyst 2955S-12: 2.0 Mpps wire speed forwarding rate • 8 MB memory architecture shared by all ports • Up to 32 MB SDRAM and 16 MB Flash memory • Configurable up to 8000 MAC addresses
Management	• BRIDGE-MIB • CISCO-BULK-FILE-MIB • CISCO-2900-MIB • CISCO-CDP-MIB • CISCO-CLASS-BASED-QOS-MIB • CISCO-CLUSTER-MIB • CISCO-CONFIG-COPY-MIB • CISCO-CONFIG-MAN-MIB • CISCO-ENVMON-MIB • CISCO-ENTITY-MIB • CISCO-ENTITY-ALARM-MIB • CISCO-FLASH-MIB • CISCO-FTP-CLIENT-MIB • CISCO-IMAGE-MIB

Table 2 Product Specifications

Feature	Description
	• CISCO-MAC-NOTIFICATION-MIB • CISCO-MEMORY-POOL-MIB • CISCO-PAGP-MIB • CISCO-PING-MIB • CISCO-PROCESS-MIB • CISCO-PRODUCTS-MIB • CISCO-RTTMON-MIB • CISCO-SMI • CISCO-STACKMAKER-MIB • CISCO-STP-EXTENSIONS-MIB • CISCO-SYSLOG-MIB • CISCO-TC • CISCO-TCP-MIB • CISCO-VLAN-MEMBERSHIP-MIB • CISCO-VTP-MIB • ENTITY-MIB • IANAifType-MIB • IF-MIB (RFC 1573) • OLD-CISCO-CHASSIS-MIB • OLD-CISCO-CPU-MIB • OLD-CISCO-INTERFACES-MIB • OLD-CISCO-IP-MIB • OLD-CISCO-MEMORY-MIB • OLD-CISCO-SYSTEM-MIB • OLD-CISCO-TCP-MIB • OLD-CISCO-TS-MIB • RFC1213-MIB (MIB-II) • RFC1398-MIB (ETHERNET-MIB) • RMON-MIB (RFC 1757) • RS-232-MIB • SNMPv2-MIB • SNMPv2-SMI • SNMPv2-TC • TCP-MIB • UDP-MIB

Table 2 Product Specifications

Feature	Description
Standards	• IEEE 802.1x support • IEEE 802.1w Rapid Spanning Tree Protocol (RSTP) • IEEE 802.1s Multiple Spanning Tree Protocol (MSTP) • IEEE 802.3x full duplex on 10BASE-T, 100BASE-TX, and 1000BASE-T ports • IEEE 802.1D Spanning-Tree Protocol • IEEE 802.1p CoS prioritization • IEEE 802.1Q VLAN • IEEE 802.3 10BASE-T specification • IEEE 802.3u 100BASE-TX specification • IEEE 802.3ab 1000BASE-T specification • IEEE 802.3ad Link Aggregation Control Protocol (LACP) • IEEE 802.3ah Ethernet in the First Mile (EFM) • RMON I and II standards • SNMPv1, SNMPv2c, and SNMPv3
Connectors and cabling	• 10BASE-T/100BASE-TX ports: RJ-45 connectors; four-pair Category 5 UTP cabling • 1000BASE-T ports: RJ-45 connectors; four-pair Category 5 UTP cabling • 100BASE-FX ports: MT-RJ connectors; 50/125 or 62.5/125 micron multimode fiber-optic cabling • 100BASE-LX ports: LC connectors; 50/125 or 62.5/125 micron single-mode fiber-optic cabling • Management console port: Eight-pin (RJ-45 to DB9) rollover cable for PC connections
MT-RJ patch cables for Cisco Catalyst 2955	*Type of cable, Cisco part number* • One-meter, MT-RJ-to-SC multimode cable, CAB-MTRJ-SC-MM-1M • Three-meter, MT-RJ-to-SC multimode cable, CAB-MTRJ-SC-MM-3M • Five-meter, MT-RJ-to-SC multimode cable, CAB-MTRJ-SC-MM-5M • One-meter, MT-RJ-to-ST multimode cable, CAB-MTRJ-ST-MM-1M • Three-meter, MT-RJ-to-ST multimode cable, CAB-MTRJ-ST-MM-3M • Five-meter, MT-RJ-to-ST multimode cable, CAB-MTRJ-ST-MM-5M • Two-meter, LC to SC single-mode cable, CAB-CP-LCSC-2M
Indicators	• Per-port status LEDs: Link integrity, disabled, activity, and indications • Dual-power-supply indicators • Major and minor alarm-relay indicators
Dimensions and weight (HxWxD)	• 3.78x8.07x5.03 in. (9.60x20.50x12.78 cm): Connectors facing forward • 5.03x8.07x3.78 in. (12.78x20.50x9.60 cm): Connectors facing downward • 3.0 lb (1.4 kg)
Relay contacts	• Surge withstand between open contacts: 1500V, FCC Part 68 • Surge withstand between contact and coil: 2500V, Bellcore • Maximum switching capacity: 1A @ 30 VDC • Maximum switching voltage: .3A @ 125 VAC

Table 2 Product Specifications

Feature	Description
Environmental ranges	• Recommended operating temperature range: –40 to 140 F (–40 to 60 C) • Recommended storage temperature range: –40 to 185 F (–40 to 85 C) • Operating relative humidity: 10 to 95% (noncondensing) • Operating altitude: 9843 ft (3000 m) @ 104 F (40 C) • Storage altitude: Up to 29,500 ft (9000 m) • Shock: 50 g trapezoidal shock (meets or exceeds ASTM D3332) • Vibration: 500 Hz (meets or exceeds MIL-STD-810, Method 514.4)
Power requirements	• External 24V (dual-redundant DC input, screw-down connectors) • Power consumption: 23W maximum, 78.53 BTU/hour • 18V minimum; 32V maximum
Predicted mean time between failure (MTBF)	• WS-C2955T 235,022 hours • WS-C2955C 206,378 hours • WS-C2955S 205,115 hours • Telcordia SR-332 Gf
Fiber port specifications	• 100BASE-FX (MT-RJ connectors @ 1,300 nm): – Optical receiver sensitivity: -30 dBm – Optical transmitter power: -19 to -14 dBm – Maximum distance: 2 km • 100BASE-LX (LC connectors @ 1,300 nm): – Optical receiver sensitivity: -38 to -31 dBm – Optical transmitter power: -15 to -8 dBm – Maximum distance: 15 km
Regulatory Agency Approvals	
Safety certifications	• CE Marking • UL 60950 • CSA 22.2/60950 • TUV GS: CB Report to IEC 60950 • UL 508 • CSA 22.2/142 • AS/NZS 3260 • NOM
Hazardous locations	• UL 1604—Class I, Div 2 Group A, B, C, D • CSA 22.2/213—Class 1, Div 2 Group A, B, C, D • EN 50021—Class I, Zone 2

Table 2 Product Specifications

Feature	Description
Electromagnetic emissions certifications	• FCC Part 15 Class A • ICES-003 Class A • EN 55022: (CISPR22 Class A) • EN 55024: (CISPR24) • VCCI Class A • AS/NZS CISPR 22 Class A • VCCI Class 1 • CE Marking • CNS 13438 • BSMI Class A • MIC Class A • EN 61131-2 • EN 55011 (CISPR 11) Class A
ITS	• NEMA TS-2
Warranty	• Limited five-year warranty
External DIN Rail Mountable Power Supply	
Input voltage	AC100–120/220–240V (switchable) 47–63 Hz
Input current	<1.3A (switch in 115V position)
Input current	<0.7A (switch in 230V position)
Output voltage	24 VDC (+5%, –1%)
Size (WxHxD)	1.92x4.92x4.05 (50x125x103 mm)
Weight	1 lb (460 g)
Worldwide approvals	UL, EN, CSA, and CB
Overload protection	Over 1.5 times normal current
Cooling	Normal convection cooling
Temperature range	–25º to +85ºC (storage) –10º to +60ºC (operating)

Service and Support

The service and support programs described in Table 3 are available as part of the Cisco Desktop Switching Service and Support solution, and are available directly from Cisco and through resellers.

Table 3 Cisco Service and Support Programs

Service and Support	Features	Benefits
Advanced Services		
Total Implementation Solutions (TIS)—available direct from Cisco *Packaged Total Implementation Solutions (Packaged TIS)*—available through resellers	• Project management • Site survey and configuration deployment • Installation, text, and cutover • Training • Major moves, adds, or changes • Design review and product staging	• Supplements existing staff • Ensures that functionality meets customer needs • Mitigates risk
Technical Support Services		
Cisco SMARTnet™ and SMARTnet Onsite—available direct from Cisco *Packaged SMARTnet*—available through resellers	• 24x7 access to software updates • Web access to technical repositories • Telephone support through the Technical Assistance Center • Advance replacement of hardware parts	• Enables proactive or expedited issue resolution • Lowers cost of ownership by using Cisco expertise and knowledge • Minimizes network downtime

Table 4 Ordering Information

Model Numbers	Configuration
WS-C2955T-12	Twelve 10/100 ports and two 10/100/1000BASE-T ports
WS-C2955C-12	Twelve 10/100 ports and two 100BASE-FX ports
WS-C2955S-12	Twelve 10/100 ports and two 100BASE-LX ports
PWR-2955-AC=	DIN Rail mountable 24V power supply (85 to 264 VAC input)
STK-RACKMNT-2955=	DIN Rail Adapter for 19” rack mounting

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WH/LW4111 0403

Data Sheet

Cisco Catalyst 4500 Series Line Cards

Product Overview

Fast Ethernet and Gigabit Line Cards

The Cisco® Catalyst® 4500 Series scalable, modular, high-density switches deliver high performance and integrated Layer 2, 3, and 4 switching with intelligent services for network control and resiliency. These switches offer a variety of Fast Ethernet and Gigabit Ethernet line cards that include fiber and copper interfaces optimized for desktops, branch office backbones, and servers for enterprise and commercial switching solutions, and service provider metropolitan Ethernet networks. Gigabit Ethernet line cards include cost-effective, high-performance 1000BASE-X gigabit interface converter (GBIC) and Small Form-Factor Pluggable (SFP)-based Gigabit Ethernet line cards and the high-density 10/100/1000BASE-T triple-speed autosensing, autonegotiating Gigabit Ethernet line cards. Fast Ethernet line cards include various densities of wire-speed 10/100, 100-FX, 100BASE-LX10, and 100BASE-BX-D options.

Power over Ethernet Line Cards

The Cisco Catalyst 4500 Series offers line cards, power supplies, and accessories required to deploy and operate a standards-based Power over Ethernet (PoE) internetwork. PoE provides –48 VDC power over standard Category 5 unshielded twisted-pair (UTP) cable up to 100 meters when an IEEE 802.3af-compliant or Cisco Systems® prestandard powered device is attached to the PoE line card port. Instead of requiring wall power, attached devices such as IP phones, wireless base stations, video cameras, and other IEEE-compliant appliances can use power provided from the Cisco Catalyst 4500 Series PoE line cards. This capability gives network administrators centralized control over power and eliminates the need to install outlets in ceilings and other out-of-the-way places where a powered device can be installed.

Although all references to “PoE,” “inline-power,” and “voice” power supplies and line cards are synonymous, there are only two versions: Cisco prestandard and IEEE 802.3af compliant. Every Cisco Catalyst 4500 Series chassis and PoE power supply supports the IEEE 802.3af standard and the Cisco prestandard power implementation, helping ensure backward compatibility with existing devices powered by Cisco. All IEEE 802.3af-compliant line cards can distinguish an IEEE or Cisco prestandard powered device from an unpowered network interface card (NIC), helping ensure power is applied only when an appropriate device is connected.

Ethernet in the First Mile

Cisco Catalyst 4500 Series line cards for delivering Ethernet in the First Mile (EFM) fulfill the high-density, high-bandwidth, and long-reach requirements of network operators to build next-generation metropolitan-area networks. Cisco Catalyst 4500 Series EFM line cards let service providers deliver any combination of data, voice, and video services over a single optical connection to homes, business parks, and multitenant units. EFM line cards also are appropriate for manufacturing facilities, transportation monitoring, and fiber-to-the-desktop applications. Ethernet over fiber enables operation in noisy electromagnetic environments, providing physical security and longer reaches with the same well-understood Ethernet transport. EFM line cards include 1000BASE-X, 100FX, 100BASE-LX10, and 100BASE-BX-D for fiber-based options and 10/100 or 10/100/1000BASE-T line cards for copper-based options when media converters are used.

Features and Benefits

Functionally Transparent

Cisco Catalyst 4500 Series switches offers an extensive line of modules that support numerous speeds and physical media combinations. These line cards are functionally transparent; all the packet processing, queuing, buffering, and quality of service (QoS) occur in the supervisor engine. To that end, the line cards acquire the features and capabilities of the installed supervisor engine. This architecture enables customers to easily upgrade all Ethernet line cards on their Cisco Catalyst 4500 Series systems to higher-layer switching functions by adding a new supervisor engine. The simple design of the line cards results in a very high mean time between failures (MTBF), helping ensure high availability for a single connection to an end user.

Modular Versatility

The Cisco Catalyst 4500 Series is a centralized architecture that is designed to provide dedicated wire-speed bandwidth to each line card slot within the chassis. Each line card has a dedicated bandwidth to the supervisor engine for packet processing. All network data that flows into the Cisco Catalyst 4500 Series through the various line cards goes through the supervisor engine for processing, even in single-slot port-to-port communications. All line cards have some per-slot bandwidth that allows network administrators to design a system that offers full dedicated bandwidth-to-server and switch-to-switch applications and still provide high performance over subscribed Gigabit to the desktop.

A modular centralized design allows customers to use their investment in high-performance line cards across the entire line of Cisco Catalyst 4500 Series chassis and supervisor engines. For example, line cards shipping with the original Cisco Catalyst 4003 Switch will work in the new Cisco Catalyst 4500 Series running the Cisco Catalyst 4500 Series Supervisor Engine V-10GE.

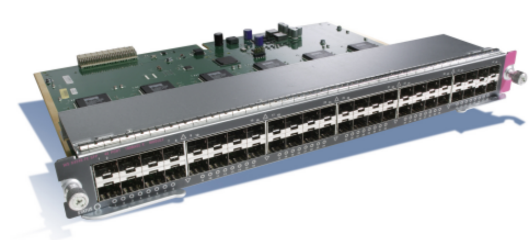
Following are descriptions of line cards that are available for Cisco Catalyst 4500 Series switches.

Fast Ethernet over Fiber

WS-X4248-FE-SFP

- 48-port 100BASE-X (SFP optional)
- Customers can mix and match 100BASE-X SFP optics on the same line card.
- An alternative to the Cisco Catalyst 4500 fixed 100BASE-X line cards (WS-X4148-FX-MT, WS-X4124-FX-MT, WS-X4148-FE-LX-MT and WS-X4148-FE-BD-LC).
- SFP optics supported in Cisco IOS® Software Release 12.2(25)SG include: 100BASE-FX, 100BASE-LX10, 100BASE-BX-D, and 100BASE-BX-U.
- IEEE 802.3, IEEE 802.3ah, IEEE 802.3x flow control
- Enterprise and commercial: Fiber-to-the-desktop applications
- Metro Ethernet: For service providers running point-to-point Fast Ethernet to the home or business

Figure 1
WS-X4248-FE-SFP



WS-X4124-FX-MT

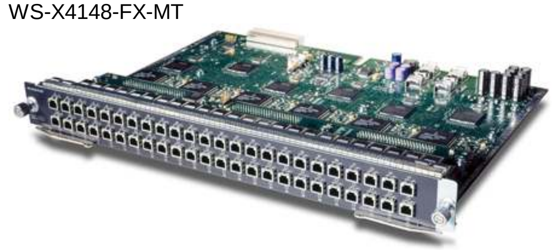
- 24 ports
- 100BASE-FX multimode fiber (MMF) (MT-RJ)
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3
- Enterprise and commercial: affordable connection for fiber-to-the-desktop applications. Optimized for government or for anyone requiring the security and resiliency of fiber to the desktop.
- Metro Ethernet: residential customers located within a 1.2-mile (2-km) radius

Figure 2
WS-X4124-FX-MT

WS-X4148-FX-MT

- 48 ports
- 100BASE-FX MMF (MT-RJ)
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3
- Enterprise and commercial: affordable high-density connection for fiber-to-the-desktop applications. Optimized for government or for anyone requiring the security and resiliency of fiber to the desktop.
- Metro Ethernet: residential customers located within a 1.2-mile (2-km) radius

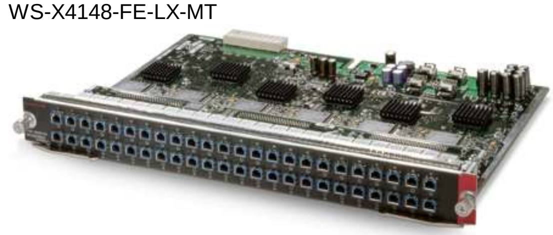
Figure 3
WS-X4148-FX-MT



WS-X4148-FE-LX-MT

- 48 ports
- 100BASE-LX10 SMF (MT-RJ)
- Cisco IOS Software Release 12.1(13)EW or later
- IEEE 802.3ah, IEEE 802.3
- Metro Ethernet: designed for both residential and small-business customers over distances up to 6.2 miles (10 km)

Figure 4
WS-X4148-FE-LX-MT



WS-X4148-FE-BD-LC

- 48 ports
- 100BASE-BX10-D for single strand of single-mode fiber
- Cisco IOS Software Release 12.2(18)EW or later
- IEEE 802.3ah, IEEE 802.3
- Bidirectional Fast Ethernet operates over a single strand of fiber
- Metro Ethernet: designed for network operators building the next-generation Metro Ethernet network over distances up to 6.2 miles (10 km)

Figure 5
WS-X4148-FE-BD-LC

Fast Ethernet over Copper

WS-X4124-RJ45

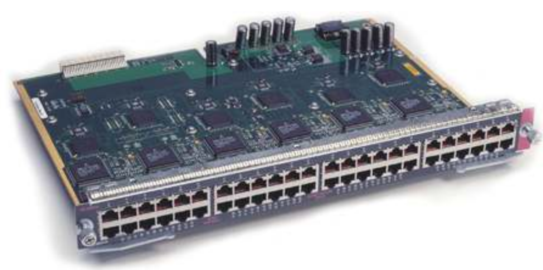
- 24 ports
- 10/100BASE-T module (RJ-45)
- Cisco IOS Software Release 12.2(20)EW or later
- IEEE 802.3
- Enterprise and commercial: designed for desktop connectivity and wiring closets

Figure 6
WS-X4124-RJ45

WS-X4148-RJ

- 48 ports
- 10/100BASE-T module (RJ-45)
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3
- Enterprise and commercial: high-port-density solution for desktop connectivity

Figure 7
WS-X4148-RJ



WS-X4148-RJ21

- 48 ports
- Telco 10/100BASE-T module (4 x RJ-21)
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3
- Enterprise and commercial: high-port-density solution with improved cable management RJ-21 connectors for desktop connectivity

Figure 8
WS-X4148-RJ21

WS-X4232-RJ-XX

- 32 ports plus modular uplink slot
- 10/100BASE-T (RJ-45)
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3
- Provides a fiber uplink option for investment protection and a clear upgrade path
- Enterprise and commercial: high-port-density solution for desktop connectivity

Figure 9

WS-X4232-RJ-XX

WS-U4504-FX-MT (Uplink Daughter Card)

- 4-port uplink daughter card
- 100BASE-FX MMF (MT-RJ)
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3
- Adds four 100BASE-FX uplinks to WS-X4232-RJ-XX line card

Figure 10

WS-U4504-FX-MT (Uplink Daughter Card)

WS-X4232-GB-RJ

- 32 ports plus 2 Gigabit (GBIC) ports
- 10/100BASE-T (RJ-45), 2- 1000BASE-X Gigabit Ethernet (GBIC) module
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3
- Enterprise and commercial: designed for desktop connectivity with additional Gigabit Ethernet uplinks
- Metro Ethernet: long-distance fiber uplink

Figure 11

WS-X4232-GB-RJ

Fast Ethernet Power over Ethernet

WS-X4148-RJ45V

- 48 ports
- Cisco prestandard 10/100 (RJ-45)
- Cisco IOS Software Release 12.1(8a)EW minimum for data, Cisco IOS Software Release 12.1(11b)EW minimum for power
- Not IEEE 802.3af compliant (Cisco prestandard only)
- PoE provides –48 VDC power over standard Category 5 cable
- Enterprise and commercial: designed for desktop connectivity and to power IP phones, wireless access points, or any other Cisco prestandard PoE device

Figure 12
WS-X4148-RJ45V

WS-X4224-RJ45V

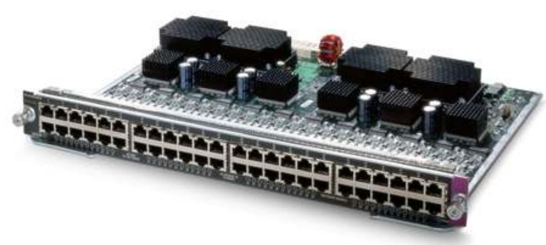
- 24 ports
- 10/100 (RJ-45)
- Cisco IOS Software Release 12.2(20)EW or later
- IEEE 802.3af PoE and Cisco prestandard PoE
- Enterprise and commercial: designed to power IP phones, wireless base stations, video cameras, and other IEEE-compliant powered devices

Figure 13
WS-X4224-RJ45V

WS-X4248-RJ45V

- 48 ports
- 10/100 (RJ-45)
- Cisco IOS Software Release 12.2(18)EW or later
- IEEE 802.3af PoE and Cisco prestandard
- Enterprise and commercial: designed to power IP phones, wireless base stations, video cameras, and other IEEE-compliant powered devices

Figure 14
WS-X4248-RJ45V



WS-X4248-RJ21V

- 48 ports
- 10/100 (RJ-21)
- Cisco IOS Software Release 12.2(18)EW or later
- IEEE 802.3af PoE and Cisco prestandard
- Enterprise and commercial: designed to power IP phones, wireless base stations, video cameras, and other IEEE-compliant powered devices with improved cable management RJ-21 connectors

Figure 15
WS-X4248-RJ21V

Gigabit Ethernet (GBIC or SFP)

The Cisco Catalyst 4500 Series offers a variety of GBIC- or SFP-enabled gigabit solutions for high-performance Gigabit Ethernet uplinks and server farm connectivity. The five GBIC- or SFP-enabled gigabit line card options for the Cisco Catalyst 4500 Series include 2-, 6-, 18-, and 48-port versions. GBIC or SFP technology allows customers to intermix intrabuilding MMF connections and long-distance single-mode connections simply by changing the GBIC or SFP type. (See Table 2 for more information.)

WS-X4302-GB

- 2 ports
- 1000BASE-X GBIC
- Cisco IOS Software Release 12.1(19)EW or later
- IEEE 802.3 standard Ethernet over fiber
- L2-4 Jumbo Frame Support (up to 9216 bytes)
- Enterprise and commercial: designed for uplinks, server farms, and switch-to-switch applications
- Metro Ethernet: GBIC flexibility designed for network operators building the next generation of Metro Ethernet networks

Figure 16
WS-X4302-GB

WS-X4306-GB

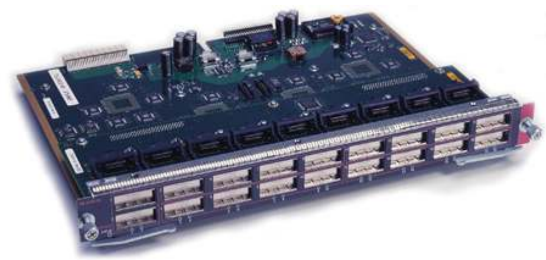
- 6 ports
- 1000BASE-X (GBIC)
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3
- L2-4 Jumbo Frame Support (up to 9216 bytes)
- Enterprise and commercial: designed for high-speed backbone, switch-to-switch applications, or small server farms
- Metro Ethernet: GBIC flexibility, six ports of dedicated 1000BASE-X Gigabit Ethernet uplinks

Figure 17
WS-X4306-GB

WS-X4418-GB

- 18 ports
- 1000BASE-X (GBIC)
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3, IEEE 802.3x flow control
- 2 ports of wire-speed 1000BASE-X Gigabit Ethernet uplinks
- 16 ports: 4:1 oversubscribed
- Enterprise and commercial: designed for fiber to the desktop, switch-to-switch applications, or small server farms
- Metro Ethernet: GBIC flexibility designed for network operators building the next generation of Metro Ethernet networks

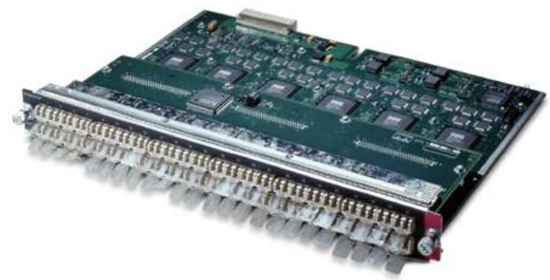
Figure 18
WS-X4418-GB



WS-X4448-GB-LX

- 48 ports
- 1000BASE-LX (SFP)
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3, IEEE 802.3x flow control
- Includes 48 1000BASE-LX SFP optics preloaded at the factory
- Bandwidth is allocated across six 8-port groups, providing 1 Gbps per port group
- Enterprise and commercial: designed for fiber to the desktop
- Metro Ethernet: optimized for service aggregation and business customer connectivity, designed for service providers to run point-to-point Gigabit Ethernet over single-mode fiber

Figure 19
WS-X4448-GB-LX



WS-X4448-GB-SFP

- 48 ports
- 1000BASE-X (SFP)
- Cisco IOS Software Release 12.2(20)EW or later
- IEEE 802.3x flow control
- Bandwidth is allocated across six 8-port groups, providing 1 Gbps per port-group
- Enterprise and commercial: designed for server farms and switch-to-switch applications
- Metro Ethernet: designed for service providers to run point-to-point Gigabit Ethernet over single-mode fiber

Figure 20
WS-X4448-GB-SFP

WS-X4506-GB-T

- 6-port 10/100/1000 and 6-port SFP (any combination of up to 6 ports can be active at one time)
- 10/100/1000 RJ-45 PoE and 1000BASE-X (SFP)
- Cisco IOS Software Release 12.2(20)EWA
- PoE IEEE 802.3af and Cisco prestandard (RJ-45 only)
- Provides full line-rate Gigabit switching on all ports
- L2-4 Jumbo Frame Support (up to 9216 bytes)
- Designed to give customers the choice of RJ-45 with or without PoE and SFP without incurring extra costs
- Enterprise and commercial: high-performance desktop connectivity and server farms; designed to power IP phones, wireless base stations, video cameras, and other IEEE-compliant appliances
- Metro Ethernet: designed for service providers to run point-to-point Gigabit Ethernet over single-mode fiber

Figure 21
WS-X4506-GB-T

Gigabit Ethernet over Copper

The Cisco Catalyst 4500 Series offers a variety of gigabit-over-copper solutions for wiring closets and server farms, enabling high-density gigabit connectivity to the desktop and servers over Category 5 copper cabling. The line card options for the Cisco Catalyst 4500 Series (Table 1) include a 24- and 48-port 10/100/1000BASE-T module in both PoE and non-PoE versions. These modules provide wiring closet investment protection by allowing Fast Ethernet desktops to migrate to Gigabit Ethernet in the future without replacing the switch line cards.

WS-X4424-GB-RJ45

- 24 ports
- 10/100/1000 module (RJ-45)
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3x flow control
- Bandwidth is allocated across six 4-port groups, providing 1 Gbps per port group
- Enterprise and commercial: designed for Gigabit-to-the-desktop and server-farm applications

Figure 22
WS-X4424-GB-RJ45

WS-X4448-GB-RJ45

- 48 ports
- 10/100/1000 module (RJ-45)
- Cisco IOS Software Release 12.1(8a)EW or later
- IEEE 802.3x flow control
- Bandwidth is allocated across six 8-port groups, providing 1 Gbps per port group
- Enterprise and commercial: designed for Gigabit-to-the-desktop applications

Figure 23
WS-X4448-GB-RJ45

WS-X4548-GB-RJ45

- 48 ports
- 10/100/1000 module (RJ-45)
- Cisco IOS Software Release 12.1(19)EW or later
- IEEE 802.3x flow control
- Bandwidth is allocated across six 8-port groups, providing 1 Gbps per port group
- More power efficient and more cost effective than the WS-X4448-GB-RJ45
- Enterprise and commercial: designed for Gigabit-to-the-desktop

Figure 24
WS-X4548-GB-RJ45

Gigabit Ethernet over Copper with Power over Ethernet

WS-X4524-GB-RJ45V

- 24 ports
- 10/100/1000 (RJ-45)
- Cisco IOS Software Release 12.2(20)EW or later
- IEEE 802.3af and Cisco prestandard PoE, IEEE 802.3x flow control
- Bandwidth is allocated across six 4-port groups, providing 1 Gbps per port group
- Enterprise and commercial: designed to power IP phones, wireless base stations, video cameras, and other IEEE-compliant powered devices

Figure 25
WS-X4524-GB-RJ45V

WS-X4548-GB-RJ45V

- 48 ports
- 10/100/1000 (RJ-45)
- Cisco IOS Software Release 12.2(18)EW or later
- IEEE 802.3af and Cisco prestandard PoE, IEEE 802.3x flow control
- Bandwidth is allocated across six 8-port groups, providing 1 Gbps per port-group
- Enterprise and commercial: designed to power IP phones, wireless base stations, video cameras, and other IEEE-compliant powered devices

Figure 26
WS-X4548-GB-RJ45V

Specification Summary

Tables 1 through 6 summarize product specifications.

Table 1. Port Information for Line Cards

Line Card	Number of Ports	Port Speed	Port Type	Wire Rate	Cisco Catalyst 4500 Series Min/Max Ports		
					4503	4506/ 4507R	4510R
Fast Ethernet over Fiber Line Cards							
WS-X4248-FE-SFP	48	100BASE-X	SFP	Yes	48/96	48/240	48/384
WS-X4124-FX-MT	24	100BASE-FX (MT-RJ)	–	Yes	24/48	24/120	24/168
WS-X4148-FX-MT	48	100BASE-FX	MMF MT-RJ	Yes	48/96	48/240	48/384
WS-X4148-FE-LX-MT	48	100BASE-LX10	SMF MT-RJ	Yes	48/96	48/240	48/384
WS-X4148-FE-BD-LC	48	100BASE- BX10-D	SMF Single LC	Yes	48/96	48/240	48/384
Fast Ethernet over Copper Line Cards							
WS-X4124-RJ45	24	10/100	RJ-45	Yes	24/48	24/120	24/168
WS-X4148-RJ	48	10/100	RJ-45	Yes	48/96	48/240	48/384
WS-X4148-RJ21	48	10/100	RJ-21	Yes	48/96	48/240	48/384
WS-X4232-RJ-XX	32	10/100	RJ-45 Modular uplink slot	Yes	32/64	32/160	32/224
WS-U4504-FX-MT	4	100BASE-FX		Yes	–	–	–
WS-X4232-GB-RJ	32 + 2	10/100 1000BASE	32 x RJ-45 2 x GBIC	Yes	32/64 2/4	32/160 2/10	32/224 2/16
Fast Ethernet PoE Line Cards							
WS-X4148-RJ45V	48	10/100	RJ-45 Cisco prestandard PoE	Yes	48/96	48/240	48/384
WS-X4224-RJ45V	24	10/100	RJ-45 PoE IEEE 802.3af and Cisco prestandard	Yes	24/48	24/120	24/168

Line Card	Number of Ports	Port Speed	Port Type	Wire Rate	Cisco Catalyst 4500 Series Min/Max Ports		
					4503	4506/ 4507R	4510R
WS-X4248-RJ45V	48	10/100	RJ-45 PoE IEEE 802.3af and Cisco prestandard	Yes	48/96	48/240	48/384
WS-X4248-RJ21V	48	10/100	RJ-45 PoE IEEE 802.3af and Cisco prestandard	Yes	48/96	48/240	48/384
Gigabit Ethernet (GBIC or SFP) Line Cards							
WS-X4302-GB	2	1000BASE-X IEEE 802.3	GBIC	Yes	2/4	2/10	2/16
WS-X4306-GB	6	1000BASE-X	GBIC	Yes	6/12	6/30	6/42
WS-X4418-GB	18	1000BASE-X	GBIC	2 ports FULL 16 ports 4-to-1*	18/36	18/90	18/126
WS-X4448-GB-LX	48	1000BASE-LX	48 SFPs (included)	8-to-1*	48/96	48/240	48/384
WS-X4448-GB-SFP	48	1000BASE-X	SFP	8-to-1*	48/96	48/240	48/384
WS-X4506-GB-T	6 + 6	10/100/1000 1000BASE-X (SFP)	RJ-45 PoE IEEE 802.3af and Cisco prestandard	Yes	6/12	6/30	6/42
Gigabit Ethernet (Copper) Line Cards							
WS-X4424-GB-RJ45	24	10/100/1000	RJ-45	4-to-1*	24/48	24/120	24/168
WS-X4448-GB-RJ45	48	10/100/1000	RJ-45	8-to-1*	48/96	48/240	48/384
WS-X4548-GB-RJ45	48	10/100/1000	RJ-45	8-to-1*	48/96	48/240	48/384
Gigabit-over-Copper PoE Line Cards							
WS-X4524-GB-RJ45V	24	10/100/1000	RJ-45 PoE IEEE 802.3af and Cisco prestandard	4-to-1*	24/48	24/120	24/168
WS-X4548-GB-RJ45V	48	10/100/1000	RJ-45 PoE IEEE 802.3af and Cisco prestandard	8-to-1*	48/96	48/240	48/384

* The amount of oversubscription can be controlled by varying the number of ports used at 1000 Mbps. All ports can use Gigabit EtherChannel® or IEEE 802.3ad for high-speed interconnection applications. All oversubscribed ports use the standard IEEE 802.1x flow control (PAUSE frame) mechanism to control Gigabit Ethernet host traffic.

Table 2. GBIC and SFP Options

Interface Type	Name	Max Distance	Cable Type	Part Number
1000BASE-T	Category 5 twisted pair	100m	Category 5	• SFP: GLC-T • GBIC: WS-G5483
1000BASE-SX	Short wavelength	550m	Multimode fiber (MMF)	• SFP: GLC-SX-MM • GBIC: WS-G5484
1000BASE-LX	Long wavelength/long haul	10 km on SMF 5 km on MMF	SMF	• SFP: GLC-LH-SM • GBIC: WS-G5486
1000BASE-ZX	Extended distance	70 km to 100 km	SMF	• SFP: GLC-ZX-SM • GBIC: WS-G5487
CWDM	Coarse wavelength-division multiplexing	100 km	SMF	• SFP: CWDM-SFP-XXXX • GBIC: CWDM-GBIC-XXXX
DWDM	Dense wavelength-division multiplexing	–	–	GBIC only

Table 3. Fast Ethernet Optical Transmission Characteristics

Port Type	BER	Nominal Wavelength (NM)	Launch Power Max (dBm)	Launch Power Min (dBm)
100BASE-FX	2.5 x 10e-(10)	1270–1380	–14	–20
100BASE-LX10*	1 x 10e-(12)	1260–1360	–8	–15
100BASE-BX10-D**	1 x 10e-(12)	1480–1580	–8	–14

* Draft 1.3

** Draft 2.0

Table 4. Fast Ethernet Optical Reception Characteristics

Port Type	BER	Nominal Wavelength (NM)	Receive Sensitivity Max (dBm)	Receive Sensitivity Min (dBm)
100BASE-FX	2.5 x 10e-(10)	1270–1380	–14	–31
100BASE-LX10*	1 x 10e-(12)	1260–1360	–8	–25
100BASE-BX10-D**	1 x 10e-(12)	1260–1360	–8	–28.2

* Draft 1.3

** Draft 2.0

Table 5. Gigabit Ethernet Port Cabling Specifications

Port Type	Wavelength (Nanometer)	Fiber Type	Core Size (Micron)	Modal Bandwidth (MHz/km)	Cable Distance
Cisco 1000BASE-SX	850	MMF	62.5	160	722 ft (220m)
			62.5	200	902 ft (275m)
			50.0	400	1640 ft (500m)
			50.0	500	1804 ft (550m)
Cisco 1000BASE-LX	1300	MMF	62.5	500	1804 ft (550m)
			50.0	400	1804 ft (550m)
		SMF	50.0	500	1804 ft (550m)
			9/10		32,810 ft (10 km)
Cisco 1000BASE-ZX	1550	SMF	9/10	–	44–62 miles (70–100 km)

Table 6. Gigabit Ethernet Link Distance

Fiber Core	62.5um MMF	50um MMF	9/10um SMF
Fiber Modal Bandwidth	• 160/500 MHz-km • 200/500 MHz-km	• 400/400 MHz-km • 500/500 MHz-km	–
1000BASE-SX	• 220m • 275m	• 500m • 550m	–
1000BASE-LX/LH	• 550m • 550m	• 550m • 550m	10 km
1000BASE-ZX	–	–	70 to 100 km

Coarse Wavelength-Division Multiplexing (CWDM)	–	–	100 km

Product Specifications

Table 7 lists product specifications.

Table 7. Product Specifications

Feature	Description
Standards	• Gigabit Ethernet: IEEE 802.3z, IEEE 802.3x, IEEE 802.3ab • 1000BASE-X (GBIC), 1000BASE-SX, 1000BASE-LX/LH, 1000BASE-ZX, CWDM
EtherChannel Technology	• Gigabit EtherChannel: All 1000 Mbps ports • IEEE 802.3ad (Link Aggregation Control Protocol): All 1000 Mbps ports • Port Aggregation Protocol (PagP): Yes • Number of ports per tuple: 8 • EtherChannel and IEEE 802.3ad technology across line cards: Yes
Physical Dimensions	• Occupies one slot in the Cisco Catalyst 4500 Series platform • Dimensions (H x W x D): 1.2 x 14.25 x 10.75 in. (3.0 x 36.2 x 27.3 cm)
Environmental Conditions	• Operating temperature: 32° to 104°F (0° to 40°C) • Storage temperature: –40° to 167°F (–40° to 75°C) • Relative humidity: 10 to 90%, noncondensing • Operating altitude: –60 to 4000m
Safety Conditions	Fiber optic lasers: Class 1 laser products
Safety Certifications	• UL 1950 • EN 60950 • CSA-C22.2 no 950 • IEC 950
Electromagnetic Emissions Certifications	• FCC 15J Class A • VCCI Class A • CE Marking • EN 55022 Class A • EN 55024 Class A • CISPR 22 Class A • AS/NZ 3548 • NEBS Level 3 (GR-1089-CORE, GR-63-CORE) • ETSI ETS-300386-2

Ordering Information

To place an order, visit the Cisco Ordering Home Page. Table 8 gives ordering information.

Table 8. Ordering Information

Part Number (“=” indicates “spare”)	Product Name
WS-X4248-FE-SFP (=)	Cisco Catalyst 4500 Fast Ethernet Switching Module, 48-port 100BASE-X (SFP)

Part Number (“=” indicates “spare”)	Product Name
WS-X4124-FX-MT(=)	Cisco Catalyst 4500 Fast Ethernet Switching Module, 24-port 100BASE-FX (MT-RJ)
WS-X4148-FX-MT(=)	Cisco Catalyst 4500 Fast Ethernet Switching Module, 48-port 100BASE-FX MMF
WS-X4148-FE-LX-MT(=)	Cisco Catalyst 4500 Fast Ethernet Switching Module, 48-port 100BASE-LX10 SMF
WS-X4148-FE-BD-LC(=)	Cisco Catalyst 4500 Series 48-port 100BASE-BX10-D Fast Ethernet Line Card for single strand of SMF
WS-X4124-RJ45(=)	Cisco Catalyst 4500 10/100 Module, 24 ports (RJ-45)
WS-X4148-RJ(=)	Cisco Catalyst 4500 10/100 Module, 48 ports (RJ-45)
WS-X4148-RJ21(=)	Cisco Catalyst 4500 10/100 Module, 48-port telco (4 x RJ-21)
WS-X4148-RJ45V(=)	Cisco Catalyst 4500 Cisco prestandard 10/100, 48 ports (RJ-45)
WS-X4248-RJ21V(=)	Cisco Catalyst 4500 PoE IEEE 802.3af 10/100, 48 ports (RJ-21)
WS-X4224-RJ45V(=)	Cisco Catalyst 4500 PoE IEEE 802.3af 10/100, 24 ports (RJ-45)
WS-X4248-RJ45V(=)	Cisco Catalyst 4500 PoE IEEE 802.3af 10/100, 48 ports (RJ-45)
WS-X4232-GB-RJ(=)	Cisco Catalyst 4500 32-port 10/100 (RJ-45), 2-Gigabit Ethernet (GBIC) module
WS-X4232-RJ-XX(=)	Cisco Catalyst 4500 32-port 10/100 (RJ-45), plus modular uplink slot
WS-U4504-FX-MT(=)	Cisco Catalyst 4500 Fast Ethernet Uplink Daughter Card, 4-port 100BASE-FX (MT-RJ)
WS-X4506-GB-T(=)	Cisco Catalyst 4500 6-port 10/100/1000 RJ-45 PoE IEEE 802.3af and 1000BASE-X (SFP)
WS-X4302-GB(=)	Cisco Catalyst 4500 Gigabit Ethernet Module, 2 ports (GBIC)
WS-X4306-GB(=)	Cisco Catalyst 4500 Gigabit Ethernet Module, 6 ports (GBIC)
WS-X4418-GB(=)	Cisco Catalyst 4500 Gigabit Ethernet Module, server switching 18 ports (GBIC)
WS-X4448-GB-LX(=)	Cisco Catalyst 4500 48-port 1000BASE-LX (SFP)
WS-X4448-GB-SFP(=)	Catalyst 4500 Gigabit Ethernet Module, 48-port 1000X (SFP)
WS-X4424-GB-RJ45(=)	Cisco Catalyst 4500 24-port 10/100/1000 Module (RJ-45)
WS-X4448-GB-RJ45(=)	Cisco Catalyst 4500 48-port 10/100/1000 Module (RJ-45)
WS-X4548-GB-RJ45(=)	Cisco Catalyst 4500 Enhanced 48-port 10/100/1000 Module (RJ-45)
WS-X4524-GB-RJ45V(=)	Cisco Catalyst 4500 PoE IEEE 802.3af 10/100/1000, 24 ports (RJ-45)
WS-X4548-GB-RJ45V(=)	Cisco Catalyst 4500 PoE IEEE 802.3af 10/100/1000, 48 ports (RJ-45)

Service and Support

Cisco offers a wide range of services programs to accelerate customer success. These innovative services programs are delivered through a unique combination of people, processes, tools, and partners, resulting in high levels of customer satisfaction. Cisco services help you to protect your network investment, optimize network operations, and prepare the network for new applications to extend network intelligence and the power of your business. For more information about Cisco Services, see Cisco Technical Support Services or Cisco Advanced Services.

For More Information

For more information about the Cisco Catalyst 4500 Series line cards, visit www.cisco.com/en/US/products/hw/switches/ps4324/index.html or contact your local account representative.

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Pa/LW9337 10/05

Printed in USA

Data Sheet

Cisco Catalyst 4500 Series Switches

The Cisco Catalyst 4500 Series switches integrate resiliency for advanced control of converged networks.

Figure 1. Cisco Catalyst 4500 Series

OVERVIEW

The Cisco® Catalyst® 4500 Series offers nonblocking Layer 2–4 switching with integrated resiliency, further enhancing control of converged networks. Converged voice, video, and data networks with high availability help enable business resiliency for enterprises, small and medium-sized businesses (SMBs), and Metro Ethernet customers deploying Internet-based business applications.

The Cisco Catalyst 4500 Series includes four Catalyst chassis: the Catalyst 4510R (10 slots), the Catalyst 4507R (seven slots), Catalyst 4506 (six slots), and Catalyst 4503 (three slots). Integrated resiliency enhancements offered in the Catalyst 4500 Series include 1+1 supervisor-engine redundancy (Catalyst 4507R and 4510R), redundant fans, software-based fault tolerance, and 1+1 power-supply redundancy. Integrated resiliency in both hardware and software minimizes network downtime, helping to ensure workforce productivity, profitability, and customer success.

The Cisco Catalyst 4500 Series extends control to the network edge with intelligent network services, including sophisticated quality of service (QoS), predictable performance, advanced security, comprehensive management, and integrated resiliency. Offering compatibility with all Catalyst 4500 Series line cards and supervisor engines, the Catalyst 4500 Series reduces the cost of ownership by minimizing recurring operational expenses, improving return on investment (ROI).

CISCO CATALYST 4500 SERIES CHASSIS

The Cisco Catalyst 4500 Series offers four chassis options and four supervisor-engine options. It provides a common architecture that can scale up to 388 ports. The Cisco Catalyst 4507R and 4510R offer high availability in supporting 1+1 redundant supervisor engines with subsecond failover time. Using the same line cards and supervisor engines as the widely deployed Catalyst 4000 Series Switch, the Catalyst 4500 Series enhances the Cisco commitment to affordable enterprise and branch scalability. It provides a cost-effective, flexible network solution that scales to meet today's high-performance needs with investment protection (Table 1).

Table 1. Cisco Catalyst 4500 Series Chassis Features

Feature	Cisco Catalyst 4503 Chassis	Cisco Catalyst 4506 Chassis	Cisco Catalyst 4507R Chassis	Cisco Catalyst 4510R Chassis
Total Number of Slots	3	6	7	10
Supervisor-Engine Slots	1*	1*	2**	2**
Supervisor-Engine Redundancy	No	No	Yes (Supervisor II-Plus, II-Plus-10GE, IV, V, V-10GE)	Yes (Supervisor V and V-10GE)
Supervisor Engines Supported	• Supervisor II-Plus • Supervisor II-Plus-TS • Supervisor II-Plus-10GE • Supervisor IV • Supervisor V • Supervisor V-10GE	• Supervisor II-Plus • Supervisor IV • Supervisor II-Plus-10GE • Supervisor V • Supervisor V-10GE	• Supervisor II-Plus • Supervisor IV • Supervisor II-Plus-10GE • Supervisor V • Supervisor V-10GE	• Supervisor V • Supervisor V-10GE
Line-Card Slots	2	5	5**	8**
Number of Power-Supply Bays	2	2	2	2
AC Input Power	Yes	Yes	Yes	Yes
DC Input Power	Yes	Yes	Yes	Yes
Integrated Power over Ethernet	Yes	Yes	Yes	Yes
Minimum Number of Power Supplies	1	1	1	1
Number of Fan-Tray Bays	1	1	1	1
Location of 19 in. Rack Mount* **	Front	Front	Front	Front
Location of 23 in. Rack Mount	Front (option)	Front (option)	Front (option)	Front (option)

* Slot 1 is reserved for supervisor engine only; slots 2 and higher are reserved for line cards.

** Slots 1 and 2 are reserved for supervisor engines only in Cisco Catalyst 4507R and 4510R; slots 3 and higher are reserved for line cards.

*** Chassis can be mounted in racks and cabinets that meet ANSI/EIA-310-D and ETS 300 119-3.

Note: Supervisor-engine slots do not support switching line-card modules. Line-card slots do not support supervisor engines.

CONFIGURATION ALTERNATIVES

The Cisco Catalyst 4500 Series offers a powerful and flexible network solution that can be built with four supervisor-engine alternatives. Each provides a high-performance, centralized, shared-memory switch fabric, protecting your line-card investment by supporting the addition of optional higher-layer engines (Table 2).

Table 2. Cisco Catalyst 4500 Series Supervisor Engine Support and Performance

Feature	Catalyst 4500 Supervisor II-Plus-TS	Catalyst 4500 Supervisor II-Plus	Catalyst 4500 Supervisor II-Plus-10GE	Catalyst 4500 Supervisor IV	Catalyst 4500 Supervisor V	Catalyst 4500 Series Supervisor V-10GE
Cisco Catalyst 4503 Chassis	64 Gbps, 48 mpps	28 Gbps, 21 mpps	72 Gbps, 54 mpps	28 Gbps, 21 mpps	28 Gbps, 21 mpps	64 Gbps, 48 mpps
Cisco Catalyst 4506 Chassis	Not supported	64 Gbps, 48 mpps	108 Gbps, 81 mpps	64 Gbps, 48 mpps	64 Gbps, 48 mpps	100 Gbps, 75 mpps
Cisco Catalyst 4507R Chassis	Not supported	Supported, 64 Gbps, 48 mpps	108 Gbps, 81 mpps	Supported 64 Gbps, 48 mpps	68 Gbps, 51 mpps	100 Gbps, 75 mpps
Cisco Catalyst 4510R Chassis	Not supported	Not supported	Not supported	Not supported	96 Gbps, 72 mpps	136 Gbps, 102 mpps

The Cisco Catalyst 4500 Series has flexible interface types and port densities that allow network configurations to be mixed and matched to meet the specific needs of campus networks (Table 3).

Table 3. Cisco Catalyst 4500 Series Port Densities

Cisco Catalyst 4500 Series Switching Modules	Number of Interfaces Supported per Line Card	Cisco Catalyst 4503	Cisco Catalyst 4506	Cisco Catalyst 4507R	Cisco Catalyst 4510R
Switched 10/100 Fast Ethernet (RJ-45)	24, 32, or 48	96	240	240	384*
Switched 10/100 Fast Ethernet (RJ-45) with IEEE 802.3af Power over Ethernet (PoE)	24, 48	96	240	240	384*
Switched 10/100 Fast Ethernet (RJ-21) with or without IEEE 802.3af PoE	48	96	240	240	384*
Switched 100 FX Fast Ethernet (MT-RJ)	4**, 24, or 48	96	240	240	384*
Switched 100 LX-10 (MT-RJ) or 100 BX-D (LC) Fast Ethernet	48	96	240	240	384*
Switched 1000 Gigabit Ethernet (fiber)	2, 6, 18, or 48	104***	244	244	388*
Switched 10/100/1000BASE-T Gigabit Ethernet	24 or 48	108***	240	240	384*
Switched 10/100/1000BASE-T Gigabit Ethernet with IEEE 802.3af PoE	24 or 48	108***	240	240	384*
Switched 10,000 (10 Gigabit Ethernet)	2	2	2	2	2

* When using the Cisco Catalyst 4000/4500 Supervisor Engine V, 340 ports are supported. The Catalyst 4510R can support up to 388 ports with Catalyst 4500 Series Supervisor Engine V-10GE. When Catalyst 4000/4500 Supervisor Engine V is used in the Catalyst 4510R chassis, slot 10 (Flex-slot) supports a subset of line cards: 2-port Gigabit Interface Converter (GBIC) and Access Gateway Module This is because of the switching capacity of the Catalyst 4000/4500 Supervisor Engine V, and not a limitation of the Catalyst 4510R chassis. The Catalyst 4500 Series Supervisor Engine V-10GE allows slot 10 to accommodate any and all line cards.

** Four 100BASE-FX, multimode fiber (MMF) interfaces are supported through the uplink module using the Cisco Catalyst 32-port, 10/100, RJ-45 line card.

*** Cisco Catalyst 4500 Series Supervisor II-Plus-TS required for 104 1000BASE-X ports or 108 10/100/1000 ports.

CONFIGURATION FLEXIBILITY AND MODULAR SUPERIORITY

Cisco Catalyst 4500 Series modules can be mixed and matched to suit numerous LAN Access, data center, SMB, or branch-office deployments. The Cisco Catalyst 4500 Series supports the following switching modules, listed by part number:

- **WS-F4531**—Cisco Catalyst 4500 NetFlow Services Daughter Card
- **WS-X4248-FE-SFP**—Cisco Catalyst 4500 Fast Ethernet Switching Module, 48-port 100BASE-X (Optional SFP optics)
- **WS-X4148-FE-LX-MT**—Cisco Catalyst 4500 Fast Ethernet Switching Module, 48-port 100BASE-LX10 single-mode fiber (SMF) (MT-RJ)
- **WS-X4148-FE-BD-LC**—Cisco Catalyst 4500 Fast Ethernet Switching Module, 48-port 100BASE-BX-D SMF (LC)
- **WS-X4124-FX-MT**—Cisco Catalyst 4000 Fast Ethernet Switching Module, 24-port 100BASE-FX (MT-RJ)
- **WS-X4148-FX-MT**—Cisco Catalyst 4500 Fast Ethernet Switching Module, 48-port 100BASE-FX multimode fiber (MMF) (MT-RJ)
- **WS-X4124-RJ45**—Cisco Catalyst 4500 10/100 Module, 24-port (RJ-45)
- **WS-X4148-RJ**—Cisco Catalyst 4500 10/100 Module, 48-port (RJ-45)
- **WS-X4148-RJ21**—Cisco Catalyst 4500 10/100 Module, 48-port telco (4 x RJ-21)
- **WS-X4248-RJ21V**—Cisco Catalyst 4500 PoE 802.3af 10/100, 48-port (RJ-21)
- **WS-X4148-RJ45V**—Cisco Catalyst 4500 Cisco prestandard PoE 10/100, 48-port (RJ-45)
- **WS-X4224-RJ45V**—Cisco Catalyst 4500 PoE 803.3af 10/100, 24-port (RJ-45)
- **WS-X4248-RJ45V**—Cisco Catalyst 4500 PoE 802.3af 10/100, 48-port (RJ-45)
- **WS-X4232-GB-RJ**—Cisco Catalyst 4500 32-port 10/100 (RJ-45), 2-Gigabit Ethernet (GBIC) Module
- **WS-X4232-RJ-XX**—Cisco Catalyst 4500 32-port 10/100 (RJ-45), plus modular uplink slot
- **WS-U4504-FX-MT**—Cisco Catalyst 4500 Fast Ethernet Uplink Daughter Card for WS-X4232-RJ-XX, 4-port 100BASE-FX (MT-RJ)
- **WS-X4302-GB**—Cisco Catalyst 4500 Gigabit Ethernet Module, 2-port (GBIC)
- **WS-X4306-GB**—Cisco Catalyst 4500 Gigabit Ethernet Module, 6-port (GBIC)
- **WS-X4506-GB-T**—Cisco Catalyst 4500 Gigabit Ethernet Module, 6-port 10/100/1000 802.3af PoE or 1000BASE-X (SFP)
- **WS-X4418-GB**—Cisco Catalyst 4500 Gigabit Ethernet Module, server switching 18-port (GBIC)
- **WS-X4448-GB-LX**—Cisco Catalyst 4500 48-Port 1000BASE-LX (SFP optics included)
- **WS-X4448-GB-SFP**—Cisco Catalyst 4500 Gigabit Ethernet Module, 48-Port 1000BASE-X (Optional SFP optics)
- **WS-X4424-GB-RJ45**—Cisco Catalyst 4500 24-Port 10/100/1000 Module (RJ-45)
- **WS-X4448-GB-RJ45**—Cisco Catalyst 4500 48-Port 10/100/1000 Module (RJ-45)
- **WS-X4548-GB-RJ45**—Cisco Catalyst 4500 Enhanced 48-Port 10/100/1000 Module (RJ-45)
- **WS-X4524-GB-RJ45V**—Cisco Catalyst 4500 PoE 802.3af 10/100/1000, 24-port (RJ-45)
- **WS-X4548-GB-RJ45V**—Cisco Catalyst 4500 PoE 802.3af 10/100/1000, 48-port (RJ-45)
- **WS-G5483**—Cisco 1000BASE-T GBIC
- **WS-G5484**—Cisco 1000BASE-SX Short-Wavelength GBIC (multimode only)
- **WS-G5486**—Cisco 1000BASE-LX/LH Long-Haul GBIC (single-mode or multimode)
- **WS-G5487**—Cisco 1000BASE-ZX Extended-Reach GBIC (single-mode)
- **GLC-T**—1000BASE-T SFP
- **GLC-SC-MM**—GE SFP, LC connector SX transceiver
- **GLC-LH-SM—**GE SFP, LC connector LX/LH transceiver
- **GLC-ZX-SM**—1000BASE-ZX SFP
- **GLC-FE-100FX**—FE SFP, LC connector FX transceiver, 2 kilometers
- **GLC-FE-100LX**—FE SFP, LC connector LX10 transceiver, 10 kilometers
- **GLC-FE-100BX-D**—FE SFP, LC connector BX-D transceiver, 10 kilometers
- **GLC-FE-100BX-U**—FE SFP, LC connector BX-U transceiver, 10 kilometers
- **GLC-FE-100FX24**—24 units of GLC-FE-100FX

- **GLC-FE-100FX48**—48 units of GLC-FE-100FX
- **GLC-FE-100LX48**—48 units of GLC-FE-100LX
- **GLC-FE-100BX-D48**—48 units of GLC-FE-100BX-D
- Cisco CWDM GBIC solution
- Cisco CWDM SFP solution
- X2 Optic Support

Table 4 lists the minimum software requirements for the Cisco Catalyst supervisor engines, and Table 5 compares the Cisco Catalyst chassis.

Table 4. Cisco Catalyst Supervisor Engine Software Minimum Requirements

Specification	Minimum Software Requirement
Cisco Catalyst 4503 with Supervisor II-Plus-TS	Cisco IOS® Software Release 12.2(20)EWA or later
Cisco Catalyst 4503, 4506, and 4507R with Supervisor Engine II-Plus	Cisco IOS Software Release 12.1(19)EW or later
Cisco Catalyst 4503, 4506, and 4507R with Supervisor Engine II-Plus-10GE	Cisco IOS Software Release 12.2(25)SG or later
Cisco Catalyst 4503, 4506, and 4507R with Supervisor Engine IV	Cisco IOS Software Release 12.1(12c)EW or later
Cisco Catalyst 4503, 4506, 4507R, and 4510R with Supervisor Engine V	Cisco IOS Software Release 12.2(18)EW
Cisco Catalyst 4503, 4506, 4507R, and 4510R with Supervisor Engine V-10GE	Cisco IOS Software Release 12.2(25)EW

Table 5. Comparison Between Cisco Catalyst Chassis

Feature	Cisco Catalyst 4006	Cisco Catalyst 4503	Cisco Catalyst 4506	Cisco Catalyst 4507R	Cisco Catalyst 4510R
Power over Ethernet (PoE)	Yes—with external Power shelf	Yes—integrated	Yes—integrated	Yes—integrated	Yes—integrated
PoE per Line-Card Slot Maximum	400W	830W	830W	830W	830W
Power-Supply Redundancy	2 + 1	1 + 1	1 + 1	1 + 1	1 + 1
Supervisor-Engine Redundancy	No	No	No	Yes	Yes
Supported Line Cards	All Catalyst 4500 Series line cards	All Catalyst 4500 Series line cards	All Catalyst 4500 Series line cards	All Catalyst 4500 Series line cards	All Catalyst 4500 Series line cards
Supervisor Engines Supported	Supervisor engines II-Plus, IV, and V	Supervisor engines II-Plus, II-Plus-TS, II-Plus-10GE, IV, V, and V-10GE	Supervisor engines II-Plus, II-Plus-10GE, IV, V, and V-10GE	Supervisor engines II-Plus, II-Plus-10GE, IV, V, and V-10GE	Supervisor engines V and V-10GE
Internal Power Supplies Supported	400W AC	• 1000W AC • 1400W AC • 1300W ACV • 2800W ACV • 4200W ACV • 1400W DC	• 1000W AC • 1400W AC • 1300W ACV • 2800W ACV • 4200W ACV • 1400W DC	• 1000W AC • 1400W AC • 1300W ACV • 2800W ACV • 4200W ACV • 1400W DC	• 1400W AC* • 2800W ACV* • 4200W ACV* • 1400W DC

* The 1400W AC, 4200W AC and 2800W AC power supplies are required to support a fully loaded Cisco Catalyst 4510R. The 1000W AC and 1300W AC power supplies can be deployed in the Catalyst 4510R; however, power management is required.

Standard Network Protocols

- Ethernet
  - IEEE 802.3, 10BASE-T
- Fast Ethernet
  - IEEE 802.3u, 100BASE-TX
  - IEEE 802.3, 100BASE-FX
- Gigabit Ethernet
  - IEEE 802.3z
  - IEEE 802.3x
  - IEEE 802.3ab
- 1000BASE-X (GBIC)
  - 1000BASE-SX
  - 1000BASE-LX/LH
  - 1000BASE-ZX
- VLAN trunking and tagging
  - IEEE 802.1Q
  - IEEE 802.3ad
- Spanning Tree Protocol
  - IEEE 802.1D
  - IEEE 802.1w
  - IEEE 802.1s
- Security
  - IEEE 802.1x
- Power over Ethernet (PoE)
  - IEEE 802.3af

NETWORK MANAGEMENT

CiscoWorks Resource Manager Essentials, a component of CiscoWorks LAN Management Solution (LMS), provides the following benefits to the Cisco Catalyst 4500 Series:

- Builds and maintains an up-to-date hardware and software inventory
- Maintains an active archive and simplifies deployment of configuration changes to multiple devices
- Simplifies and accelerates software-image analysis and automates deployment
- Records and displays comprehensive reports of software, hardware, and configuration changes
- Highlights critical devices and their ability to respond
- Isolates network error conditions and suggests probable causes
- Network-topology discovery and display services
- VLAN provisioning and logical display representation
- Traffic monitoring and performance assessment
- End-station tracking with search utilities
- CiscoView graphical device management
- Network-topology integrity checking
- Cisco Discovery Protocol

- Cisco Virtual Trunking Protocol (VTP)
- Simple Network Management Protocol (SNMP) Version 1 (RFCs 1155-1157)
- SNMP Version 2c
- Cisco Workgroup MIB
- Ethernet MIB (RFC 1643)
- Ethernet Repeater MIB (RFC 1516)
- SNMP MIB II (RFC 1213)
- Remote Monitoring (RMON) (RFC 1757)
- RMON II (RFC 2021)
- Interface table (RFC 1573)
- Bridge MIB (RFC 1493)
- Switched Port Analyzer (SPAN)
- Enhanced Switched Port Analyzer (ESPAN)
- Port snooping and connection steering
- Standard Cisco IOS Software security capabilities: passwords and TACACS+
- Telnet, Trivial File Transfer Protocol (TFTP), and BOOTP for management access

PHYSICAL SPECIFICATIONS

Table 6. Physical Specifications of Cisco Catalyst 4500 Series Chassis

Specification	Cisco Catalyst 4503	Cisco Catalyst 4506	Cisco Catalyst 4507R	Cisco Catalyst 4510R
Dimensions (H x W x D)	12.25 x 17.31 x 12.50 in. (31.12 x 43.97 x 31.70 cm)	17.38 x 17.31 x 12.50 in. (44.13 x 43.97 x 31.70 cm)	19.19 x 17.31 x 12.50 in. (48.74 x 43.97 x 31.70 cm)	24.35 x 17.31 x 12.50 in. (61.84 x 43.97 x 31.70 cm)
Rack Units (RU)	7 RU	10 RU	11 RU	14 RU
Chassis Weight (with fan tray)	31.25 lb (14.18 kg)	40.50 lb (18.37 kg)	44.25 lb (20.07 kg)	51.50 lb (23.36 kg)
Mounting	19 and 23 in. rack compatible (19 in. rack and cable guide hardware included)	19 and 23 in. rack compatible (19 in. rack and cable guide hardware included)	19 and 23 in. rack compatible (19-in. rack and cable guide hardware included)	19 and 23 in. rack compatible (19 in. rack and cable guide hardware included)

POWER SUPPLY INDICATORS AND INTERFACES

- **Fan cooling:** Integrated in hot-insertion/hot-extraction unit
- **Good:** Green
- **Fail:** Red (faulty)
- SNMP MIB supported

Table 7. Cisco Catalyst 4500 Series Power Supply Specifications (Data-Only)

Power Supply	1000W AC	1400W AC	1400W DC Triple Input
Integrated PoE	No (data only)	No (data Only)	No (data only)
Input Current (rated)	12A at 100 VAC, 5A at 240 VAC	16A at 100 VAC, 7A at 240 VAC	• 2x –48 VDC at 15A • 1x –48 VDC at 12.5A

Power Supply	1000W AC	1400W AC	1400W DC Triple Input
Output Current (data)	• 12V at 83.4A • 3.3V at 12.2A	• 12V at 113.4A • 3.3V at 12.2A	• 12V at 1360W • 3.3V at 40W
Output Power Redundant Mode (data)	1000W + 40W	1360W + 40W	1400W + 40W
Output Power Combined Mode (data)	1667W	2473W	–
Heat Dissipation[1]	943 Btus per hour	1048 Btus per hour	1048 Btus per hour
Holdup Time	20 ms	20 ms	20ms
Hot Swappable	Yes	Yes	Yes

1 Calculations are based on one power supply operating at maximum output power.

Table 8. Cisco Catalyst 4500 Series Power Supply Specifications (Data and PoE)

Power Supply	1300W AC	2800W AC	4200W AC	1400W DC with PEM	2500W AC—Power Shelf
Integrated PoE	Yes (up to 800W)	Yes (up to 1400W)	Yes (up to 3855W)	Up to 7500W (minus the power consumed for data) when connected directly to a DC power plant or 2 external AC power shelves	2500W per power supply; 5000W per shelf (minus the power consumed for data)
IEEE 802.3af-Compliant PoE	Yes	Yes	Yes	Yes	Yes
Input Current (rated)	• 16A at 100 VAC • 7A at 240 VAC	16A at 200 VAC	• 2x 12A @ 100VAC Or • 2x 12A @ 200VAC	• 31A at –60 VDC (data only) • 180A at –48 VDC (PoE)	15A at 200 VAC
Output Current (data)	• 12V at 84.7A • 3.3V at 12.5A	• 12V at 113.3A • 3.3V at 12.1A	• 12V @ 115.3A • 3.3V @ 12.5A	• 12V at 120A • 3.3V at 10A	–52 VDC at 50A (total output per supply)
Output Current (PoE)	–50V at 16.7A	–50V at 28A	• -50V @ 77.1A (200V) • -50V @ 38A (100V)	140A at –48/–60 VDC	–52 VDC at 50A (total output per supply)
Output Power Redundant Mode (data)	1000W + 40W	1360W + 40W	1383W + 40W	1360W + 40W	Up to 1400W (through DC supply)
Output Power Redundant Mode (PoE)	800W maximum per power supply	1400W maximum per power supply	• 3855W (200V) • 1900W (100V)	Up to 7500W (minus the power consumed for data)	2500W per supply (minus the power consumed for data)
Output Power Combined Mode (data)	1667W	2473W	2766W	–	–
Output Power Combined Mode (PoE)	1333W	2333W	7710W (200V)	3800W (100V)	–
Heat Dissipation*	1568 Btus per hour	2387 Btus per hour	3580 BTU/hr	• Data only: 1591 Btus per hour • Data and voice: 2905 Btus per hour	1210 Btus per hour, per power supply

Power Supply	1300W AC	2800W AC	4200W AC	1400W DC with PEM	2500W AC—Power Shelf
Holdup Time	20 ms	20 ms	20 ms	4 ms	20 ms
Number of 802.3af Class 2 Power Devices Supported with 1 Power Supply (1+1)	102	178	• 384 PDs (200V) • 241 PDs (100V)	384**	384**
Number of 802.3af Class 0 and 3 Power Devices Supported with 1 Power Supply (1+1)	46	80	• 222 PDs (200V) • 109 PDs (100V)	384**	384**
Hot Swappable	Yes	Yes	Yes	Yes	Yes

* Calculations are based on one power supply operating at maximum output power.

** Measured when two AC power shelves are strapped together and contain 3x2500W AC power supplies.

Additional notes for Table 7 and 8:

1. Output power is per power supply, unless otherwise stated.
2. Heat dissipation numbers represent the power-conversion losses of the power supply in operation.
3. The number of power devices supported will depend on customer configuration.

FAN TRAYS

Each Cisco Catalyst 4500 Series chassis uses a single fan tray for cooling. All fan trays are composed of independent fans. If one fan fails, the system will continue to operate without a significant degradation in cooling. The system will detect and notify the user (through LED, command-line interface [CLI], and SNMP) that a fan has failed and the tray needs to be replaced.

FABRIC-REDUNDANCY MODULES (CISCO CATALYST 4507R AND 4510R ONLY)

The Cisco Catalyst 4500 Series redundancy scheme uses removable fabric-redundancy modules on the passive backplane to switch traffic to the active supervisor engine. There is one fabric-redundancy module per line card. Fabric-redundancy modules and redundant clocks ship standard with every Cisco Catalyst 4507R and 4510R chassis. Spare fabric-redundancy modules and clock modules are available for serviceability.

ENVIRONMENTAL CONDITIONS

The Cisco Catalyst 4500 Series requires the following conditions:

- **Operating temperature:** 32 to 104ºF (0 to 40ºC)
- **Storage temperature:** –40 to 167ºF (–40 to 75ºC)
- **Relative humidity:** 10 to 90 percent, noncondensing
- **Operating altitude:** –60 to 2000 meters (m)

REGULATORY STANDARDS COMPLIANCE

Table 9 lists the regulatory standards compliance of the Cisco Catalyst 4500 Series.

Table 9. Regulatory Standards Compliance

Specification	Standard
Regulatory Compliance	CE Marking
Safety	• UL 60950 • CAN/CSA-C22.2 No. 60950 • EN 60950 • IEC 60950 • TS 001 • AS/NZS 3260
EMC	• FCC Part 15 (CFR 47) Class A • ICES-003 Class A • EN55022 Class A • CISPR22 Class A • AS/NZS 3548 Class A • VCCI Class A • EN 55022 • EN 55024 • EN 61000-6-1 • EN 50082-1 • EN 61000-3-2 • EN 61000-3-3 • ETS 300 386
Industry EMC, Safety, and Environmental Standards	• NEBS Level 3 • ETS 300 019 Storage Class 1.1 • ETS 300 019 Transportation Class 2.3 • ETS 300 019 Stationary Use Class 3.1 • ETS 300 386
Telecom (E1)	• CTR 12/13 • CTR 4 • ACA TS016
Telecom (T1)	• FCC Part 68 • Canada CS-03 • JATE Green Book

ORDERING INFORMATION

Table 10 lists the ordering information for equipment that is commonly used with the Cisco Catalyst 4500 Series.

Table 10. Ordering Information

Product Number	Description
WS-C4503	Cisco Catalyst 4503 Switch (3-slot chassis), fan, no power supply
WS-C4506	Cisco Catalyst 4506 Switch (6-slot chassis), fan, no power supply
WS-C4507R	Cisco Catalyst 4507R Switch (7-slot chassis), fan, no power supply, redundant supervisor capable
WS-C4510R	Cisco Catalyst 4510R Switch (10-slot chassis), fan, no power supply; redundant supervisor capable
PWR-C45-1000AC	Cisco Catalyst 4500 Series 1000W AC power supply (data only)
PWR-C45-1400AC	Cisco Catalyst 4500 Series 1400W AC power supply (data only)
PWR-C45-1300ACV	Cisco Catalyst 4500 Series 1300W AC power supply (with integrated PoE)
PWR-C45-2800ACV	Cisco Catalyst 4500 Series 2800W AC power supply (with integrated PoE)
PWR-C45-4200ACV	Cisco Catalyst 4500 Series 4200W AC power supply (with integrated PoE)
PWR-C45-1400DC-P	Cisco Catalyst 4500 Series 1400W DC power supply with integrated power entry module (PEM)
PWR-C45-1400DC	Cisco Catalyst 4500 Series triple input 1400W DC power supply (data only)
WS-P4502-1PSU	Catalyst 4500 Series auxiliary power shelf (2-slot), including 1 PWR-4502
PWR-4502	Catalyst 4500 Series auxiliary power-shelf redundant power supply
WS-X4013+	Cisco Catalyst 4500 Series Supervisor Engine II-Plus
WS-X4013+TS	Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS, twelve 10/100/1000 PoE (RJ-45) and eight 1000-X SFP ports included on supervisor-engine faceplate
WS-X4013+10GE	Cisco Catalyst 4500 Series Supervisor Engine II-Plus-10GE
WS-X4515	Cisco Catalyst 4500 Supervisor Engine IV
WS-X4516	Cisco Catalyst 4000/4500 Supervisor Engine V
WS-X4516-10GE	Cisco Catalyst 4500 Series Supervisor Engine V-10GE
MEM-C4K-FLD64M	Compact Flash memory, 64-MB option
MEM-C4K-FLD128M	Compact Flash memory, 128-MB option

WARRANTY

The warranty for the Cisco Catalyst 4500 Series is 90 days; it includes hardware replacement with a 10 day turnaround from return to manufacturer authorization (RMA).

CISCO TECHNICAL SUPPORT SERVICES

Cisco Systems® offers Cisco Technical Support Services to help ensure that your Cisco products operate efficiently, remain highly available, and benefit from current system software to assist you in effectively managing your network service while controlling operational costs.

Cisco Technical Support Services provide significant benefits that go beyond what is offered under the Cisco warranty policy. Services available under a Cisco SMARTnet® service contract that are not covered under a warranty include the following:

- Latest software updates
- Rapid replacement of hardware in next-day, 4-hour, or 2-hour dispatch options
- Ongoing technical support through Cisco Technical Assistance Center (TAC)
- Registered access to Cisco.com

Tables 11 and 12 list the components and competitive differentiators of Cisco Technical Support Services.

Table 11. Technical Support Services—Components

Service Feature Overview	Benefits
Software Support	Offers maintenance and minor and major updates for licensed feature set. Downloading new maintenance releases, patches, or updates of Cisco IOS Software helps to enhance and extend the useful life of Cisco devices. Through major software updates it is possible to extend the life of equipment and maximize application technology investments by: • Increasing the performance of current functions • Adding new capability that, in many cases, requires no additional hardware investment • Enhancing network and application availability, reliability, and stability
TAC Support	With more than 1000 highly trained customer support engineers, 390 CCIE® certifications, and access to 13,000 research and development engineers, Cisco TAC complements your in-house staff with a high level of knowledge in voice, video, and data communications networking technology. Its sophisticated call-routing system quickly routes calls to the correct technology personnel. The Cisco TAC is available 24 hours a day, 365 days a year.
Cisco.com	This award-winning Website provides 24-hour access to an extensive collection of online product and technology information, interactive network-management and troubleshooting tools, and knowledge-transfer resources that can help customers reduce costs by increasing staff self-sufficiency and productivity.
Advance Hardware Replacement	Advance replacement and onsite field-engineer options supply fast access to replacement hardware and field resources for installing hardware, minimizing the risk of potential network downtime.

Table 12. Technical Support Services—Competitive Differentiators

Feature	Benefits
Worldwide Virtual Lab • TAC Training • Boot Camps • Tech Calls	This extensive lab of Cisco equipment and Cisco IOS Software releases provides an invaluable engineering resource and knowledge base for training, product information, and recreation and testing of selected network issues to help decrease time to resolution.
Tech Forums	Cisco is committed to providing customers the latest in technology support. These TAC training programs assist customers in case avoidance as well as provide knowledge transfer of Cisco networking expertise.
Cisco Live	A powerful suite of Internet-enabled tools with firewall-friendly features; these secure, encrypted Java applets can turn a simple phone call into an interactive collaboration session, allowing a customer and Cisco TAC support engineer to work together more effectively.
Global Logistics	Delivers award-winning, worldwide hardware-replacement support with 650 depots, covering 120 countries, at a US$2.3 billion investment in inventory, using 10,000 onsite field engineers.
Cisco IOS Software	Employs 100 discrete technologies with more than 2000 features. 400 new features are added each year. Cisco IOS Software is installed in more than 10 million devices and is running on more than 10,000 networks worldwide. It operates on the world's largest IPv6 and VoIP networks and in all major service provider networks worldwide.

FOR MORE INFORMATION

To learn more about how you can take advantage of Cisco Technical Support Services, talk to your Cisco representative or visit Cisco Technical Support Services at http://www.cisco.com/en/US/products/svcs/ps3034/ps2827/serv_group_home.html.

For additional information about the Cisco Catalyst 4500 Series, visit http://www.cisco.com/go/catalyst4500.

For additional information about Cisco products, contact:

- **United States and Canada:** 800 553-NETS (6387)
- **Europe:** 32 2 778 4242
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- http://www.cisco.com

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205389.BW_ETMG_CC_10.05

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	Costo ($)
Sala de equipos	36957.06
Sala de Control	4815.12
Equipos de Campo	59969.41
Costo de la Red	101741.59


MUNICIPALIDAD DE LIMA METROPOLITANA
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DEL
CENTRO HISTÓRICO
01

Ideal server for small businesses—built to last, easy to use and backed by IBM

IBM eserver® xSeries 100 Express Models

Highlights

- ***Reliable, pretested server backed by IBM service and support***
- ***Easy-to-use server for deployment out-of-the-box and simplified management***
- ***Entry-level, fixed-function server provides powerful functionality***

The IBM eserver® xSeries® 100 Express Models combine entry-level affordability with server-class features to address the needs of small businesses. With the x100, you can rely on a proven server that is easy to implement and deploy.

Powerful functionality designed to last

The x100 is designed to support your business as it grows.

- *New technologies such as DDR II memory, optional dual-core processors and PCI-Express help extend the life of the server*
- *Memory, hard disk drives and I/O can be added to expand your x100*
- *Pretested server components such as tape backup and uninterruptible power supplies provide upgrade options that will perform superbly*

Easy to use

Protect your investment with an easy-to-implement, complete server solution that features the following:

- *IBM ServerGuide™ makes system set-up and configuration hassle-free*
- *New models preloaded with Microsoft® Windows® Small Business Server 2003*

And IBM service and support provides peace of mind for small businesses without large IT staff.

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to buy direct or to locate an IBM reseller

xSeries 100 Express Models at a glance	
Form factor/height	Tower
Processor (L2 cache/CPU GHz/front-side bus MHz max)	Intel® Pentium® D (2x2MB/up to 3.0/800), Intel Pentium 4 (1MB or 2MB/up to 3.4/800), or Intel Celeron® (256KB/up to 2.66/533), all support Intel Extended Memory 64 Technology
Number of processors (std/max)	1/1
Memory (std/max)[1]	256MB or 512MB/8GB PC2-4200 DDR II via 4 DIMM slots
Expansion slots	2 PCI, 2 PCI-Express
Disk bays (total)	2 fixed Serial ATA (SATA)
Maximum internal storage (std/max)[1, 2]	80GB/500GB SATA
Network interface	Integrated Gigabit Ethernet
Power supply (std/max)	310W 1/1
RAID support	Optional
Systems management	IBM ServerGuide™
Operating systems supported	Windows Small Business Server 2003, Microsoft Windows Server 2003 Standard Edition/Enterprise Edition, Red Hat® Enterprise Linux®, SUSE LINUX Enterprise Server
Limited warranty[3]	1-year onsite limited warranty

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[1] Maximum internal hard disk and memory capacities may require the replacement of any standard hard drives and/or memory and the population of all hard disk bays and memory slots with the largest currently supported drives available. When referring to variable speed CD-ROMs, CD-Rs, CD-RWs and DVDs, actual playback speed will vary and is often less than the maximum possible.

[2] When referring to storage capacity, GB = 1,000,000,000 bytes. Accessible capacity is less.

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IBM Systems and Technology Group
Route 100
Somers, NY 10589

Produced in the United States of America
January 2006

XSD01233-USEN-01

Affordable, easy-to-use, single-socket server for Web and infrastructure solutions

IBM eserver® xSeries 306m

Highlights

- ***Facilitates ease of management, deployment and service***
- ***Offers resiliency and performance in an entry-level server***
- ***Utilizes next-generation technologies while maximizing and protecting your IT investment***

The IBM eserver® xSeries® 306m features easy management, deployment and service, providing outstanding performance and high availability at an entry-level price.

Simplified computing

The x306m is an easy-to-use server ideally suited for handling Web content-serving and edge-of-network applications. Integration of industry-standard software tools and remote systems management, monitoring and alerting capabilities combine to deliver stress-free systems management and high availability. These features include:

- *Simple-swap and hot-swap hard disk drives (HDDs) allow administrators tool-free entry without removing the system from the rack.*
- *Access true remote management capabilities with IPMI-compliant mini BMC and the optional Remote Supervisor Adapter II to save administrators time.*
- *Rack-optimized design and small form factor enable easier and more efficient systems management.*

Performance at entry-level pricing

Serial Attached SCSI (SAS) HDDs and PCI-Express ensure even greater integrated I/O performance and compatibility with future, next-generation devices for added long-term investment protection. Integrated Host RAID increases your resiliency and protects your critical data by performing incessant data backup. Designed to accommodate high-performance, single- and dual-core 64-bit processors, the x306m optimizes performance of your Web and network infrastructure.

xSeries 306m at a glance	
Form factor/height	22" depth/1U
Processor (L2 cache/CPU GHz/front-side bus MHz max)	Intel® Pentium® D (dual-core) (2MB or 4MB/up to 3.2/800) or single-core Intel Pentium 4 (1MB or 2MB/up to 3.6/800), both support Intel Extended Memory 64 Technology
Number of processors (std/max)	1/1
Memory (std/max)[1]	512MB/8GB PC4200 DDR II via 4 DIMM slots
Expansion slots	2 PCI-X 64-bit/100 MHz or 1 PCI-Express x8 and 1 PCI-X 64-bit/100 MHz
Disk bays total/hot-swap	Up to 2 simple swap Serial ATA, or 2 hot-swap Serial ATA or Serial Attached SCSI hard disk drives
Maximum internal storage[2]	500GB Serial ATA or 600GB Serial Attached SCSI
Network interface	Dual Gigabit Ethernet
Power supply (std/max)	350W 1/1
Hot-swap components	Serial ATA and Serial Attached SCSI hard disk drives
RAID support	Integrated ServeRAID™-8e, ServeRAID-7t for simple-swap Serial ATA hard disk drives
Systems management	Automatic Server Restart, IBM Director, ServerGuide™, Remote Deployment Manager, Wake on LAN®, optional Remote Supervisor Adapter II
Operating systems supported	Microsoft® Windows® Server™ 2003 Standard Edition/Enterprise Edition/Web Edition, Windows Small Business Server 2003, Red Hat® Enterprise Linux®, SUSE LINUX Enterprise Server, Windows 2000 Server and Advanced Server, Novell NetWare 6.5
Limited warranty[3]	1-year or 3-year onsite limited warranty

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1 Maximum internal hard disk and memory capacities may require the replacement of any standard hard drives and/or memory and the population of all hard disk bays and memory slots with the largest currently supported drives available. When referring to variable speed CD-ROMs, CD-Rs, CD-RWs and DVDs, actual playback speed will vary and is often less than the maximum possible.

2 When referring to storage capacity, GB = 1,000,000,000 bytes. Accessible capacity is less.

3 Visit **ibm.com**/pc/safecomputing periodically for the latest information on safe and effective computing. Warranty information: For a copy of applicable product warranties, write to: Warranty Information, P.O. Box 12195, RTP, NC 27709, Attn: Dept. JDJA-B203. IBM makes no representation or warranty regarding third-party products or services including those designated as ServerProven or ClusterProven. Telephone support may be subject to additional charges. For onsite labor, IBM will attempt to diagnose and resolve the problem remotely before sending a technician.

IBM Systems and Technology Group
Route 100
Somers, NY 10589

Produced in the United States of America
January 2006

XSD01231-USEN-02

Ultra-dense 1U, 2-way SMP server for performance computing

IBM *e*server® xSeries 336

Highlights

- ***New dual-core Intel® Xeon™ Processors deliver outstanding performance over a wide range of applications***
- ***Integrated system management processor and optional Remote Supervisor II SlimLine simplify administration with flexible levels of control***
- ***New high-availability features help improve system and application uptime***

Performance optimized for 32- and 64-bit environments

The IBM *e*server® xSeries® 336 offers superb performance for demanding Web and collaborative applications. Support for dual-core Intel Xeon Processors helps provide investment protection, better levels of performance and reliability. Intel Extended Memory 64 Technology provides outstanding performance by allowing operating systems and applications to physically address more memory. To take advantage of this, the x336 supports eight DIMM slots for a maximum of 16GB of DDR II memory.

Enjoy improved manageability

The x336 offers advanced features that help simplify systems management. An integrated service processor and optional Remote Service Adapter II SlimLine offer complete, in-band local and remote management capabilities. IBM Director software provides an easy-to-use interface to manage groups of systems together.

Take advantage of greater ease of use

Advanced usability features on the x336 include new, optional hot-swap redundant power supplies to help reduce unplanned downtime. Hot-swap and redundant fans keep components cool and enable easy fan replacement without taking the server offline. In the event of a problem, a drop-down light path diagnostics panel enables administrators to troubleshoot often without opening the server. And Remote Deployment Manager helps simplify server installation by allowing you to remotely deploy hundreds of servers from a single console.

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BUILT FOR MID-SIZED BUSINESS.

Select configurations of the x336 are part of the IBM Express Portfolio™, designed, developed and priced to meet the specific needs of mid-sized businesses. The IBM Express Portfolio of solutions is easy to acquire, install and manage. Express models and configurations vary by country.

xSeries 336 at a glance	
Form factor/height	Rack/1U
Processor (max)	Intel Xeon Processor up to 3.80 GHz/800 MHz front-side bus and Dual-Core Intel Xeon Processor 2.8 GHz
Number of processors (std/max)	1/2
Cache (max)	Up to 2MB L2 per processor core
Memory[1] (max)	512MB or 1GB/16GB PC2-3200 DDR II
Expansion slots	1 PCI-X (64-bit 100 MHz) and 1 PCI-X (64-bit 133 MHz) or 1 PCI-Express x8
Disk bays (total/hot-swap)	2/2 or 4/4
Maximum internal storage[1,2]	600GB Ultra320 SCSI or 500GB simple-swap SATA
Network interface	Integrated dual Gigabit Ethernet
Power supply (std/max)	585W 1/2
Hot-swap components	Power supply, fans, hard disk drives (select models)
RAID support	Integrated RAID-1, -1E, optional RAID-5
Systems management	Integrated Service Processor, Diagnostic LEDs, drop-down light path diagnostics panel, Automatic Server Restart, Alert Standard Format 2.0, optional Remote Supervisor Adapter II SlimLine, IBM Director, ServerGuide™ and optional Remote Deployment Manager
Operating systems supported	Microsoft® Windows® Server™ 2003, Windows 2000 Server/Advanced Server, Red Hat® Enterprise Linux® 3.0, SUSE LINUX Enterprise Server 8.0 and 9.0, TurboLinux Enterprise Server 8.0, Novell NetWare 6.5 and VMware™ ESX Server™ v2.5
Limited warranty[3]	3-year onsite limited warranty

For more information

World Wide Web

U.S.	**ibm.com**/eserver/xseries
Canada	**ibm.com**/ca/eserver/xseries

[1] Maximum internal hard disk and memory capacities may require the replacement of any standard hard drives and/or memory and the population of all hard disk bays and memory slots with the largest capacity supported drives available. When referring to variable speed CD-ROMs, CD-Rs, CD-RWs and DVDs, actual playback speed will vary and is often less than the maximum possible.

[2] GB and TB = 1,000,000,000 and 1,000,000,000,000 bytes, respectively, when referring to storage capacity. Accessible capacity is less.

[3] **Visit ibm.com**/pc/safecomputing **periodically for the latest information on safe and effective computing.** Warranty Information: For a copy of applicable product warranties, write to: Warranty Information, P.O. Box 12195, RTP, NC 27709, Attn: Dept. JDJA/B203. IBM makes no representation or warranty regarding third-party products or services, including those designated as ServerProven® or ClusterProven®. Telephone support may be subject to additional charges. For onsite labor, IBM will attempt to diagnose the problem remotely before sending a technician.

IBM®

XSD00361-USEN-04

Mission-critical performance for data-dense environments

IBM eserver® xSeries 346

Highlights

- ***New dual-core Intel® Xeon™ Processors deliver outstanding performance for a wide range of applications***
- ***Feature-rich, application-serving platform integrates standard, advanced functionality to help lower total solution cost***
- ***Easy deployment and management features provide enhanced flexibility and help control administrative costs***

New levels of performance and reliability

The IBM eserver® xSeries® 346 delivers mission-critical performance and reliability for data-dense environments. New support for dual-core Intel Xeon Processors helps provide investment protection, outstanding performance and reliability through:

- *Improved front-side bus speed with 800 MHz Intel Xeon Processors*
- *Up to 16GB DDR II memory improves performance*
- *Faster I/O speed with optional support for PCI-Express, a new standard for PCI adapters*

Innovation helps lower total costs

The x346 delivers many advanced features as standard—keeping more slots free and helping to control total solution cost. The dual-channel Ultra320 SCSI controller provides standard hard drive mirroring to help reduce system downtime. Integrated management and RAID-5 options maximize flexibility and expansion capability.

Easy to deploy and manage

Simplified management features help the x346 improve manageability and uptime. The standard Integrated Systems Management processor provides robust standards-based remote control at no extra cost. The optional Remote Supervisor Adapter II SlimLine helps expand systems management functionality by providing virtual control of remote servers. And the front, drop-down light path panel improves ease of use by letting administrators view diagnostics information.

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Select configurations of the x346 are part of the IBM Express Portfolio, designed, developed and priced to meet the specific needs of midsized businesses. The IBM Express Portfolio of solutions is easy to acquire, install and manage. Express models and configurations vary by country.

xSeries 346 at a glance	
Form factor	Rack/2U
Processor	Intel Xeon Processor up to 3.80 GHz/800 MHz front-side bus and Dual-Core Intel Xeon Processor 2.8 GHz
Number of processors (std/max)	1/2
Cache (max)	Up to 2MB L2 per processor core
Memory[1] (std/max)	512MB, 1GB or 2GB/16GB PC2-3200 DDRII via 8 DIMM slots
Expansion slots	4 PCI-X or 2 PCI-X and 2 PCI-Express
Disk bays (total/hot-swap)	6/6
Maximum internal storage[1,2]	1.8TB Ultra320 SCSI
Network interface	Integrated dual Gigabit Ethernet
Power supply (std/max)	1/2 625W
Hot-swap components	Power supply, fans and hard disk drives
RAID support	Integrated RAID-0/-1, optional RAID-5
Systems management	Automatic Server Restart; Predictive Failure Analysis® on hard disk drives, processors, VRMs, fans and memory; light path diagnostics with drop-down panel; integrated IPMI System Management Processor; IBM Director; Remote Supervisor Adapter II SlimLine and ServerGuide™
Operating systems supported	Microsoft® Windows® Server 2003, Windows 2000®/Advanced Server, Red Hat® Linux®, SUSE LINUX, Novell NetWare, VMware™ ESX Server™ 2.5
Limited warranty[3]	3-year onsite limited warranty
Internal tape (optional)	IBM 36/72GB DDS Generation5 Internal Tape Drive

For more information

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[3] **Visit ibm.com**/pc/safecomputing **periodically for the latest information on safe and effective computing.** Warranty Information: For a copy of applicable product warranties, write to: Warranty Information, P.O. Box 12195, RTP, NC 27709, Attn: Dept. JDJA/B203. IBM makes no representation or warranty regarding third-party products or services including those designated as ServerProven® or ClusterProven®. Telephone support may be subject to additional charges. For onsite labor, IBM will attempt to diagnose and resolve the problem remotely before sending a technician.

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[1] Maximum internal hard disk and memory capacities may require the replacement of any standard hard drives and/or memory and the population of all hard disk bays and memory slots with the largest currently supported drives available. When referring to variable speed CD-ROMs, CD-Rs, CD-RWs and DVDs, actual playback speed will vary and is often less than the maximum possible.

[2] When referring to storage capacity, GB = 1,000,000,000 bytes. Accessible capacity is less.

XSD00362-USEN-04

Magnum 14E and 14EH

100 Mb Fiber Media Converters

Features

- Two models, regular for wiring closets and Hardened for Industrial, AC and DC power
- Provides 100Mb Ethernet media conversion between twisted pair and fiber, FDX and HDX, with Link Pass-Through
- Supports IEEE 802.3u auto-negotiation on the RJ-45 port to enable an attached switch port to operate at 100Mb/s FDX for full fiber distance
- Available with fiber connectors for SC, ST, LC, or MTRJ types, multi-mode, single-mode, or 40km "long reach" single mode
- Metal enclosure. Panel mounting, DIN-Rail or Rack-mount tray option

All fiber media types, robust packaging, a selection of extended temperatures, choice of AC and DC power types, ease-of-use features, and energy efficiency are the primary features of the Magnum™ 100 Mb 14E and 14EH Media Converters.

The Magnum 14E regular-package units are for wiring closet environments and offer the choice of external AC power supplies for either 0° to 40°C or the more stressful industrial 0° to 50°C ambient temperature. A heavy duty metal case with convection cooling is featured.

The Magnum 14EH Hardened units feature a sealed metal case which is also used as a heat sink. No internal air flow is required for cooling, so the 14EH resists dust, dirt, moisture, smoke and insects, and is rated for above-the-ceiling "plenum" applications. Choices of models for use with external AC or internal DC power are available. Ambient temperature rating is up to –40°C to +75°C depending on the power source used. The 14EH is suitable for temperature un-controlled "outdoor" applications. Mounting options include stand-alone panel-mounting, DIN-rail, or rack-mount tray.

All models supports both full and half-duplex mode via auto-negotiation so that an attached auto-negotiating RJ-45 switch or hub port operates at its highest performance level. A manual AN/reg switch allows the user to select auto-negotiation, and then the Media Converter transmits applicable auto-negotiation Fast Link Pulses (FLPs) to the attached device at LINK-enable. Operation on both the copper port and the fiber port is at 100 Mb F/H transparent in any case, providing support for full length 100 Mb fiber media distances on all fiber types.

The Link Pass-Through feature is standard so that managed switches can "see through" the Media Converter for LINK indication that includes downstream cable segments. For the installer, a blinking LED on the fiber side shows fiber cable status.

The up-link switch on the TX port allows the unit to gracefully fit into any installation without crossover cables. All models come with two (2) sets of LED indicators, one set on the front for viewing convenience when the Media Converter is wall-mounted, and one LED set mounted in the end adjacent to the media ports for easy viewing when units are in a rack-mount tray. The Magnum 14E and 14EH Media Converters and other Magnum products are designed and manufactured in the USA and backed by a three-year warranty.

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Specifications

100Mb Media Converters Model 14E and 14EH

PERFORMANCE:
Data Rate: 100Mbps, FDX and HDX mode, transparent.
Auto-negotiation support on the RJ-45 port user selectable.
Link Pass-through feature is standard, see LINK indicators.

NETWORK STANDARDS:
Ethernet IEEE 802.3u; 100BASE-TX, 100BASE-FX
Physical-layer products, operate independent of all software.

OPERATING ENVIRONMENT:
Ambient Temperature - see Matrix below
Cold start down to -25°C
Storage temperature: -40° to 185°F (-40°to 85°C)
Ambient Relative Humidity: 5% - 95% (non-condensing)
Conformal coating (humidity protection) option, request quote.
Designed for NEBS compliance, including vibration, shock, and altitude.

PACKAGING:
Enclosure: Rugged sheet metal (steel)
Dimensions of units: 3.5 in H x 3.0 in W x 1.0 in D
(8.9 cm x 7.6 cm x 2.5 cm)
Weight: Media Converter Units: 4.6 oz (130g)
Power Supply - d, i: 5.8 oz (165g)
Power Supply - Hd, Hi: 3 oz (85g)
Cooling Method: Case used as a heat sink on "H"models

Metal panel mounting clips: included
DIN-Rail mounting option:
Model # DIN-RAIL MC2, illustrated here;
Rack-mount option: Model MC14-TRAY.
Depth: 6.0", Width 17",
Height 2.25"(15 cm D x 43cm W x 5.7cm H)

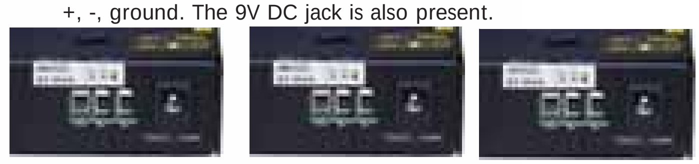
SWITCHES:
UP-LINK: Thumb-operated slide switch, converts RJ-45 TX port from a regular (= position) user segment port to a crossover (X position) up-link port for connection to a shared or switched hub.
AN /reg: Manually select auto-negotiation on RJ-45 port, or regular operation

CONNECTORS:
RJ-45, 100BASE-TX: shielded 8-Pin female, with up-link switch
"ff" selections of the "fiber flavor" (see table below):
"SC"= 100BASE-FX-SC: fiber optic multi-mode with SC type, 2 km
"ST"= 100BASE-FX-ST: fiber optic multi-mode with ST type, 2 km
"MTRJ"= 100BASE-FX-MTRJ: fiber optic multi-mode w/ MTRJ, 2 km
"SSC"= 100BASE-FX-SSC: fiber optic single-mode with SC, 20 km
"SSCL"= 100BASE-FX-SSCL: fib. op. sgl-m SC, "Long Reach" 40 km
"SST"= 100BASE-FX-SST: fiber optic single-mode with ST type , 20 km
"SLC"- 100BASE-FX-SLC: fiber optic sgl-m with LC-type , 15 km
For specialty connectors such as single strand,

LED INDICATORS (dual, front and end):
POWER: ON for power applied
LINK, per port: Steady ON when both attached cable segments are operational at the other end.
RX/ACT, per port: Activity, blinking when receiving packets.

POWER SUPPLY:
Power Input 9V DC jack is 2.5mm center +ve, with 6ft. DC cord
-d: external, 120V AC at 60Hz.
-i: external, 230V AC at 50hz, IEC receptacle built-in
-Hd: external, 100-240V AC at 50-60Hz (see footnote 1)
-Hi: external, 100-240V AC at 50-60Hz, includes power plug adapters for international receptacles (see footnote 2)

9V DC internal (range of 7.5 to 15V DC), built-in screw terminal block for +, -, ground. The 9V DC jack is also present.
24V DC internal (range of 18 to 36V DC) built-in screw terminal for +, -, ground. The 9V DC jack is also present.
-48V DC internal (range of 30 to 60V DC), built-in screw terminal block for +, -, ground. The 9V DC jack is also present.



Power Consumption, all models: 3 Watts typical. 3.5 Watts max.

AGENCY APPROVALS AND STANDARDS COMPLIANCE:
UL listed (UL60950), cUL, CE, Emissions meet FCC Part 15, Class A.
NEBS L3 and ETSI compliant
H model: IEEE 1613 Env. Std for Electric Power Substations
H model: NEMA TS-2 and TEES for traffic control equipment
H model: designed for UL 2043 above-the-ceiling installation
IEC61850 EMC and Operating Conditions Class C for Power Substations

WARRANTY:
Three years Made in USA

Footnotes:
1: External 9V 1A power supply, wall plug for North American receptacles, universal AC input at 50-60 Hz, 100-240V AC. *(Order model PSW-9V1A-Hd as a spare part.)*
2: External 9V 1A power supply, wall plug for international receptacles (via non-North American adapters), universal AC input at 50-60 Hz, 100-240V AC (*Order model PSW-9V1A-Hi as a spare part.)*

Model Typical Application	AMBIENT TEMPERATURE				POWER SOURCE				
	0° to 40°C (104°F)	0° to 50°C (122°F)	-40° to 55°C (131°F)	-40° to 75°C (167°F)	d, i AC external	Hd, Hi AC, external	9V DC, term.block	24V DC, term. block	-48V DC, term. block
14E-ff-d, 14E-ff-i Office	X				X				
14E-ff-Hd, 14E-ff-Hi Industrial		X				X			
14EH-ff-Hd, 14EH-ff-Hi Extended Temp. AC			X			X	X		
14EH-ff-9V DC Extended Temp. 9V DC				X			X		
14EH-ff-24V DC Extended Temp. 24V DC				X				X	
14EHR-ff-24V DC Includes DIN-Rail MC2				X				X	
14EH-ff-48V DC Extended Temp. -48V DC				X					X

"ff" in the model number corresponds to your selection of the desired fiber port connector; "ff" selection, see ***CONNECTORS*** *above.*

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Magnum ES42

Edge Switch with 100 Mb Fiber

Features

- Provides six switch ports, one or two of which may be 100 Mb fiber, others are 10/100 copper

- Three models for three application environments:
  - Office, wiring closet
  - Factory floor
  - Outdoors

- Includes Link-Loss-Learn (LLL) feature for use in self-healing LAN structures

- AC power for all models, Factory floor and Outdoor models also have integral DC terminal blocks and Power Alarm Relay

- Packaging and mounting options are similar to the popular Magnum 14-Series Converter Switches

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Office and Wiring Closet


Hardened for Factory Floor


Premium-rated for Outdoors

Magnum™ ES42 Edge Switches go out where the action is. In heavy-duty industrial applications, Ethernet LANs increasingly are used where small groups of nodes at the edge need to be connected into larger LAN structures. The Magnum ES42 , a versatile family of small Edge Switches, uses the latest networking technology and innovative product packaging features to serve edge-of-the-network applications.

The compact ES42 Edge Switch design delivers 6 Ethernet ports. The base models have either two 100 Mb fiber and 4 10/100 copper ports, or one fiber and five copper ports, or 6 copper ports. Fiber port choices cover all multi-mode and single-mode fiber connector types. Power input selections include AC or DC (or both) with 12V, 24V and 48V DC terminal block models for all industrial application environments.

Extending the range of the popular Magnum CS14 Converter Switches, the Magnum ES42 Edge Switches are similarly available in regular (office), Hardened (factory floor), and Premium-rated (outdoor) versions. This selection of models and fiber port types offers the best price-to-value ratio for each installation.

The Magnum Edge Switches include Link-Loss-Learn (LLL), enabling them to be used in self-healing and redundant LAN structures. The LLL feature causes ES42 Switches to sense Link Loss or standard STP / RSTP reconfiguration signals on designated ports, flush internal address buffers to permit a change in LAN packets flow, and pass the reconfiguration signal down the line to other products in the redundant network structure. Magnum Edge Switches, combined with managed switches running STP or RSTP or S-Ring, can often provide high availability redundant LANs at lower total cost than was previously possible.

The Magnum ES42H Hardened units are for factory floor applications. The ES42H models are built with high-grade components and are constructed using special thermal techniques (patent pending) and a metal case for heavy-duty industrial jobs. In addition to a Hardened AC power option and jack, terminals for internal DC power choices at 8 to 15V, 24V or -48V DC are included. Two terminals provide connections to monitor an internal power-sense relay. The ambient temperature rating is for industrial use. No internal air flow is required for cooling, so it resists dust, dirt, moisture, smoke and insects. Mounting choices include stand-alone panel-mounting, DIN-Rail, or rack-mount tray.

The Magnum ES42P Premium-rated units are for temperature uncontrolled sheltered applications, typically located outdoors. The ES42P models are built with premium-grade extended temperature components, and use similar thermal techniques (patent pending) as the ES42H Hardened units. In addition to a Premium-rated AC power option and jack, terminals the power-sense relay and for internal DC power choices at 8 to 15V, 24V or -48V DC are included. When used outdoors, the ES42P should be sheltered from the elements. Mounting choices include stand-alone panel-mounting, DIN-rail, or rack-mount tray.

All ES42 Edge Switch models come with two (2) sets of LED indicators. One set is on the front for viewing convenience when the unit is DIN-Rail or wall-mounted, and one LED set is mounted in the end adjacent to the ports for easy viewing when units are in a rack-mount tray. The Magnum ES42 Edge Switches and other Magnum products are designed and manufactured in the USA and backed by a three-year warranty.

PERFORMANCE:
Fiber ports: 100Mb, all types of connectors for m-m and single-mode
Fiber ports are factory set for FDX. RFQ for internal settings at HDX
RJ-45 Ports Data Rate: 10 / 100 Mbps, FDX and HDX modes.
Auto-negotiation and auto-cross MDI-MDIX on all RJ-45 ports
Occurs at LINK-enable. No cross-over cables required.
Non-blocking switching, 128KB packet buffer memory
Address buffer storage = 2K addresses
Address buffer age-out time = 300 seconds (see also LLL)

NETWORK STANDARDS:
Ethernet IEEE 802.3, IEEE 802.3u; IEEE 802.1p, 100BASE-TX, 10BASE-T, 100BASE-FX

LLL (Link-Loss-Learn)
SUPPORT: Factory default is Activated on Ports 1 and 2.
RFQ for other Activated Ports selections.
On Activated Ports, when a Loss of Link or reconfiguration BPDU for STP or RSTP is detected, the ES42 will flush internal address buffers and will pass the signal to other LLL Activated ports. This enables the ES42 to change the direction of packets flow and propagate the self-healing reconfiguration signal down the line.

OPERATING ENVIRONMENT:
Ambient Temperature ratings:
ES42: the ambient temperature rating is 0°C to 40°C.
ES42H: the ambient temperature rating is –25°C to 60°C long term per independent agency tests (UL), or –40°C to 85°C short term per IEC Type Tests
ES42P: the ambient temperature ratings of –40°C to 75°C long term per indep. agency tests (UL), or –50°C to 100°C short term per IEC Type Tests.
Storage temperature, all models: -40° to 185°F (-40°C to 85°C)
Cold start: ES42H model to -20°C, ES42P model to -40°C
Ambient Relative Humidity, all models: 5% - 95% (non-condensing)
Altitude, all models: -200 to 50,000 ft. (-60 to 15,000m)
Conformal coating (humidity protection) optional, request quote.

PACKAGING:
Enclosure: Robust sheet metal (steel)
Dimensions of units: 3.6 in H x 3.0 in W x 1.7 in D (9.2 cm x 7.6 cm x 4.3 cm)
Weight: ES42 Switch Units: 13 oz (370g)
Power Supply - d, i: 5.8 oz (165g)
Power Supply - Hd, Hi: 5.8 oz (165g)
Power Supply - Pd, Pi: 7.9 oz (225g)
Cooling Method: Convection on regular model, case used as a heat sink on H and P models.

MOUNTING FOR ES42 FAMILY OF SWITCH UNITS:
Metal panel mounting clips: included
DIN-Rail mounting option:
Model # DIN-RAIL MC2, illustrated here;
Rack-mount option: Model MC14-TRAY.
Depth: 6.0", Width 17",
Height 2.25"(15 cm D x 43cm W x 5.7cm H)

FIBER PORT CONNECTORS:
"ff" selections of the "fiber flavor" (see table below):
Use 2ff for a 2-fiber 4-copper model, 1ff for 1-fiber 5-copper model
No entry in the "ff" field designates a 6-copper port ES42 Switch.
"1SC" or "2SC"= 100BASE-FX-SC: FO multi-mode with SC type, 2 km
"1ST" or "2ST"= 100BASE-FX-ST: FO multi-mode with ST type, 2 km
"1MTRJ" or 2MTRJ" = 100BASE-FX-MTRJ: FO m-mode w/ MTRJ, 2 km
"1SSC" or "2SSC" = 100BASE-FX-SSC: FO single-mode with SC, 20 km
"1SSCL" or "2SSCL"= 100BASE-FX-SSCL: sgl-m SC Long Reach 40 km
"1SST" or "2SST" = 100BASE-FX-SST: FO single-mode with ST, 20 km
"1SLC" or "2SLC" = 100BASE-FX-SLC: FO sgl-m with LC-type, 15 km
For other fiber connector types, request quote.

RJ-45 PORT CONNECTORS:
RJ-45 with auto-cross, 100BASE-TX and 10BASE-T: shielded 8-Pin female. Supports shielded (STP) and unshielded (UTP) Cat. 3, 4, 5. For PoE Pass-through option on H and P models, request quote.

LED INDICATORS, dual, top front and in end:
POWER: ON for power applied
10/100 per RJ-45 port: Steady ON for 100 Mb, OFF for 10 Mb speed
LK/ACT per port: Steady ON for LINK with no traffic, blinking for Activity.
F/H per port in end: Steady ON for F/D mode, OFF for H/D mode.

POWER SUPPLIES for AC (EXTERNAL):
Power input DC jack (8 to 15V) is 2.5mm, center +ve, with 6ft. DC cord
Input: 95-125vac at 60 Hz for "-d" models, 215-240vac at 50 Hz for "-i" models that have IEC power connector in the ext power unit.
Input: 100-240vac at 47-63 Hz for "-Hd", "Hi" models, see footnote 1
Input: 100-240vac at 47-63 Hz for "-Pd", "Pi" models, see footnote 2

POWER INPUT OPTIONS for DC:
12V DC, internal (range of 8.0 to 15V DC), built-in screw terminal block for +, -, ground. The 12V DC jack is also present.
24V DC internal (range of 10 to 36V DC) built-in screw terminal for +, -, ground. The DC jack is also present, see footnote 3
-48V DC internal (range of 30 to 60V DC), built-in screw terminal block for +, -, ground. The 12V DC jack is also present.
Note1: the 12V DC jack can be used for dual source DC power input
Note2: internal DC power floats, user may ground + or – if desired.

POWER CONSUMPTION: all models: 7.0 Watts typical. 9 Watts max.

ALARM TERMINAL BLOCK, H and P Models, two screw terminals:
Internal 60VA relay contact: Open for Power Off, Closed for Power On

AGENCY APPROVALS AND STANDARDS COMPLIANCE:
UL listed (UL60950), cUL, CE, Emissions meet FCC Part 15, Class A. (see footnote 4)
NEBS L3 and ETSI compliant including vibration, shock, and altitude
H and P models: IEEE 1613 Env. Std for Electric Power Substations
IEC61850 EMC and Operating Conditions Class C for Power Substations
P model: NEMA TS-2 and TEES for traffic control equipment
P model: designed for above-the-ceiling (plenum) installation

WARRANTY:
Three years Made in USA

1: External 12V1A power supply, wall plug or power cord for North America AC receptacles. Temperature rating same as ES42H, see above. (North America: for spare, order Model PSH-12V1A-Hd. Intl: order Model PSH-12V1A-Hi with IEC plug).
2: External 12V1A power supply, rated for outdoor temperatures same as ES42P, see above. Universal AC input with recessed IEC plug. (North America: for spare, order Model PSP-12V1A-Pd, Intl: order Model PSP-12V1A-Pi with IEC plug).
3: For dual source 24V power input to DC jack, order Model DUAL-SRC-24KIT.
4: These products are tested are approved under IEC61850 for use in Class C sheltered locations where neither temperature nor humidity is controlled. The equipment needs to be protected against solar radiation, rainfall, other precipitations, and wind. UL has not approved these products for Annex-T outdoor use.

	AMBIENT TEMPERATURE			ALARM CONTACT	POWER INPUT						MOUNTING
Model No.	0° to 40°C	-25° to +60°C	-40° to +75°C	2 position term. block	d,i AC external	Hd, Hi AC external + 12V T.B.	Pd, Pi AC external + 12V T.B.	12V DC Term. Block	24V DC Term. Block	-48V DC Term. Block	Panel Clips included or DIN-Rail
ES42-ff-d, i	X				X						X
ES42H-ff-Hd, Hi		X		X		X		X			X
ES42H-ff-12VDC		X		X				X			X
ES42H-ff-24VDC		X		X					X		X
ES42HR-ff-24VDC		X		X					X		DIN-Rail
ES42H-ff-48VDC		X		X						X	X
ES42P-ff-Pd,Pi			X	X			X	X			X
ES42P-ff-12VDC			X	X				X			X
ES42P-ff-24VDC			X	X					X		X
ES42PR-ff-24VDC			X	X					X		DIN-Rail
ES42P-ff-48VDC			X	X						X	X

Office & wiring closet   Factory Floor   Outdoors

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RESUMEN DE ENTREVISTA E INSPECCIÓN OCULAR EN LA GERENCIA DE TRANSPORTE URBANO DE LA MUNICIPALIDAD DE LIMA

El principal operador del transporte urbano es la Gerencia de Transporte Urbano (GTU) de la Municipalidad de Lima, cuya Sede Central está ubicado en la Av. Nicolás de Piérola #617, a cargo del Ingeniero Víctor Pacahuala Velásquez. La parte de Ingeniería en el GTU está bajo la responsabilidad de la subgerencia de tránsito, que tiene a su cargo 3 áreas: el área de Semaforización, el área de Señalización y el área de Obras Civiles. El Área que ha sido consultada fue la de Semaforización, por estar relacionada al control del tránsito en la ciudad de Lima, y que está a cargo del Ingeniero Percy Sinchi. A continuación se resume la información que se logró conseguir en esta institución:

Orígenes

A principios de los años 90's, la Municipalidad de Lima decidió implementar un Sistema de Semaforización Centralizada para el Centro Histórico de Lima, con la finalidad de mejorar el tránsito en los alrededores, esto debido a la importancia de la zona, ya que es la sede de las principales instituciones gubernamentales, centrales financieros, y áreas o locales turísticos.

Área de Semaforización

Esta área esta dividido en dos grupos: el grupo de estudio y el grupo de mantenimiento.

El grupo de estudio se encarga de realizar el estudio de campo en las vías más transitadas, en las que se recoge información del tránsito tales como flujo de vehículos y volumen ocupado en las vías. Para ello se envía personal a las vías urbanas con el fin de recoger la información necesaria, esto se realiza manualmente y no a través de equipos de adquisición de datos. Esto tiene como finalidad determinar si una vía necesita de semaforización, y en caso tuviera semaforización, ajustar los planes de tiempo para esa intersección.

El grupo de mantenimiento es el encargado de velar por el funcionamiento de la semaforización en todo Lima Metropolitana. Además, a través de la Central de Tráfico, ofrece servicios de control y monitoreo de los semáforos en el Centro Histórico de Lima.

Sistema de Semaforización Centralizada

El Sistema de Semaforización cuenta con una Central de Tráfico, desde donde se controla el funcionamiento de los semáforos que existen en el Centro de Lima. Para ello los controladores de semáforos se interconectan con la Central de Tráfico de manera alámbrica, a través de los ductos de comunicación que existe en todo el Centro Histórico de Lima.

Control de Tráfico

El Centro Histórico de Lima cuenta con aproximadamente 120 semáforos, los cuales son controlados a través de cuatro controladores maestros. Este sistema se realizó en varias etapas, la primera etapa consiste en el control de 65 semáforos, cubriendo toda el área entre la Av. Abancay y Av. Tacna; y entre el Jr. Superunda y Av. Nicolás de Piérola. La segunda etapa consiste en el resto de semáforos, cubriendo toda el área entre la Av. Nicolás de Piérola y el Hotel Sheraton; y entre la Av. Gracilazo de la Vega y Av.

Alfonso Ugarte. La primera etapa fue implementada con controladores Americanos Eagle EPAC300, mientras que la segunda etapa fue implementada con controladores españoles.

Sistema de Comunicación

La comunicación entre los controladores locales (que están en las intersecciones) y el controlador maestro (ubicado en la central de Tráfico) se realiza mediante enlaces punto a punto, y transmitiendo la información en forma serial con señal modulada FSK, utilizando cables par (usados en las líneas telefónicas). Los controladores maestros además están conectados cada uno a una PC de escritorio, el cual a través de un software del fabricante del controlador se realiza el monitoreo del estado de cada uno de los controladores locales, además de realizar el ajuste de la configuración de tiempos en caso se requiera. La conexión entre la PC y el controlador maestro se realiza a través de un MODEM.

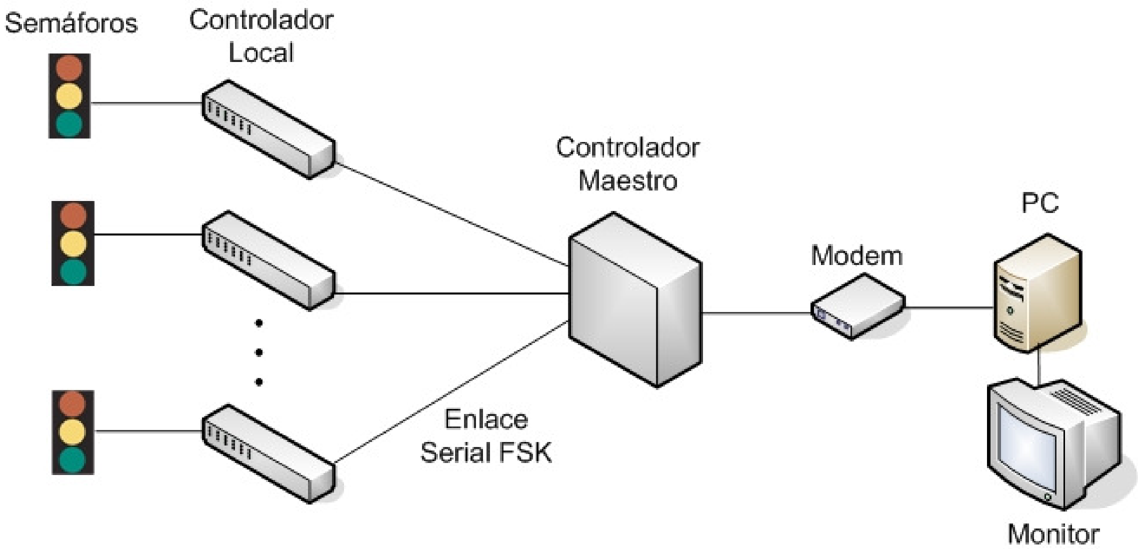

Figura 1. Diagrama del sistema actual de Semaforización

Desafortunadamente, de los cuatro controladores maestros que existían, solo queda uno funcionando, esto porque no se logro reparar los equipos averiados. Estos equipos necesitaban de la revisión del mismo fabricante, por lo que decidieron no realizarlo a falta de dinero. Además, debido a que quedo un controlador, se puede controlar solo 64 de los controladores locales, ya que el resto son de otro fabricante, y por lo tanto existe incompatibilidad.

Central de Tráfico

La Central de Tráfico se encuentra ubicado en la Av. Lampa #971. Este consiste de una sala de control, dos habitaciones distribuidas en el primer y segundo piso respectivamente para propósito de almacén y taller de reparación, y una habitación para la planta de energía del sistema de semaforización.

La salida hacia los ductos de comunicación que existen en el Centro Histórico de Lima se encuentra en la Sala de Control, a una altura de 1 metro. La ruta se da a través de dos tubos PVC de 3” empotradas en la pared.

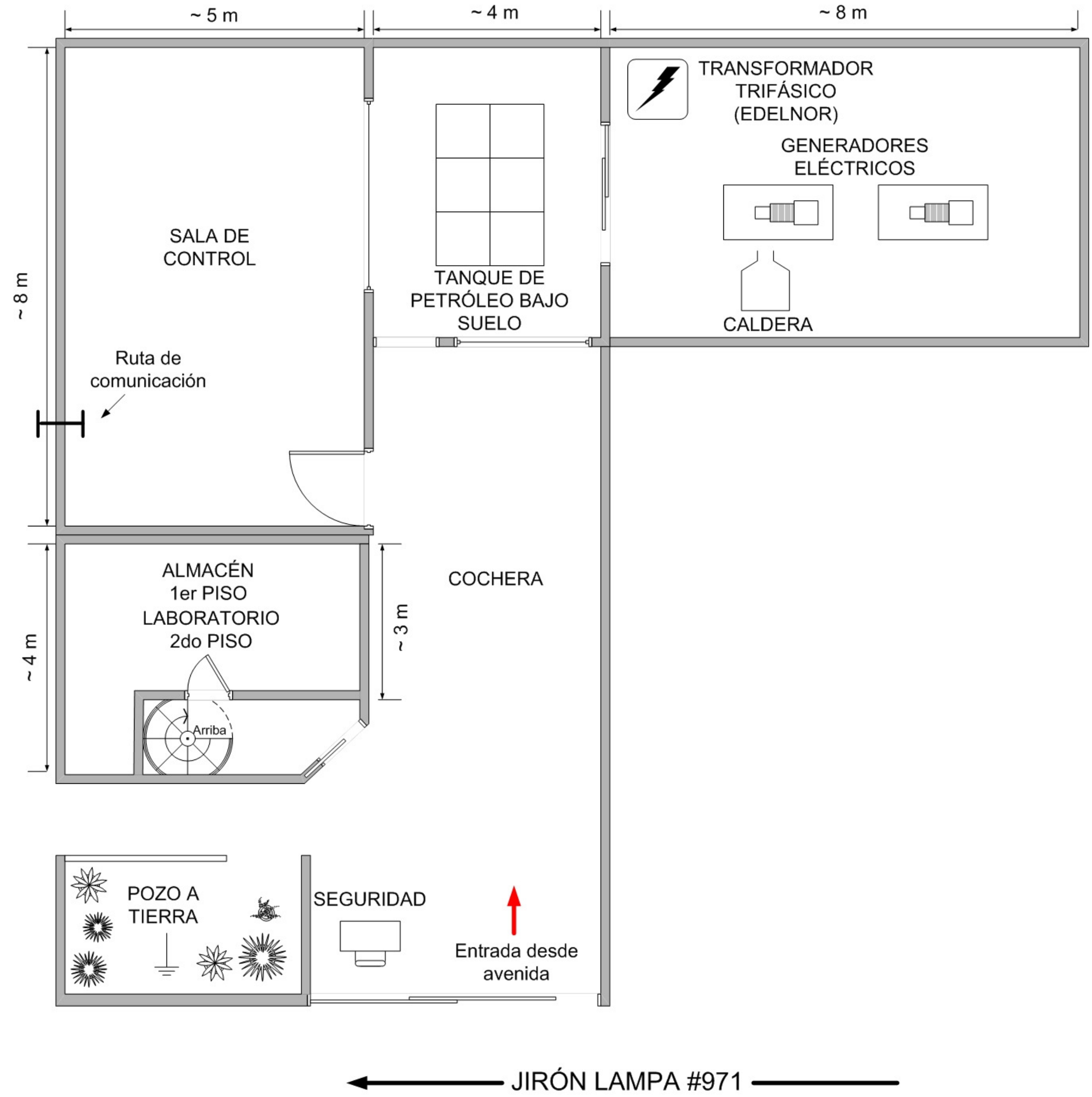

Figura 2. Bosquejo de la Central de Tráfico

Sistema Eléctrico

La Central de Tráfico cuenta con el debido sistema eléctrico para los equipos que se encuentran en el local y en las intersecciones que se controlan. Para ello se ha instalado un transformador eléctrico en la Central de Tráfico, propiedad de la empresa Edelnor y con capacidad de 500KVA, además de 2 generadores eléctricos de 150KVA/125KW que funcionan a través de petróleo, y cuyo tanque de almacenamiento se ubica fuera de la habitación de la planta de energía. Se tiene además un solo panel de distribución en la sala de control, con su respectiva protección.

Sistema de Protección

Los equipos de la Central de Tráfico se encuentran protegidos a través de un pozo a tierra instalada dentro del local.

A Joint Standard of AASHTO, ITE, and NEMA

NTCIP 1201:1996 v01.10

National Transportation Communications for ITS Protocol

Global Object Definitions

December 2001

Includes Jointly Approved NTCIP 1201 Amendment 1 v07

The Adobe® PDF copy of this NTCIP standard is available for a limited time through support from the U.S. DOT / Federal Highway Administration, whose assistance is gratefully acknowledged.

Published by

American Association of State Highway and Transportation Officials (AASHTO)
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Washington, D.C. 20001

Institute of Transportation Engineers (ITE)
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ACKNOWLEDGEMENTS

This publication was prepared by the NTCIP Global Object Working Group, which is a subdivision of the Joint Committee on the NTCIP. The Joint Committee is organized under a Memorandum of Understanding among the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the National Electrical Manufacturers Association (NEMA). The Joint Committee on the NTCIP consists of six representatives from each of the standards organizations, and provides guidance for NTCIP development.

At the time that this document was prepared, the following individuals were active members of the NTCIP Global Object Working Group:

- Bob De Roche
- Curtis Herrick
- Bud Kent
- Gary Meredith
- Nu Rosenbohm
- Ken Vaughn (Chair)

In addition to the many volunteer efforts, recognition is also given to those organizations who supported the efforts of the working groups by providing comments and funding for the standard, including:

- Eagle Traffic Control Systems
- Econolite Control Products, Inc.
- Gardner Systems
- Iteris, Inc.
- PB Farradyne Inc
- Peek Traffic Systems, Inc.

FOREWORD

This document uses only metric units.

The purpose of this publication is to identify and define the common object definitions that may be supported by devices that are NTCIP-compliant. This document is an NTCIP Data Dictionary Standard. Data Dictionary Standards provide formal definitions of data elements for use within NTCIP systems.

For more information about NTCIP standards, visit the NTCIP Web Site at http://www.ntcip.org. For a hardcopy summary of NTCIP information, contact the NTCIP Coordinator at the address below.

In preparation of this NTCIP document, input of users and other interested parties was sought and evaluated. Inquires, comments, and proposed or recommended revisions should be submitted to:

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Approvals

This document was separately balloted and approved by AASHTO, ITE, and NEMA after recommendation by the Joint Committee on the NTCIP. Each organization has approved this standard as the following standard type, as of the date:

AASHTO – Standard Specification; 1997
ITE – Software Standard; December 1997
NEMA – Standard; October 1996

History

From 1996 to 1999, this document was referenced as NEMA TS 3.4. However, to provide an organized numbering scheme for the NTCIP documents, this document is now referenced as NTCIP 1201. The technical specifications of NTCIP 1201 are identical to the former reference, except as noted in the development history below:

NEMA TS 3.4-1996 v96.01.7, April 7, 1997. October 1996 – Version 1.5 approved by NEMA. April 1997 – Version 1.7 published by NEMA with editorial corrections. October 1996 – Accepted as a Recommended Standard by the Joint Committee on the NTCIP. Approved by AASHTO in 1997 and approved by ITE in December 1997.

NEMA TS 3.4 Amendment 1 v98.01.07. October 1998 – Version 98.01.05 accepted as a Recommended Amendment by the Joint Committee on the NTCIP, and edited v01.07 referred for balloting and approval by NTCIP Standards Bulletin B0032 in May 1999. Approved by AASHTO in October 1999, approved by ITE in January 2001, and approved by NEMA in December 1999.

NTCIP 1201:1996 [assigned version 01.08]. August 1999 – Assigned NTCIP 1201 document number in NTCIP Standards Bulletin B0038. August 2000 – Joint NTCIP Standards Publication cover used over TS 3.4 contents.

NTCIP 1201:1996 v01.10, December 2001. January 2002 – Formatted for printing: incorporated Amendment 1 v07 into text; updated title page date and version number; modified and reorganized front matter to conform to NTCIP 8002. Most references to TS 3 standard designations were changed to equivalent NTCIP standard numbers.

INTRODUCTION

This publication provides definitions of data elements for use with various transportation devices. The data is defined using the Simple Network Management Protocol (SNMP) object-type format as defined in RFC 1212 and the defined NTCIP format defined in NTCIP 8004. This data would typically be exchanged using one of the NTCIP 1103 recognized Application Layers (e.g., SNMP).

This standard defines requirements that are applicable to all NTCIP environments and it also contains optional and conditional clauses that are applicable to specific environments for which they are intended.

The following keywords apply to this document: AASHTO, ITE, NEMA, NTCIP, global, data, data dictionary, object.

In 1992, the NEMA 3-TS Transportation Management Systems and Associated Control Devices Section began the effort to develop the NTCIP. The Transportation Section's purpose was to respond to user needs to include standardized systems communication in the NEMA TS 2 standard, *Traffic Controller Assemblies*. Under the guidance of the Federal Highway Administration's NTCIP Steering Group, the NEMA effort was expanded to include the development of communications standards for all transportation field devices that could be used in an Intelligent Transportation Systems (ITS) network.

In September 1996, an agreement was reached among NEMA, ITE, and AASHTO to jointly develop, approve, and maintain NTCIP Standards. In late 1998, the Global Object Working Group was tasked with the effort to update the Global Object Definitions document. The first meeting of this working group was held in January 1999.

The first version of this document was published as NEMA TS 3.4-1996; however, in 1997, both AASHTO and ITE adopted the standard. Thus, in order to provide an organized numbering scheme and to reflect the joint approval of AASHTO, ITE, and NEMA, the updated document is now numbered NTCIP 1201. The reformatted version was developed to reflect lessons learned and to add new features from the approved amendment.

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Joint AASHTO, ITE, and NEMA
NTCIP Management Information Base and Data Dictionary
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The information in this publication was considered technically sound by the consensus of persons engaged in the development and approval of the document at the time it was developed. Consensus does not necessarily mean that there is unanimous agreement among every person participating in the development of this document.

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CONTENTS

Section 1
GENERAL

1.1 SCOPE

The messaging between Transportation Management and field devices is accomplished by using the NTCIP Application Layer services to convey requests to access or modify values stored in a given device; these values are referred to as objects. The purpose of this publication is to identify and define these objects definitions that may be supported by multiple device types (e.g., actuated signal controllers and variable message signs). The grouping of objects for a given device type is performed in the device-type-specific object definition standard.

1.2 REFERENCES

For approved revisions, contact:

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National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209-3801

For proposed revisions, which are under discussion by the relevant NTCIP Working Group, and recommended revisions of the Joint Committee on the NTCIP, visit the web at http://www.ntcip.org.

The following standards (normative references) contain provisions which, through reference in this text, constitute provisions of this Standard. Other documents and standards (other references) are referenced in these documents, which might provide a complete understanding of the entire protocol and the relations between all parts of the protocol. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standard listed below.

1.2.1 Normative References

ANSI
11 West 42nd Street, 13th Floor
New York, NY 10036

ISO/IEC 8824-1:1995 *Information Technology—Abstract Syntax Notation One (ASN.1): Specification of Basic Notation*

ISO/IEC 8824-2:1995 *Information Technology—Abstract Syntax Notation One (ASN.1): Information Object Specification*

DDN Network Information Center
14200 Park Meadow Drive
Suite 200
Chantilly, VA 22021

Electronic copies of RFC documents may be obtained using "anonymous FTP" to the host <nic.ddn.mil> or <ds.internic.net>. Printed copies are available from: (800) 365-3642 or (703) 802-4535.

RFC 1155 *Structure and Identification of Management Information for TCP/IP-based Internets*. K. McCloghrie; M. Rose; 05/10/1990

RFC 1212 *Concise MIB Definitions*. K. McCloghrie; M. Rose; 03/26/1991

1.2.2 Other References

National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209

NEMA TS 2-1992 *Traffic Controller Assemblies*

NTCIP 1101:1996 *National Transportation Communications for ITS Protocol – Simple Transportation Management Framework*

NTCIP 2001:1996 *National Transportation Communications for ITS Protocol - Class B Profile*

ANSI
11 West 42nd Street, 13th Floor
New York, New York 10036
(212) 642-4900

ISO/IEC 8824-3:1995 *Information Technology—Abstract Syntax Notation One (ASN.1): Constraint Specification*

ISO/IEC 8824-4:1995 *Information Technology—Abstract Syntax Notation One (ASN.1): Parameterization of ASN.1 Specifications*

ISO/IEC 8825-1:1995 *Information Technology—ASN.1 Encoding Rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER).*

DDN Network Information Center
14200 Park Meadow Drive
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Chantilly, VA 22021

RFC 1213 *Management Information Base for Network Management of TCP/IP-based Internets:* MIB-II. K. McCloghrie; M. Rose; CP/IP-base

RFC 1157 *A Simple Network Management Protocol (SNMP)*. M. Schoffstall; M. Feder; J. Davin; J. Case; 05/10/1990

1.3 TERMS

Conformance level: Each of the defined Profiles have one or more layers specifying the protocols that must be implemented in a device to correspond to a particular level of NTCIP support.

Profile: Refers to a set of protocols, each of which operates independently on one of the seven (7) OSI Layers, if this layer is utilized. Different protocols are utilized at the same layer within different profiles.

1.4 ABBREVIATIONS

The abbreviations used in this standard publication are defined as follows:

CRC—Cyclic Redundancy Check; polynomial algorithm performed on a specified range of data resulting in a 16 or 32 bit value.

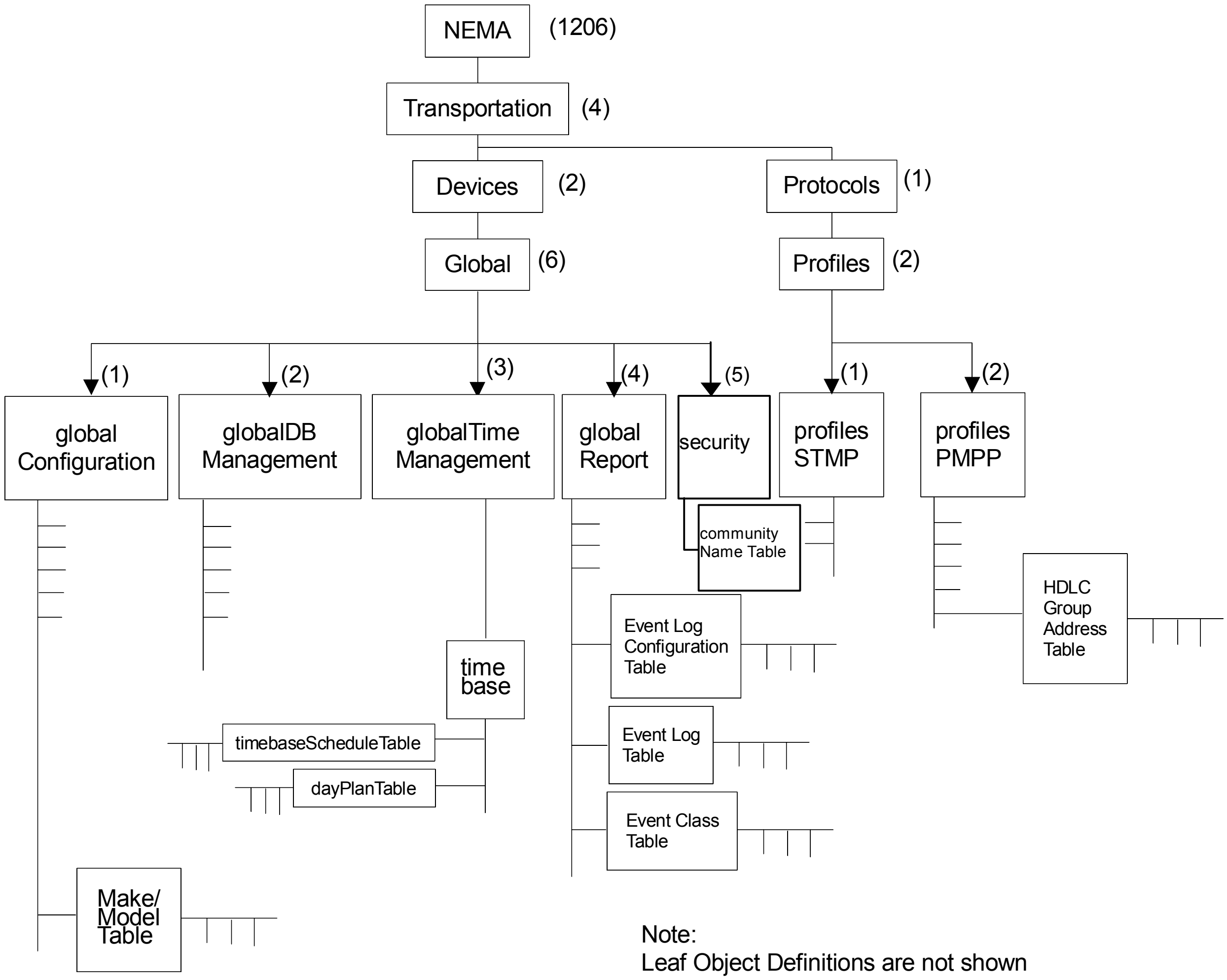
MIB—Management Information Base; a collection of objects defined using Abstract Syntax Notation One (ASN.1) that can be accessed via a network management protocol.

NVT-ASCII—Network Virtual Terminal – American Standard Code for Information Interchange as defined in RFC 854.

PMPP—Point-to-MultiPoint Protocol, a new protocol under development that will enable the standardized, simultaneous communications between multiple devices on the same communications line/channel.

STMP—Simple Transportation Management Protocol, part of the newly developed NEMA standard called Simple Transportation Management Framework (STMF) that used the well known Simple Network Management Protocol (SNMP) besides the STMP.

1.5 OBJECT TREE



Note:
Leaf Object Definitions are not shown

Section 2
OBJECT DEFINITIONS

This section defines those objects which are expected to be used by different device types such as actuated traffic signal controllers, variable message signs, ramp meter controllers. The objects are defined in OJBECT-TYPE macro defined in RFC 1212, laid out in ASN.1 format as defined in ISO/IEC 8824-1, ISO/IEC 8824-2, ISO/IEC 8824-3, and ISO/IEC 8824-4. The OBJECT-TYPE macro used in this document is defined in RFC 1212. The text provided from Clause 2.1 through the end of the section (except the clause headings) constitutes the NEMA Standard Global MIB.

The clauses below present the objects in lexigraphical order of their OBJECT IDENTIFIERS which correspond to their physical location within the global naming tree. All of the objects defined in this document reside under the "global" node of the global naming tree. To aid in object management, the “global” node has been subdivided into logical categories, each defined by a node under the "global" node. The individual objects are then located under the appropriate node.

Nodes should not be confused with conformance groups, which are defined in Section 3. A conformance group is a logical grouping of objects which is used for conformance statements. While conformance groups will frequently correspond to the nodal structure, a conformance group may contain objects which are not lexigraphically ordered. For example, a schedule conformance group may contain both "global" and "asc" specific objects.

Text preceded by a double hyphen in the MIB definitions represent normative text for this standard.

2.1 NTCIP OBJECTS

```
--NTCIP OBJECTS
GLOBAL DEFINITIONS ::= BEGIN

--For the purpose of this section, the following OBJECT IDENTIFIERS are used:
IMPORTS
    OBJECT-TYPE
    FROM RFC-1212
    transportation
    FROM NEMA_SMI
    devices, protocols, profiles
    FROM TMIB
    Opaque, Counter
    FROM RFC1155-SMI

    global OBJECT IDENTIFIER ::= { devices 6 }
```

2.2 GLOBAL CONFIGURATION NODE

```
globalConfiguration OBJECT IDENTIFIER
::= { global 1 }
--This node is an identifier used to group all objects for support of configuration functions
-- that are common to most device types.
```


2.2.1 Global Set ID Parameter

```
globalSetIDParameter OBJECT-TYPE
    SYNTAX      INTEGER (0..65535)
    ACCESS      read-only
    STATUS      optional
    DESCRIPTION "Specifies a relatively unique ID for all user-changeable parameters of the particular
    device-type currently implemented in the device.  Often this ID is calculated using a CRC algorithm."
    ::= { globalConfiguration 1 }
```

2.2.2 Maximum Modules Parameter

```
globalMaxModules   OBJECT-TYPE
    SYNTAX      INTEGER (0..255)
    ACCESS      read-only
    STATUS      mandatory
    DESCRIPTION
    "The number of rows that are listed in the Global Module Table."
    ::= { globalConfiguration 2 }
```

2.2.3 Module Table

```
globalModuleTable   OBJECT-TYPE
    SYNTAX      SEQUENCE OF ModuleEntry
    ACCESS      not-accessible
    STATUS      mandatory
    DESCRIPTION
    " A table containing information regarding manufacturer of software and hardware and the associated
    module models and version numbers as well as an indicator if the module is hardware or software
    related. The number of rows in this table shall equal the value of the globalMaxModule object."
    ::= { globalConfiguration 3 }

moduleEntry OBJECT-TYPE
    SYNTAX      ModuleTableEntry
    ACCESS      not-accessible
    STATUS      mandatory
    DESCRIPTION
    "This object defines an entry in the module table"
    INDEX { moduleNumber }
    ::= { globalmoduleTable 1 }

ModuleTableEntry ::= SEQUENCE {
    moduleNumber            INTEGER,
    moduleDeviceNode        OBJECT IDENTIFIER,
    moduleMake              OCTET STRING,
    moduleModel             OCTET STRING,
    moduleVersion           OCTET STRING,
    moduleType              INTEGER }
```

2.2.3.1 Module Number Parameter

```
moduleNumber OBJECT-TYPE
    SYNTAX      INTEGER (1..255)
    ACCESS      read-only
    STATUS      mandatory
    DESCRIPTION
```



```
    "This object contains the row number (1..255) within this table for the associated module."
    ::= { moduleTableEntry 1 }
```

2.2.3.2 Module Device Node Parameter

```
moduleDeviceNode   OBJECT-TYPE
    SYNTAX     OBJECT IDENTIFIER
    ACCESS     read-only
    STATUS     mandatory
    DESCRIPTION
    "This object contains the device node number of the device-type."
    ::= { moduleTableEntry 2 }
```

2.2.3.3 Module Make Parameter

```
moduleMake   OBJECT-TYPE
    SYNTAX     OCTET STRING
    ACCESS     read-only
    STATUS     mandatory
    DESCRIPTION
    "This object specifies the manufacturer of the associated module.  A null-string shall be transmitted if
    this object has no entry."
    ::= { moduleTableEntry 3 )
```

2.2.3.4 Module Model Parameter

```
moduleModel  OBJECT-TYPE
    SYNTAX     OCTET STRING
    ACCESS     read-only
    STATUS     mandatory
    DESCRIPTION
    "This object specifies the model number (hardware) or firmware reference (software) of the
    associated module.  A null-string shall be transmitted if this object has no entry."
    ::= { moduleTableEntry 4 }
```

2.2.3.5 Module Version Parameter

```
moduleVersion OBJECT-TYPE
    SYNTAX     OCTET STRING
    ACCESS     read-only
    STATUS     mandatory
    DESCRIPTION
    "This object specifies the version of the associated module.  A null-string shall be transmitted if this
    object has no entry."
    ::= { moduleTableEntry 5 )
```

2.2.3.6 Module Type Parameter

```
moduleType  OBJECT-TYPE
    SYNTAX     INTEGER {
                       other (1),
                       hardware (2),
                       software (3) }
    ACCESS     read-only
    STATUS     mandatory
    DESCRIPTION
```

"This object specifies if the associated module is a hardware or software module."
::= { moduleTableEntry 6 }

2.3 GLOBAL DATABASE MANAGEMENT NODE

globalDBManagement OBJECT IDENTIFIER
::= { global 2 }

-- This node is an identifier used to group all objects for support of database
-- functions that are common to most device types.

2.3.1 Database Creation Transaction

```
dbCreateTransaction   OBJECT-TYPE
SYNTAX          INTEGER {       normal (1),
                                transaction (2),
                                verify (3),
                                done (6)
}
ACCESS          read-write
STATUS          mandatory
```

DESCRIPTION:
"This object provides transaction control for device configuration. The transaction mode changes the behavior of the agent to force buffering of database objects until all related database objects have been modified. In the normal mode, SET operations to database objects may be stored in a device's database immediately with no regard to whether other changes will be made. In the transaction mode, SET operations to database objects are buffered until a verify state performs a consistency check. When the consistency check completes, the device automatically transitions to the done state where a normal or transaction command can be issued.

A database object is a user provided piece of setup information that is necessary for the proper operation of a device. It is static in nature in that the agent would never change it without direction from the management station. For example, a parameter that defines a default mode of operation would be a database object. A parameter that indicates the current state of the device would not be a database object.

The states and commands are defined as:

NORMAL: SET operations behave as normal SNMP SETs and can have an immediate effect on the value of any database objects used by the device. This is the default state of this object.

The only command that may be written to dbCreateTransaction while in this state is TRANSACTION. Any other values written to this object in this state shall result in an error response of 'badValue'.

TRANSACTION: SET operations of database objects are buffered by the agent device for later consistency checks. Standard SYNTAX checking takes place at the time of the SET operation. A transaction may consist of multiple SET operations over multiple frames.

The only commands that can be written to dbCreateTransaction while in this state are VERIFY and NORMAL. A VERIFY command will change the state to VERIFY. If a NORMAL command is received, all buffered data is discarded and the state is returned to NORMAL. Any other values written to this object when in this state shall result in an error response of 'badValue'.

VERIFY: Specific database objects are checked for consistency. When consistency checks are complete the device will automatically advance to the DONE state.

The state of dbCreateTransaction cannot be changed when in the VERIFY state. Any other values written to this object in this state shall result in an error response of 'badValue'.

The consistency check analyzes certain critical objects 'in context' and treats them as an interrelated whole rather than separate non-related data items. The consistency check rules are not defined in this standard. They are device and implementation specific. Where applicable, the consistency check rules are defined in application specific object definition standards. A specific implementation may add additional checks beyond those defined in the standards. As a simplified example of a consistency check, consider the following. Two objects are defined to specify the month and the day-of-month of an event. Valid values for day-of-month would normally be 1 to 31, but in the context of month 9 (September), only the values 1 to 30 are correct.

DONE: This state is entered automatically once consistency checks have completed in the VERIFY mode. The value of dbVerifyStatus and dbVerifyError indicate whether the consistency check found any errors.

Only two valid values can be written to dbCreateTransaction in this state: NORMAL and TRANSACTION. Any other values written to this object in this state shall result in an error response of 'badValue'.

If a NORMAL command is issued and dbVerifyStatus indicates doneWithNoError, the buffered data is transferred to the device memory and the state is returned to NORMAL. If a NORMAL command is issued and dbVerifyStatus indicates something other than doneWithError then the buffered data is discarded and the state is returned to NORMAL.

If a TRANSACTION command is issued, regardless of dbVerifyStatus, no action takes place (the buffered data is not changed) and the TRANSACTION state is re-entered.

		COMMANDED STATE			
		transaction	*verify*	*normal*	*done*
CURRENT STATE	normal	transaction (1)	normal (2)	normal (2)	normal (2)
	transaction	transaction (2)	verify (3)	normal (4)	transaction (2)
	verify (7)	verify (2)	verify(2)	verify (2)	verify (2)
	done (8)	transaction (5)	done(2)	normal (6)	done (2)

Operational procedures and error responses:

(1) Once a copy of all database objects is placed in a buffer the state is changed to transaction and error response indicates noError. If the operation fails, the state remains the same and error response indicates genErr.
(2) No action takes place, the state remains the same, but response indicates badValue.
(3) The state is changed to verify, a consistency check is started, and response indicates noError.
(4). The buffered copy of all database objects is discarded, the state is changed to normal, and response indicates noError.

(5) The buffered copy of all database objects is not changed or reloaded, the state is changed to transaction, and response indicates noError.
(6) If dbVerifyStatus indicates doneWithNoError, then the copy of all database objects is transferred to memory, the state is changed to normal and response indicates noError. If dbVerifyStatus indicates doneWithError then the buffered data is discarded, the state is changed to NORMAL, and response indicates noError.
(7) The state will automatically change to done when the consistency check completes.
(8) dbVerifyStatus and dbVerifyError are only valid in this state."

::= { globalDBManagement 1 }

2.3.2 Database Error Type Parameter

```
dbErrorType OBJECT-TYPE
SYNTAXINTEGER { tooBig (1),
                noSuchName (2),
                badValue (3),
                readOnly (4),
                genError (5),
                updateError (6),
                noError (7) }
ACCESS      read-only
STATUS      deprecated
DESCRIPTION:
"This object returns the current error status of the transaction.  The value of this
object is only valid when the dbCreateTransaction object is in the Done or Error state."
::= { globalDBManagement 2 }
```

2.3.3 Database Error ID Parameter

```
dbErrorID  OBJECT-TYPE
SYNTAX        OBJECT IDENTIFIER
ACCESS        read-only
STATUS        deprecated
DESCRIPTION
"This object contains the object identifier of the first object in the transaction buffer that caused an error
while dbCreateTransaction object was in the Verifying or Updating state.  The value of this object is only
valid when the dbCreateTransaction object is in the Error state.  It is undefined when the
dbCreateTransaction object is in other states."
::= { globalDBManagement 3 }
```

2.3.4 Database Transaction ID Parameter

```
dbTransactionID  OBJECT-TYPE
SYNTAX      INTEGER (0..255)
ACCESS      read-write
STATUS      deprecated
DESCRIPTION
"This object contains the transaction ID value that is to be contained in all SET operation writes while the
dbCreateTransaction object is not in the Normal state.  During transaction operations every SET
command shall begin with a write to this object with the current value of this object.  If a SET operation is
performed without writing to this object, or with a value that does not match the current value, then an
error response of 'genError' shall be returned.  This mechanism is used to determine that the same
```


management station that started the transaction is performing the SET operations that are being buffered or modifying the state of dbCreateTransaction."
::= { globalDBManagement 4 }

2.3.5 Database Make ID Parameter

dbMakeID OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS deprecated
DESCRIPTION
"This object is used to create unique transaction ID's for management stations to use when starting transactions using the dbCreateTransaction object. This object will be incremented by one every time it is read, so that different values will be returned for each read. Management stations wishing to start a transaction should first read the dbCreateTransaction object to verify that it is in the Normal state. If so then the management shall GET dbMakeID to obtain a transaction ID to use, then SET dbCreateTransaction to startCmd and dbTransactionID to the value just received. If the response to the SET operation is 'noError' then the management station has started a transaction. If the response to the SET operation is 'genError' then the management station should read the dbCreateTransaction and dbTransactionID objects to ensure that the error was not due to a communications retry. If the dbCreateTransaction is in the Transaction state, and the dbTransactionID is the same value returned by the read of this object, then the management station is the owner of the transaction. If the dbTransactionID does not match the value originally returned by this object, then the management station is not the owner of the transaction and must wait until the dbCreateTransaction object returns to the Normal state before attempting to start the transaction."
::= { globalDBManagement 5 }

2.3.6 Database Verify Status Parameter

dbVerifyStatus OBJECT-TYPE
SYNTAX INTEGER { notDone (0),
doneWithError (1),
doneWithNoError (2) }
ACCESS read-only
STATUS mandatory
DESCRIPTION
"This object indicates the current status of verify (consistency checking) processing. The value of this object is only valid when the dbCreateTransaction object is in the Verify or Done state. If read during any other state, the value of this object is not valid but no error will be indicated."
::= { globalDBManagement 6 }

2.3.7 Database Verify Error Parameter

dbVerifyError OBJECT-TYPE
SYNTAX OCTET STRING (SIZE (0..255))
ACCESS read-only
STATUS mandatory
DESCRIPTION
"This object contains a textual description of or a reference to an error that was found by the verify (consistency checking) processing. The value of this object is only valid when the dbCreateTransaction object is in the Done state and the dbVerifyStatus object is in the doneWithError state. If read during any other state, the value of this object is not valid but no error will be indicated."
::= { globalDBManagement 7 }

2.4 GLOBAL TIME MANAGEMENT NODE

globalTimeManagement OBJECT IDENTIFIER
::= { global 3 }

-- This node is an identifier used to organize all objects for support of time-related
-- functions that are common to most device types.

2.4.1 Global Time Parameter

globalTime OBJECT-TYPE
SYNTAX Counter
ACCESS read-write
STATUS mandatory
DESCRIPTION: "The current time in seconds since the epoch of 00:00:00 (midnight) January 1, 1970 UTC (a.k.a. Zulu)."
::= { globalTimeManagement 1 }

2.4.2 Global Daylight Savings Parameter

globalDaylightSaving OBJECT-TYPE
SYNTAX INTEGER { other (1),
disableDST (2),
enableUSDST (3) }
ACCESS read-write
STATUS mandatory
DESCRIPTION: "This object specifies if the Daylight Savings Time (DST) is enabled, disabled or some other form of daylight savings time is active.
disableDST - DST clock adjustments shall NOT occur.
enableUSDST - DST clock adjustments shall occur. In accordance with USA practice, DST shall begin the first Sunday in April and shall end the last Sunday on October. All changes of time occur at 2:00AM."
REFERENCE
"NEMA TS 2 Clause 3.8.2"
::= { globalTimeManagement 2 }

2.4.3 TimeBase Event Scheduler Node

timebase OBJECT IDENTIFIER
::= { globalTimeManagement 3 }

-- This node is an identifier used to organize the main objects for event scheduling.
-- Device type-specific objects (tables) pointed to are defined within the appropriate MIB.

2.4.3.1 Maximum Number of Time Base Schedule Entries Parameter

maxTimeBaseScheduleEntries OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"The value of this object specifies the maximum number of different entries supported by the device as shown by the number of rows in the timeBaseScheduleTable."
::= { timebase 1 }

2.4.3.2 Time Base Schedule Table

```
timeBaseScheduleTable   OBJECT-TYPE
SYNTAX          SEQUENCE OF TimeBaseScheduleEntry
ACCESS          not-accessible
STATUS          mandatory
DESCRIPTION
"A table containing the time base schedule parameters for the device.  The number of rows in this table
might be equal but is not allowed to exceed the value of the maxTimeBaseScheduleEntries object.  The
table references the appropriate day plan for the device.  The plan is determined by comparing the
current month (MONTH), day of week (DOW) and date of month (DOM) to the appropriate fields. The
settings for MONTH, DOW and DOM are connected with a logical AND.  In order to determine which
timebased event to select, determine the event which has the most specific date specified.  Select the
more specific event based on their MONTH settings; if the same, select the most specific DOM; if that is
still the same, select the most specific DOW;  if that's still the same, the first occurrence within the time
base event table shall be selected. "More specific" means the least number of bits set within an object.
All entries in Time Base Schedule Table are expressed in local time and date."
::= { timebase 2 }

timeBaseScheduleEntry   OBJECT-TYPE
SYNTAX          TimeBaseScheduleEntry
ACCESS          not-accessible
STATUS          mandatory
DESCRIPTION
"Event Parameters for the time based schedule programming of the device."
INDEX   { timeBaseScheduleNumber }
::= { timeBaseScheduleTable 1 }

TimeBaseScheduleEntry ::= SEQUENCE {
                timeBaseScheduleNumber          INTEGER,
                timeBaseScheduleMonth           INTEGER,
                timeBaseScheduleDay             INTEGER,
                timeBaseScheduleDate            INTEGER,
                timeBaseScheduleDayPlan         INTEGER
```

2.4.3.2.1 Time Base Schedule Number Parameter

```
timeBaseScheduleNumber   OBJECT-TYPE
SYNTAX          INTEGER (1..65535 )
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"The time base schedule number for objects in this row.  The value of this object shall not exceed the
value of the maxTimeBaseScheduleEntries object.  The activation of a scheduled entry shall occur
whenever allowed by all other objects within this table."
::= { timeBaseScheduleEntry 1 }
```

2.4.3.2.2 Time Base Schedule Month of Year Parameter

```
timeBaseScheduleMonth   OBJECT-TYPE
SYNTAX          INTEGER (0..65535)
ACCESS          read-write
STATUS          mandatory
DESCRIPTION
"The Month(s) of the Year that the schedule entry shall be allowed.  Each bit represents a specific month.
If the bit is set to one (1), then the scheduled entry shall be allowed during the associated month.  If the
```

bit is zero (0), then the scheduled entry shall not be allowed during the associated month. The bits are defined as:

Bit	Month of Year
0	Reserved
1	January
2	February
3	March
4	April
5	May
6	June
7	July
8	August
9	September
10	October
11	November
12	December
13 - 15	Reserved"

::= { timeBaseScheduleEntry 2 }

2.4.3.2.3 Time Base Schedule Day of Week Parameter

timeBaseScheduleDay OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"The Day(s) of Week that the schedule entry shall be allowed. Each bit represents a specific day of the week. If the bit is set to one (1), then the scheduled entry shall be allowed during the associated DOW. If the bit is set to zero (0), then the scheduled entry shall not be allowed during the associated DOW. The bits are defined as:

Bit	Day of Week
0	Reserved
1	Sunday
2	Monday
3	Tuesday
4	Wednesday
5	Thursday
6	Friday
7	Saturday"

::= { timeBaseScheduleEntry 3 }

2.4.3.2.4 Time Base Schedule Date Parameter

timeBaseScheduleDate OBJECT-TYPE
SYNTAX INTEGER (0..4294967295)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"The Day(s) of a month that the schedule entry shall be allowed. Each bit represents a specific date of the month. If the bit is set to one (1), then the scheduled entry shall be allowed during the associated date. If the bit is set to zero (0), then the scheduled entry shall not be allowed during the associated date. The bits are defined as:

Bit	Day Number
0	Reserved
1	Day 1
2	Day 2

||
31 Day 31"
::= { timeBaseScheduleEntry 4 }

2.4.3.2.5 Time Base Schedule Day Plan Parameter

timeBaseScheduleDayPlan OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"This object specifies what Plan number shall be associated with this timeBaseScheduleDayPlan -object."
::= { timeBaseScheduleEntry 5 }

2.4.4 Day Plan Parameters

2.4.4.1 Maximum Number of Day Plans - Parameter

maxDayPlans OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"The value of this object specifies the maximum, fixed number of different timebased Day Plans supported by the device. The value of this object represents the number of day plans (primary key into the table) available in the timeBaseDayPlanTable."
::= { timebase 3 }

2.4.4.2 Maximum Number of Day Plan Events - Parameter

maxDayPlanEvents OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"The value of this object specifies the maximum, fixed number of different timebased Day Plan Events within each Day Plan supported by the device. The value of this object represents the number of rows (secondary key into the table) available within each of the day plans that are available in the timeBaseDayPlanTable."
::= { timebase 4 }

2.4.4.3 Day Plan Table

timeBaseDayPlanTable OBJECT-TYPE
SYNTAX SEQUENCE OF TimeBaseDayPlanEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
"A table containing day plan numbers, the times when to implement them and the associated actions. The number of rows in this table shall not exceed the value of the maxDayPlans object. This table is always used in association with device-type specific objects specifying device-type specific actions such as activating a message on a VMS sign or initiating a pattern for a signal controller. The device-type specific action will only be initiated when the specific DayPlan has been activated and at the indicated time."
::= { timebase 5 }

```
timeBaseDayPlanEntry   OBJECT-TYPE
SYNTAX          TimeBaseDayPlanEntry
ACCESS          not-accessible
STATUS          mandatory
DESCRIPTION
"A table containing the timebased day plan parameters of a device."
INDEX { dayPlanNumber, dayPlanEventNumber }
::= { timeBaseDayPlanTable 1 }

TimeBaseDayPlanEntry ::= SEQUENCE {
                    dayPlanNumber               INTEGER,
                    dayPlanEventNumber          INTEGER,
                    dayPlanHour                 INTEGER,
                    dayPlanMinute               INTEGER,
                    dayPlanActionNumberOID      OBJECT IDENTIFIER }
```

2.4.4.3.1 Day Plan Number

```
dayPlanNumber   OBJECT-TYPE
SYNTAX          INTEGER (1..255)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"This object specifies the day plan number for objects in this row. The value shall not exceed the value of the maxDayPlans object.  Day plan numbers are used in the TimeBase Event Table to specify day plan numbers to be implemented on specific days of the year or as part of the week plans."
::= { timeBaseDayPlanEntry 1 }
```

2.4.4.3.2 Day Plan Event Number

```
dayPlanEventNumber   OBJECT-TYPE
SYNTAX          INTEGER (1..255)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"This object identifies day plan event number(s) to be scheduled on a specific day plan number.  Several different events can be scheduled to take place during a day, and each of these events is one entry or row within a specified day plan number.  The total number of events for one day plan shall not exceed the value of the maxDayPlanEvents-object."
::= { timeBaseDayPlanEntry 2 }
```

2.4.4.3.3 Day Plan Hour Parameter

```
dayPlanHour   OBJECT-TYPE
SYNTAX          INTEGER (0..23)
ACCESS          read-write
STATUS          mandatory
DESCRIPTION
"The Hour of day that the associated event shall become active.  Valid values for this object are 0 - 23 as the time shall be transmitted in military time."
::= { timeBaseDayPlanEntry 3 }
```


2.4.4.3.4 Day Plan Minute Parameter

```
dayPlanMinute   OBJECT-TYPE
SYNTAX          INTEGER (0..59)
ACCESS          read-write
STATUS          mandatory
DESCRIPTION
"The Minute of the hour (defined in the dayPlanHour) object that the associated event shall become
active. Valid values for this object are 0 - 59 since there are only 0 - 59 minutes in an hour."
::= { timeBaseDayPlanEntry 4 }
```

2.4.4.3.5 Day Plan Action Number OID Parameter

```
dayPlanActionNumberOID   OBJECT-TYPE
SYNTAX          OBJECT IDENTIFIER
ACCESS          read-write
STATUS          mandatory
DESCRIPTION
"This object specifies the first index-column (if multi indexed tables are pointed to, all indices have to be
specified within the OID) within a device-type specific action table that contains the actions (specified in
the associated columns within the table) that shall be executed if the time indicated within the
dayPlanTable and the timeBaseEventSchedule Table is the current time."
::= { timeBaseDayPlanEntry 5 }
```

2.4.4.4 Day Plan Status Parameter

```
dayPlanStatus   OBJECT-TYPE
SYNTAX          INTEGER (0..255)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"This object indicates the current value of the active day PlanNumber-object.  A value of zero (0)
indicates that there is no dayPlanNumber that is currently active."
::= { timebase 6 }
```

2.4.5 Global Local Time Differential Parameter

```
globalLocalTimeDifferential   OBJECT-TYPE
SYNTAX          INTEGER (-43200..43200)
ACCESS          read-write
STATUS          mandatory
DESCRIPTION
“Indicates the number of seconds offset between local time and GMT.  Positive values indicate
local times in the Eastern Hemisphere up to the International Date Line and negative values
indicate local times in the Western Hemisphere back to the International Date Line.  If one of the
daylight savings times is activated, this value will change automatically at the referenced time.
For example, Central Standard Time (CST) is -21600 and Central Daylight Time (CDT) is -
18000.”
::= { globalTimeManagement 4 }
```

2.5 REPORT PARAMETER NODE

```
globalReport OBJECT IDENTIFIER
::= { global 4 }

-- This node is an identifier used to organize all objects for support of report functions
```

-- that are common to most device types.

2.5.1 Maximum Event Log Configurations Parameter

```
maxEventLogConfigs   OBJECT-TYPE
SYNTAX          INTEGER (0..65535)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"The number of rows that exist in the static eventLogConfig table for this device."
::= { globalReport 1 }
```

2.5.2 Event Log Configuration Table

```
eventLogConfigTable   OBJECT-TYPE
SYNTAX          SEQUENCE OF EventLogConfigEntry
ACCESS          not-accessible
STATUS          mandatory
DESCRIPTION
"A table containing Event Log Configuration information. The number of rows in this table is equal to the
maxEventLogConfigs object."
::= { globalReport 2 }

eventLogConfigEntry OBJECT-TYPE
SYNTAX          EventLogConfigEntry
ACCESS          not-accessible
STATUS          mandatory
DESCRIPTION
"This object defines an entry in the event log configuration table."
INDEX { eventConfigID }
::= { EventLogConfigTable 1 }

EventLogConfigEntry ::= SEQUENCE {
          eventConfigID                  INTEGER,
          eventConfigClass               INTEGER,
          eventConfigMode                INTEGER,
          eventConfigCompareValue        INTEGER,
          eventConfigCompareValue2       INTEGER,
          eventConfigCompareOID          OBJECT IDENTIFIER,
          eventConfigLogOID              OBJECT IDENTIFIER,
          eventConfigAction              INTEGER }
```

2.5.2.1 Event Log Configuration ID Parameter

```
eventConfigID  OBJECT-TYPE
SYNTAX          INTEGER (1..65535)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"This object contains the row number which is used to identify the event associated with this row in the
eventLogConfigTable.  The number of event IDs shall not exceed the value indicated in the
maxEventLogConfigs object.  The value zero (0) is not allowed."
::= { eventLogConfigEntry 1 }
```


2.5.2.2 Event Log Configuration Class Parameter

eventConfigClass OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"This object contains the class value to assign to the event associated with this row in the event configuration table. This value is used in the event log table to organize various events defined in this table into logical groupings."
::= { eventLogConfigEntry 2 }

2.5.2.3 Event Log Configuration Mode Parameter

eventConfigMode OBJECT-TYPE
SYNTAX INTEGER { other (1),
onChange (2),
greaterThanValue (3),
smallerThanValue (4),
hysteresisBound (5),
periodic (6) }
ACCESS read-write
STATUS mandatory
DESCRIPTION
"This object specifies the mode of operation for this event. All checks and entries to the table must occur within one second of the condition becoming true. The modes are defined as follows:

VALUE	DESCRIPTION
onChange	create a log entry when value referenced by the eventTypeOID changes
greaterThanValue	create a log entry when the object value becomes greater than the value referenced to by the eventCompareValue object, if this value is exceeded for the amount of time specified in the eventConfigCompareValue2 object (in tenth of seconds) and this value is greater than zero (0). A value of zero (0) for eventConfigCompareValue2 indicates immediate logging.
smallerThanValue	create a log entry when the object value becomes less than the value referenced to by the eventCompareValue object, if this value is exceeded for the amount of time specified in the eventConfigCompareValue2 object (in tenth of seconds) and this value is greater than zero (0). A value of zero (0) for eventConfigCompareValue2 indicates immediate logging.
hysteresisBound	creates a log entry when the object value becomes either less than the lowerbound value or greater than the upperbound value. The lowerbound value is the lower value of the eventConfigCompareValue- and the eventConfigCompareValue2-objects, the upperbound is the other value.
periodic	create a log entry every x seconds, where x is defined by the value stored in eventConfigCompareValue. The values stored in eventConfigCompareValue2 and eventConfigCompareOID are ignored in this mode. "

::= { eventLogConfigEntry 3 }

2.5.2.4 Event Log Configuration Compare Value Parameter

eventConfigCompareValue OBJECT-TYPE
SYNTAX INTEGER
ACCESS read-write
STATUS mandatory
DESCRIPTION

"This object contains the comparison value to use with eventConfigMode values (greaterThanValue, smallerThanValue, hysteresisBound). No value within this object is necessary when the eventConfigMode-object has the “value onChange (2)."
::= { eventLogConfigEntry 4 }

2.5.2.5 Event Log Configuration Compare Value 2 Parameter

eventConfigCompareValue2 OBJECT-TYPE
SYNTAX INTEGER
ACCESS read-write
STATUS mandatory
DESCRIPTION
"If the eventConfigMode is set to hysteresisBound, this object specifies the second comparison value for the hysteresis. If the eventConfigMode is set to greaterThanValue or smallerThanValue, this object specifies the time (in tenth of seconds) for which the comparison must be true prior to the event condition becoming true. If the eventConfigMode is set to onChange or periodic, the value of this object shall be ignored."
::= { eventLogConfigEntry 5 }

2.5.2.6 Event Log Configuration Compare Object Identifier Parameter

eventConfigCompareOID OBJECT-TYPE
SYNTAX OBJECT IDENTIFIER
ACCESS read-write
STATUS mandatory
DESCRIPTION
"This object contains the object identifier which references the value against which the comparison is made. If the eventConfigMode is set to periodic, the value of this object shall be ignored."
::= { eventLogConfigEntry 6 }

2.5.2.7 Event Log Configuration Object Identifier Parameter

eventConfigLogOID OBJECT-TYPE
SYNTAX OBJECT IDENTIFIER
ACCESS read-write
STATUS optional
DESCRIPTION
"This object contains the object identifier which indicates what value to log when a condition or event occurs (e.g., log the phase display when the watchdog alarm status changes)."
::= { eventLogConfigEntry 7 }

2.5.2.8 Event Log Configuration Action Parameter

```
eventConfigAction  OBJECT-TYPE
SYNTAX          INTEGER { other (1),
                          disabled (2),
                          log (3) }
ACCESS          read-write
STATUS          optional
DESCRIPTION
"This value of this object indicates the action that will take place when the event described in this row of the event configuration table occurs.
   disabled - no entry will be recorded due to this event.
   log - an entry will be recorded in the event log table when this event occurs."
::= { eventLogConfigEntry 8 }
```


2.5.3 Maximum Event Log Size Parameter

```
maxEventLogSize   OBJECT-TYPE
SYNTAX          INTEGER (0..65535)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"The maximum, fixed number of rows that can be utilized within the Event Log Table."
::= { globalReport 3 }
```

2.5.4 Event Log Table

```
eventLogTable   OBJECT-TYPE
SYNTAX          SEQUENCE OF EventLogEntry
ACCESS          not-accessible
STATUS          mandatory
DESCRIPTION
"A table containing Event History data collected."
::= { globalReport 4 }

eventLogEntry OBJECT-TYPE
SYNTAX          EventLogEntry
ACCESS          not-accessible
STATUS          mandatory
DESCRIPTION
"This object defines an entry in the event log table"
INDEX { eventLogClass, eventLogNumber }
::= { eventLogTable 1 }

EventLogEntry ::= SEQUENCE {
        eventLogClass       INTEGER,
        eventLogNumber      INTEGER,
        eventLogID          INTEGER,
        eventLogTime        Counter,
        eventLogValue       Opaque }
```

2.5.4.1 Event Log Class Parameter

```
eventLogClass OBJECT-TYPE
SYNTAX          INTEGER (0..255)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"This object contains the class of the associated event as defined in the eventLogConfig Table."
::= { eventLogEntry 1 }
```

2.5.4.2 Event Log Number Parameter

```
eventLogNumber OBJECT-TYPE
SYNTAX          INTEGER (1..255)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"The event number within this class for this event.  Event numbers shall be assigned starting at 1 and
shall increase to the value specified by the associated eventClassLimit for the class associated with the
rows.  Events shall maintain a chronological ordering in the table with the oldest event of a class
```

occupying the row with eventNumber = 1, and subsequent events filling subsequent rows. This ordering shall be maintained when events are cleared."
::= { eventLogEntry 2 }

2.5.4.3 Event Log ID Parameter

eventLogID OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"This object contains the event configuration ID (from the eventLogConfigTable) that caused this table entry. It indicates the row in the eventLogConfig table responsible for this event entry. If this object is set to zero (0) then the associated row (in the eventLogTable) is cleared and the following rows shall be renumbered to maintain a sequential eventNumber sequence."
::= { EventLogEntry 3 }

2.5.4.4 Event Log Time Parameter

eventLogTime OBJECT-TYPE
SYNTAX Counter
ACCESS read-only
STATUS mandatory
DESCRIPTION
"The time that the event occurred in seconds since the epoch of 00:00:00 (midnight) January 1, 1970 per the device’s globalTime object. If the device does not have valid date and time information, then this shall be the time in seconds since the device powered up."
::= { eventLogEntry 4 }

2.5.4.5 Event Log Value Parameter

eventLogValue OBJECT-TYPE
SYNTAX Opaque
ACCESS read-only
STATUS mandatory
DESCRIPTION
"The value of this object is set to the value referenced by the eventConfigLogOID of the associated eventLogID when the event was logged. Its length is variable."
::= { eventLogEntry 5 }

2.5.5 Maximum Event Classes Parameter

maxEventClasses OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"This object defines the maximum, fixed number of rows in the eventClassTable that this device supports. This places an upper limit on the number of classes that may be defined for events in this device."
::= { globalReport 5 }

2.5.6 Event Class Table

eventClassTable OBJECT-TYPE
SYNTAX SEQUENCE OF EventClassEntry
ACCESS not-accessible


```
STATUS          mandatory
DESCRIPTION
"This table is used to configure event logging limits and log table maintenance."
::= { globalReport 6 }

eventClassEntry  OBJECT-TYPE
SYNTAX          EventClassEntry
ACCESS          not-accessible
STATUS          mandatory
DESCRIPTION
"This defines a row in the Event Class Table"
INDEX { eventClassNumber }
::= { eventClassTable 1 }

EventClassEntry ::= SEQUENCE {
        eventClassNumber            INTEGER,
        eventClassLimit             INTEGER,
        eventClassClearTime         Counter,
        eventClassDescription       OCTET STRING,
        eventClassNumRowsInLog      INTEGER }
```

2.5.6.1 Event Class Number Parameter

```
eventClassNumber OBJECT-TYPE
SYNTAX          INTEGER (1..255)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"This is a class value that is to be configured."
::= { eventClassEntry 1 }
```

2.5.6.2 Event Class Limit Parameter

```
eventClassLimit OBJECT-TYPE
SYNTAX          INTEGER (0..255)
ACCESS          read-write
STATUS          mandatory
DESCRIPTION
"This object specifies the maximum number of events of the associated class to store in the log.  Once
the limit is reached, the oldest entry of the matching class will be overwritten by any new entry of the
same class.  If the value of this object is set to a number smaller than the current number of rows within
this class in the eventLogTable, then the oldest entries shall be lost/deleted."
::= { eventClassEntry 2 }
```

2.5.6.3 Event Class Clear Time Parameter

```
eventClassClearTime OBJECT-TYPE
SYNTAX          Counter
ACCESS          read-write
STATUS          mandatory
DESCRIPTION
"This object is used to clear multiple event log entries from the event log table.  Setting this value shall
cause all events of this class that have an eventTime equal to or less than this object to be cleared from
the eventLog table.  The time is the number of seconds since the epoch of 00:00:00 (midnight) January 1,
1970."
```

::= { eventClassEntry 3 }

2.5.6.4 Event Class Description Parameter

eventClassDescription OBJECT-TYPE
SYNTAX OCTET STRING
ACCESS read-write
STATUS optional
DESCRIPTION
"This object specifies a description of the class in ASCII characters."
::= { eventClassEntry 4 }

2.5.6.5 Event Class Number of Rows in Event Log Table Parameter

eventClassNumRowsInLog OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"The number of rows for this class that currently exist in the eventLogTable."
::= { eventClassEntry 5 }

2.6 STMP OBJECT NODE

profilesSTMP OBJECT IDENTIFIER
::= { profiles 2 }

--This node is an identifier used to group all objects for support of configuration functions
-- that are common to device types that support the STMP protocol. The objects under this node are
-- placed under the Protocols\Profiles\STMP subtree within the NEMA node, but they have been listed
-- here due to the lack of a separate document that lists these objects.

2.6.1 Dynamic Object Persistence Parameter

dynamicObjectPersistence OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"The maximum power outage time in minutes that may occur before all STMP dynamic object definitions in a device shall be invalidated.
If this object is set to zero then existing dynamic object definitions shall be invalidated on device power up.
If this object is set to its maximum value (65535) the existing dynamic object definitions shall not be invalidated due to power outages of any duration.

A device that supports STMP dynamic objects shall support this object."
REFERENCE
"NEMA TS 3.2 Clause 4.2.1.1"
::= { profilesSTMP 1 }

2.7 PMPP OBJECT NODE

profilesPMPP OBJECT IDENTIFIER
::= { profiles 3 }


```
-- This node is an identifier used to group all objects for support of the PMPP function that
-- are common to all device types.  The objects under this node are placed under the
-- Protocols\Profiles\PMPP subtree within the NEMA node, but they have been listed here due to the lack
-- of a separate document that lists these objects.
```

2.7.1 Maximum HDLC Group Address Parameter

```
maxGroupAddresses     OBJECT-TYPE
SYNTAX          INTEGER (0..255)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"The maximum number of group addresses this device supports. This object indicates the maximum
number of rows in the Data Link Layer group address table."
::= { profilesPMPP 1 }
```

2.7.2 HDLC Group Address Table

```
hdlcGroupAddressTable OBJECT-TYPE
SYNTAX          SEQUENCE OF HdlcGroupAddressEntry
ACCESS          not-accessible
STATUS          mandatory
DESCRIPTION
"A table containing group addresses at which a device may receive frames."
::= { profilesPMPP 2 }

hdlcGroupAddressEntry OBJECT-TYPE
SYNTAX          HdlcGroupAddressEntry
ACCESS          not-accessible
STATUS          mandatory
DESCRIPTION
"An entry in the group address table that contains a device's data link layer group address at which it will
accept frames."
INDEX { hdlcGroupAddressIndex }
::= { hdlcGroupAddressTable 1 }

HdlcGroupAddressEntry ::= SEQUENCE {
     hdlcGroupAddressIndex      INTEGER,
     hdlcGroupAddress           INTEGER }
```

2.7.2.1 HDLC Group Address Index Parameter

```
hdlcGroupAddressIndex      OBJECT-TYPE
SYNTAX          INTEGER (0..255)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"The index number for the group address in this row."
::= { hdlcGroupAddressEntry 1 }
```

2.7.2.2 HDLC Group Address Parameter

```
hdlcGroupAddress        OBJECT-TYPE
SYNTAX          INTEGER
ACCESS          read-write
```

STATUS mandatory
DESCRIPTION
"A group address for the data link layer. For PMPP, the syntax is an 8- or 16-bit entry with the second low order bit set to a one indicating that this is a group address."
REFERENCE
"NEMA TS 3.3 Clause 3.3.3.1"
::= { hdlcGroupAddressEntry 2 }

2.8 SECURITY NODE

security OBJECT IDENTIFIER ::= global 5
-- This node is an identifier used to group all objects related to the
-- assignment of community names and the access rights they provide.

2.8.1 Community Name Administrator Parameter

communityNameAdmin OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(8..16))
ACCESS read-write
STATUS mandatory
DESCRIPTION
"This object is the community name that must be used to specifically gain access to information under the security node. A message with this value in the community name field of an SNMP message has user read-write access to the security node objects and all other objects implemented in the device. The syntax is defined as an OCTET STRING and therefore any character can have a value of 0..255."
DEFVAL { "administrator" }
::= { security 1 }

2.8.2 Maximum Community Names Parameter

communityNamesMax OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"This object specifies the maximum number of rows that are implemented in the community name table."
::= { security 2 }

2.8.3 Community Names Table

communityNameTable OBJECT-TYPE
SYNTAX SEQUENCE OF CommunityNameTableEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
"This table defines the community names that can appear in the community name field of the SNMP message and access privileges associated with that community name."
::= { security 3 }

communityNameTableEntry OBJECT-TYPE
SYNTAX CommunityNameTableEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION


```
"This is the row index of information in the community name table."
INDEX    { communityNameIndex }
::= { communityNameTable 1 }

CommunityNameTableEntry::=SEQUENCE
                    { communityNameIndex      INTEGER,
                      communityNameUser       OCTET STRING,
                      communityNameAccessMask  GAUGE
                    }
```

2.8.3.1 Community Name Index Parameter

```
communityNameIndex  OBJECT-TYPE
SYNTAX  INTEGER (1..255)
ACCESS  not-accessible
STATUS  mandatory
DESCRIPTION
"This object defines the row index into the communityNameTable. This value shall not exceed the
communityNamesMax object value."
::=  { communityNameTableEntry 1 }
```

2.8.3.2 User Community Name Parameter

```
communityNameUser  OBJECT-TYPE
SYNTAX  OCTET STRING (SIZE(6..16))
ACCESS  read-write
STATUS  mandatory
DESCRIPTION
"This object defines a community name value that a security administrator can
assign user read-write access to information (other than security) in a device
A message with this value in the community name field of an SNMP message has
user access rights as defined in the communityNameAccessMask.  The syntax is
defined as an OCTET STRING and therefore any character can have a value of
0..255."
DEFVAL  { "public" }
::=  { communityNameTableEntry 2 }
```

2.8.3.3 User Community Name Mask Parameter

```
communityNameAccessMask OBJECT-TYPE
SYNTAX  GAUGE (0..4294967295)
ACCESS  read-write
STATUS  mandatory
DESCRIPTION
"This object defines a 32-bit mask that can be used to associate 'write access'
with a community name.  A value of 0x00000000 grants the community name user
read-only access and overrides any individual object's read-write access
clause.  A value of OxFFFFFFFF grants the community name user read-write access
and an individual object's read-write access clause applies.  Values other
0x00000000 and 0xFFFFFFFF are implementation specific and may limit viewing
and/or accessing the information in a device."
DEFVAL  { 4294967295 }
::= { communityNameTableEntry 3 }

END
```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Section 3
GROUP DEFINITIONS

A conformance group is defined in [NTCIP 1101] TS 3.2 – Simple Transportation Management Network (STMF), Clause 3.3.5.

Conformance groups are defined as either mandatory or optional. If a conformance group is mandatory, all of the objects and subgroups with STATUS "mandatory" that are part of the conformance group shall be present for a device to claim conformance to the MIB defining the Conformance group. If a Conformance group is optional, all of the objects and subgroups with the STATUS "mandatory" that are part of the conformance group shall be present if the device supports the Conformance group. Optional objects with the STATUS "optional" may be supported.

When a table is included in a conformance group, all objects contained in the table are included by reference. This is because a table is defined as a SEQUENCE OF { SEQUENCE }. Thus, all objects listed in the sequence are defined as an integral part of the table. Tables are defined as either mandatory or optional. If a table is mandatory, all of the objects with STATUS "mandatory" shall be present. If a table is optional, all of the objects with the STATUS "mandatory" shall be present if the device supports the table. Objects within a table with the STATUS "optional" may be supported.

Table 3–1
OBJECT SUPPORT REQUIREMENTS

Object Status	Table Status	Conformance Group Status	Object Support
mandatory	mandatory	mandatory	mandatory
mandatory	mandatory	optional	mandatory, if conformance group is supported
mandatory	optional	mandatory	mandatory, if table is supported
mandatory	optional	optional	mandatory, if both the conformance group and table are supported
optional	mandatory	mandatory	optional
optional	mandatory	optional	optional
optional	optional	mandatory	optional
optional	optional	optional	optional

The conformance group definitions for specific device-types such as signal controllers or VMS signs are usually defined in this section but since the Global Object Definitions define the setup of objects (or functions) common to multiple device-types, it cannot and should not be prohibited that a special device-type uses these objects in different logical groupings then defined within this document.

Each conformance group defines a certain function, which has been seen as a logical grouping. The following conformance group definitions are guidelines.

3.1 CONFIGURATION CONFORMANCE GROUP

The Global Configuration Conformance group consists of a variety of global objects related to general configuration information. The Global Configuration Conformance group shall consist of the following objects and tables:

Object or Table Name	Reference
globalSetIDParameter	NTCIP 1201
globalMaxModules	NTCIP 1201
globalModuleTable	NTCIP 1201
moduleNumber	NTCIP 1201
moduleDeviceNode	NTCIP 1201
moduleMake	NTCIP 1201
moduleModel	NTCIP 1201
moduleVersion	NTCIP 1201
moduleType	NTCIP 1201

3.2 DATABASE MANAGEMENT CONFORMANCE GROUP

The Global Database Management Conformance group consists of global objects related to database management functions. The Global Database Management Conformance group shall consist of the following objects:

Object or Group Name	Reference
dBCreationTransaction	NTCIP 1201
dbVerifyStatus	NTCIP 1201:1996 Amendment 1
dbVerifyError	NTCIP 1201:1996 Amendment 1

3.3 TIME MANAGEMENT CONFORMANCE GROUP

The Global Time Management Conformance group consists of global objects related to time management functions. The Time Database Management Conformance group shall consist of the following objects:

Object or Group Name	Reference
globalTime	NTCIP 1201
globalDaylightSaving	NTCIP 1201
globalLocalTimeDifferential	NTCIP 1201:1996 Amendment 1

3.4 TIME BASE EVENT SCHEDULE CONFORMANCE GROUP

The Time Base Conformance group consists of the global schedule table objects related to time base operation. Other device-type specific objects are defined in the appropriate device-type specific documents. The Time Base Conformance group shall consist of the following objects:

Object or Conformance group Name	**Reference**
maxTimeBaseScheduleEntries	NTCIP 1201
timebaseScheduleTable	NTCIP 1201
timebaseScheduleNumber	NTCIP 1201
timebaseScheduleMonth	NTCIP 1201
timebaseScheduleDay	NTCIP 1201
timebaseScheduleDate	NTCIP 1201
timebaseScheduleDayPlan	NTCIP 1201
maxDayPlans	
maxDayPlanEvents	NTCIP 1201
timeBaseDayPlanTable	NTCIP 1201
dayPlanNumber	NTCIP 1201
dayPlanEventNumber	NTCIP 1201
dayPlanHour	NTCIP 1201
dayPlanMinute	NTCIP 1201
dayPlanActionNumberOID	NTCIP 1201
dayPlanStatus	NTCIP 1201

3.5 REPORT CONFORMANCE GROUP

The Report Conformance group consists of those global objects related to event logging. The Report Conformance group shall consist of the following objects:

Object or Group Name	**Reference**
maxEventLogConfigs	NTCIP 1201
eventLogConfigTable	NTCIP 1201
eventConfigID	NTCIP 1201
eventConfigClass	NTCIP 1201
eventConfigMode	NTCIP 1201
eventConfigCompareValue	NTCIP 1201
eventConfigCompareValue2	NTCIP 1201
eventConfigCompareOID	NTCIP 1201
eventConfigLogOID	NTCIP 1201
eventConfigAction	NTCIP 1201
maxEventLogSize	NTCIP 1201
eventLogTable	NTCIP 1201
eventLogClass	NTCIP 1201
eventLogNumber	NTCIP 1201
eventLogID	NTCIP 1201
eventLogTime	NTCIP 1201
eventLogValue	NTCIP 1201
maxEventClasses	NTCIP 1201
eventClassTable	NTCIP 1201
eventClassNumber	NTCIP 1201
eventClassLimit	NTCIP 1201
eventClassClearTime	NTCIP 1201
eventClassDescription	NTCIP 1201
eventClassNumRowsInLog	NTCIP 1201

3.6 STMP CONFORMANCE GROUP

The STMP Group consists of those objects related to STMP parameters. The STMP Group shall consist of the following objects:

Object or Group Name	Reference
dynamicObjectPersistence	NTCIP 1201

3.7 PMPP CONFORMANCE GROUP

The PMPP Group consists of those optional global objects related to PMPP parameters. The PMPP Group shall consist of the following objects:

Object or Group Name	Reference
maxGroupAddresses	NTCIP 1201
hdlcGroupAddressTable	NTCIP 1201
hdlcGroupAddressIndex	NTCIP 1201
hdlcGroupAddress	NTCIP 1201

3.8 SECURITY CONFORMANCE GROUP

The Security Group consists of those mandatory global objects related to community name parameters. The Security Group shall consist of the following objects:

Object or Group Name	Reference
communityNameAdmin	NTCIP 1201
communityNamesMax	NTCIP 1201
communityNameTable	NTCIP 1201
communityNameIndex	NTCIP 1201
communityNameUser	NTCIP 1201
communityNameMask	NTCIP 1201

Section 4
CONFORMANCE STATEMENTS

In addition to the device-type specific conformance requirements stated in the appropriate documents, all transportation related device types shall adhere to the conformance requirements specified in Table 4-1 as a minimum to claim compliance to this standard. Additional objects or groups may be supported without being non-compliant with NTCIP.

Minimum and maximum ranges of objects that differ from the values of the object's SYNTAX field may be enforced by an application running on a device.

A device which enforces range limits within the bounds specified by the values of the object's SYNTAX field shall not be categorized as being non-compliant with NTCIP.

A device which supports a subset of objects with enumerated values shall not be categorized as being non-compliant with NTCIP.

Table 4–1
CONFORMANCE TABLE

Conformance Group	Reference	Conformance Requirement
Configuration	NTCIP 1201	mandatory
Security	NTCIP 1201	mandatory
Database Management	NTCIP 1201	optional
Time Management	NTCIP 1201	optional
Timebase Event Schedule	NTCIP 1201	optional
Report	NTCIP 1201	optional
STMP	NTCIP 1201	optional
PMPP	NTCIP 1201	optional

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NTCIP 1202 v01.07

National Transportation Communications for ITS Protocol

Object Definitions for Actuated Traffic Signal Controller (ASC) Units

TS 3.5-1996 v96.01.07 April 1997
1202 v01.07d January 2005

This Adobe® PDF copy of an NTCIP standard is available at no-cost for a limited time through support from the U.S. DOT / Federal Highway Administration, whose assistance is gratefully acknowledged.

Published by

American Association of State Highway and Transportation Officials (AASHTO)
444 North Capitol Street, N.W., Suite 249
Washington, D.C. 20001

Institute of Transportation Engineers (ITE)
1099 14th Street, N.W., Suite 300 West
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History

From 1996 to 1999, this document was referenced as NEMA TS 3.5. However, to provide an organized numbering scheme for the NTCIP documents, this document is now referenced as NTCIP 1202.

NEMA TS 3.5-1996, v96.01.07. Approved by NEMA in 1996. Accepted as a Recommended Standard by the Joint Committee on the NTCIP in 1996. Approved by AASHTO and ITE in 1997. v01.07a printed with NEMA cover.

NTCIP 1202 v01. v01.07b printed with joint cover. v01.07c printed to PDF in November 2002. v01.07d printed to PDF for no-cost distribution January 2005.

NTCIP 1202 Amendment 1. November 1999 – Accepted as a User Comment Draft Amendment by the Joint Committee on the NTCIP. April 2000 -- NTCIP Standards Bulletin B0049 sent NTCIP 1202 Amendment 1 v01.06b for user comment. NTCIP 1202 Amendment 1, a User Comment Draft, was incorporated into 1202v02, and was not advanced further.

Table of Contents

Foreword

This publication describes the objects used for managing actuated traffic signal controller units.

The text consists of mandatory requirements which are classified as NEMA Standard Publication and information that is in conformance with NEMA Authorized Engineering Information. Both are defined in the back of each NEMA Standard Publication.

User inputs are solicited by canvass on each NEMA standards proposal for Transportation Management and Associated Control Equipment. This procedure provides guidance before industry action. Every comment received is acknowledged and the action taken reported to the submitter. Comments should be submitted to:

Vice President, Engineering Department
National Electrical Manufacturers Association
1300 N.17th Street
Rosslyn, Virginia 22209

This standards publication was developed by the Transportation Management Systems and Associated Control Devices section of the National Electrical Manufacturers Association. Section approval of the standard does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the Transportation Management Systems and Associated Control Devices section had the following members.

ADDCO Manufacturing Co.—St. Paul, MN
American Electronic Sign—Spokane, WA
Automatic Signal/Eagle Signal Corporation—Austin, TX
BI Tran Systems, Inc.—Sacramento, CA
Cylink Corporation—Sunnyvale, CA
Eberle Design, Inc.—Phoenix, AZ
Econolite Control Products, Inc.—Anaheim, CA
Fiberoptic Display Systems, Inc.—Smithfield, RI
Gardner-Rowe Systems, Inc.—Walnut Creek, CA
Information Station Specialists, Inc.—Zeeland, MI
Intersection Development Corp.—Fullerton, CA
ITS Product Group—Ormond Beach, FL
McCain Traffic Supply, Inc.—Vista, CA
P B Farradyne Inc.—Rockville, MD
Peek Traffic - Transyt Corp.—Tallahassee, FL
Rockwell Automation—Mayfield Heights, OH
Safetran Traffic Systems, Inc.—Colorado Springs, CO
Skyline Products, Inc.—Colorado Springs, CO
3M Intelligent Transportation Systems—St. Paul, MN
Traffic Sensor Corp.—Corona, CA
Viggen Corp.—McLean, VA
Vultron, Inc.—Rochester Hills, MI

The Joint AASHTO/ITE/NEMA Committee on the NTCIP has recommended this standards publication for adoption to both the American Association of State Highway and Transportation Officials (AASHTO) and the Institute of Transportation Engineers (ITE). After adoption is approved by AASHTO and ITE, future printings of this publication will have a Joint AASHTO/ITE/NEMA Standard cover, and will appear different from this publication. Unless noted, the content of the publications will be the same.

Section 1
General

1.1 SCOPE

This publication defines objects which are specific to actuated signal controllers. It also defines standardized object groups which can be used for conformance statements.

1.2 REFERENCES

For approved errata sheets, contact:

NTCIP Coordinator
National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209-3801
email: ntcip@nema.org

1.2.1 Normative References

Information on proposed errata, which are under discussion by the relevant NTCIP Working Group, is available on the World Wide Web at http://www.ntcip.org.

The following standards (normative references) contain provisions which, through reference in this text, constitute provisions of this Standard. Other documents and standards (other references) are referenced in these documents, which might provide a complete understanding of the entire protocol and the relations between all parts of the protocol. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standard listed below.

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. While end users of NTCIP do not need to obtain these documents, they do provide a complete understanding of the protocol. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below.

ANSI
11 West 42nd Street, 13th Floor
New York, New York 10036

ISO/IEC 8824-1:1995 *Information Technology—Abstract Syntax Notation One (ASN.1): Specification of Basic Notation*

ISO/IEC 8824-2:1995 *Information Technology—Abstract Syntax Notation One (ASN.1): Information Object Specification*

DDN Network Information Center
14200 Park Meadow Drive
Suite 200
Chantilly, VA 22021

Electronic copies of RFC documents may be obtained using "anonymous FTP" to the host <nic.ddn.mil> or <ds.internic.net>. Printed copies are available from: (800) 365-3642 or (703) 802-4535.

RFC1155 *Structure and Identification of Management Information for TCP/IP-based Internets.* K. McCloghrie; M. Rose; 05/10/1990

RFC1212 *Concise MIB Definitions*. K. McCloghrie; M. Rose; 03/26/1991

1.2.2 Other References

National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209

TS 2-1992 *Traffic Controller Assemblies*

TS 3.1-1996 *National Transportation Communications for ITS Protocol - Overview*

TS 3.2-1996 *National Transportation Communications for ITS Protocol - Simple Transportation Management Framework*

TS 3.3-1996 *National Transportation Communications for ITS Protocol - Class B Profile*

ANSI
11 West 42nd Street, 13th Floor
New York, New York 10036
(212) 642-4900

ISO/IEC 8824-3:1995 *Information Technology—Abstract Syntax Notation One (ASN.1): Constraint Specification*

ISO/IEC 8824-4:1995 *Information Technology—Abstract Syntax Notation One (ASN.1): Parameterization of ASN.1 Specifications*

ISO/IEC 8825-1:1995 *Information Technology—ASN.1 Encoding Rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER).*

DDN Network Information Center
14200 Park Meadow Drive
Suite 200
Chantilly, VA 22021

RFC1213 *Management Information Base for Network Management of TCP/IP-based Internets:* MIB-II. K. McCloghrie; M. Rose; CP/IP-base

RFC1157 *A Simple Network Management Protocol (SNMP).* M. Schoffstall; M. Feder; J. Davin; J. Case; 05/10/1990

1.3 ACTUATED CONTROLLER UNIT TERMS

These terms define the nomenclature frequently used in regard to actuated traffic signal control devices. These terms reflect the consensus of the traffic control equipment industry as represented by NEMA and are intended to be in harmony with terminology in current usage.

Actuation: The operation of any type of detector.

Automatic Flash: Automatic programmed flash mode not caused by manual switch activation or fault condition or startup.

Auxiliary Function: A control that may activate auxiliary functions or outputs in an actuated controller unit.

Backup Mode: Control by local TBC or Interconnect based on absence of master or central command.

Barrier: A barrier (compatibility line) is a reference point in the preferred sequence of a multi-ring CU at which all rings are interlocked. Barriers assure there will be no concurrent selection and timing of conflicting phases for traffic movement in different rings. All rings cross the barrier simultaneously to select and time phases on the other side.

Call: A registration of a demand for right-of-way by traffic (vehicles or pedestrians) to a controller unit.

Call, Serviceable Conflicting: A call which:

a. Occurs on a conflicting phase not having the right-of-way at the time the call is placed.
b. Occurs on a conflicting phase which is capable of responding to a call.
c. When occurring on a conflicting phase operating in an occupancy mode, remains present until given its right-of-way.

Channel: Three circuits of a Monitor Device wired to monitor the green, yellow, and red outputs of the associated load switch position in the Terminal & Facilities. Channel 1 is assumed to monitor Load Switch 1, etc.

Check: An output from a controller unit that indicates the existence of unanswered call(s).

Concurrency Group: A group of phases which describes possible timing combinations. A phase within the group shall be able to time concurrently with any other phase from another ring contained in the group. For example, in the typical dual-ring eight phase design, phases 1, 2, 5 and 6 form one concurrency group and phases 3, 4, 7, and 8 form another concurrency group.

Concurrent Timing: A mode of controller unit operation whereby a traffic phase can be selected and timed simultaneously and independently with another traffic phase.

Controller Assembly: A complete electrical device mounted in a cabinet for controlling the operation of a traffic control signal display(s).

Controller Unit: A controller unit is that portion of a controller assembly that is devoted to the selection and timing of signal displays.

Coordination: The control of controller units in a manner to provide a relationship between specific green indications at adjacent intersections in accordance with a time schedule to permit continuous operation of groups of vehicles along the street at a planned speed.

Coordinator: A device or program/routine which provides coordination.

Cycle: The total time to complete one sequence of signalization around an intersection. In an actuated controller unit, a complete cycle is dependent on the presence of calls on all phases. In a pretimed controller unit it is a complete sequence of signal indications.

Cycle Length: The time period in seconds required for one complete cycle.

Detector, Pedestrian: A detector that is responsive to operation by or the presence of a pedestrian.

Detector, System: Any type of vehicle detector used to obtain representative traffic flow information.

Detector, Vehicle: A detector that is responsive to operation by or the presence of a vehicle.

Dial: The cycle timing reference or coordination input activating same. Dial is also frequently used to describe the cycle.

Display Map: A graphic display of the street system being controlled showing the status of the signal indications and the status of the traffic flow conditions.

Dual Entry: Dual entry is a mode of operation (in a multi-ring CU) in which one phase in each ring must be in service. If a call does not exist in a ring when it crosses the barrier, a phase is selected in that ring to be activated by the CU in a predetermined manner.

Dwell: The interval portion of a phase when present timing requirements have been completed.

First Coordinated Phase: The coordinated phase which occurs first within the concurrent group of phases containing the coordinated phase(s) when there are constant calls on all phases.

Flash: Operation where one section in each vehicle signal (yellow or red) is alternately on and off with a one second cycle time and a 50 percent duty cycle.

Fault Monitor State: internal CU diagnostics have determined that the CU device is not in a safe operational state. An output may be asserted to indicate this condition.

Force Off: A command to force the termination of the green interval in the actuated mode or Walk Hold in the nonactuated mode of the associated phase. Termination is subject to the presence of a serviceable conflicting call. The Force Off function shall not be effective during the timing of the Initial, Walk, or Pedestrian Clearance. The Force Off shall only be effective as long as the condition is sustained. If a phase specific Force Off is applied, the Force Off shall not prevent the start of green for that phase.

Free: Operation without coordination control from any source.

Gap Reduction: A feature whereby the Unit Extension or allowed time spacing between successive vehicle actuations on the phase displaying the green in the extensible portion of the interval is reduced.

Group: Any portion of a traffic control network (system) that can be controlled by a common set of timing plans.

Hold: A command that retains the existing Green interval.

Hold-On Line: A signal to an intersection controller commanding it to remain under computer control.

Interconnect: A means of remotely controlling some or all of the functions of a traffic signal.

Intersection status: The knowledge of whether a controlled intersection is on-line and which mode it is currently operating in.

Interval: The part or parts of the signal cycle during which signal indications do not change.

Load Switch Driver Group: The set of three outputs which are used to drive load switch inputs to provide a Green, Yellow, or Red output condition for vehicle signals or Walk, Ped Clear, or Dont Walk output condition for pedestrian signals.

Malfunction Management Unit (MMU): A device used to detect and respond to improper and conflicting signals and improper operating voltages in a traffic controller assembly.

Maximum Green: The maximum green time with an serviceable opposing actuation, which may start during the initial portion.

Minimum Green Interval: The shortest green time of a phase. If a time setting control is designated as Minimum Green, the green time shall be not less than that setting.

Multi-Ring Controller Unit: A multi-ring CU contains two or more interlocked rings which are arranged to time in a preferred sequence and to allow concurrent timing of all rings, subject to barrier restraint.

Nonlocking Memory: A mode of actuated-controller-unit operation which does not require the retention of a call for future utilization by the controller assembly.

Occupancy: A measurement of vehicle presence within a zone of detection, expressed in seconds of time a given point or area is occupied by a vehicle.

Off-line: A controller assembly not under the control of the normal control source.

Offset: The time relationship, expressed in seconds, between the starting point of the first coordinated phase Green and a system reference point.

Omit, Phase: A command that causes omission of a selected phase.

On-line: A controller assembly under the control of the normal control source.

Overlap: A Green indication that allows traffic movement during the green intervals of and clearance intervals between two or more phases.

Passage Time: The time allowed for a vehicle to travel at a selected speed from the detector to the stop line.

Pattern: A unique set of coordination parameters (cycle value, split values, offset value, and sequence).

Pedestrian Clearance Interval: The first clearance interval for the pedestrian signal following the pedestrian WALK indication.

Pedestrian Recycle: A method of placing a recurring demand for pedestrian service on the movement when that movement is not in its Walk interval.

Permissive: A time period, during which the CU is allowed to leave the coordinated phase(s) under coordination control to go to other phases.

Phase Sequence: A predetermined order in which the phases of a cycle occur.

Phase, Active: The indicated phase is currently timing. A phase is always active if it is Green or Yellow (Walk or Pedestrian Clear for Pedestrian Phases). It is also active if it is timing Red Clearance. It may be considered active during Red Dwell.

Phase, Conflicting: Conflicting phases are two or more traffic phases which will cause interfering traffic movements if operated concurrently.

Phase, Nonconflicting: Nonconflicting phases are two or more traffic phases which will not cause interfering traffic movements if operated concurrently.

Phase, Pedestrian: A traffic phase allocated to pedestrian traffic which may provide a right-of-way pedestrian indication either concurrently with one or more vehicular phases, or to the exclusion of all vehicular phases.

Phase, Traffic: Those green, change and clearance intervals in a cycle assigned to any independent movement(s) of traffic.

Phase, Vehicular: A vehicular phase is a phase which is allocated to vehicular traffic movement as timed by the controller unit.

Preemption: The transfer of the normal control of signals to a special signal control mode for the purpose of servicing railroad crossings, emergency vehicle passage, mass transit vehicle passage, and other special tasks, the control of which require terminating normal traffic control to provide the priority needs of the special task.

Preemptor: A device or program/routine which provides preemption.

Progression: The act of various controller units providing specific green indications in accordance with a time schedule to permit continuous operation of groups of vehicles along the street at a planned speed.

Red Clearance Interval: A clearance interval which may follow the yellow change interval during which both the terminating phase and the next phase display Red signal indications.

Red Revert: Provision within the controller unit to assure a minimum Red signal indication in a phase following the Yellow Change interval of that phase .

Rest: The interval portion of a phase when present timing requirements have been completed.

Ring: A ring consists of two or more sequentially timed and individually selected conflicting phases so arranged as to occur in an established order.

Sequence, Interval: The order of appearance of signal indications during successive intervals of a cycle.

Single Entry: Single entry is a mode of operation (in a multi-ring CU) in which a phase in one ring can be selected and timed alone if there is no demand for service in a nonconflicting phase on the parallel ring(s).

Single-Ring Controller Unit: A single-ring CU contains two or more sequentially timed and individually selected conflicting phases so arranged as to occur in an established order.

Special Function: A control that may activate specific functions or outputs in an actuated controller unit.

Split: The segment of the cycle length allocated to each phase or interval that may occur (expressed in seconds). In an actuated controller unit, split is the time in the cycle allocated to a phase.

Standby Mode: An operational state called by master or central command which directs the controller unit to select Pattern, Automatic Flash, or Automatic Free based on local Time Base schedule or Interconnect inputs.

Time Base Control: A means for the automatic selection of modes of operation of traffic signals in a manner prescribed by a predetermined time schedule.

Timing Plan: The Split times for all segments (Phase/Interval) of the coordination cycle.

Volume: The number of vehicles passing a given point per unit of time.

Yellow Change Interval: The first interval following the green interval in which the signal indication for that phase is yellow.

Yield: A command which permits termination of the green interval.

1.4 ABBREVIATIONS AND ACRONYMS

The abbreviations used in this Standard Publication are defined as follows:

BIU—Bus Interface Unit

CA—Controller Assembly

CU—Controller Unit

MMU—Malfunction Management Unit

TBC—Time Base Control

TF—Terminals and Facilities

Section 2
OBJECT DEFINITIONS

This section defines those objects which are specifically used by actuated traffic signal controllers. The objects are defined using the OBJECT-TYPE macro specified in RFC 1212. The text provided from Clause 2.1 through the end of the section (except the clause headings) constitutes the NEMA Standard ASC MIB.

The clauses below present the objects in lexigraphical order of their OBJECT IDENTIFIERS which correspond to their physical location within the global naming tree. All of the objects defined in this document reside under the "asc" node of the global naming tree. To aid in object management, the "asc" node has been subdivided into logical categories, each defined by a node under the "asc" node. The individual objects are then located under the appropriate node.

Nodes should not be confused with Conformance Groups, which are defined in Section 3. A Conformance Group is a logical grouping of objects which is used for conformance statements. While Conformance Groups will frequently correspond to the nodal structure, a Conformance Group may contain objects which are not lexigraphically ordered. For example, a Schedule Conformance Group may contain both "global" and "asc" specific objects.

Text preceded by a double hyphen in the MIB definitions represent normative text for this standard.

2.1 MIB HEADER

```
ASC_MIB1 DEFINITIONS::= BEGIN
-- the following OBJECT IDENTIFIERS are used in the ASC MIB:

IMPORTS
    devices
    FROM TMIB;

asc OBJECT IDENTIFIER::= { devices 1 }
```

2.2 PHASE PARAMETERS

```
phase OBJECT IDENTIFIER
::= { asc 1 }
```

-- This node shall contain objects that configure, monitor or control phase functions for this device.

2.2.1 Maximum Phases

```
maxPhases   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The Maximum Number of Phases this Actuated Controller Unit supports. This object
            indicates the maximum rows which shall appear in the phaseTable object."
        ::= { phase 1 }
```

2.2.2 Phase Table

```
phaseTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF PhaseEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "A table containing Actuated Controller Unit phase parameters. The number of rows in this
            table is equal to the maxPhases object."
::= { phase 2 }

phaseEntry   OBJECT-TYPE
        SYNTAX   PhaseEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "Parameters for a specific Actuated Controller Unit phase."
        INDEX   { phaseNumber }
::= { phaseTable 1 }

PhaseEntry ::= SEQUENCE {
        phaseNumber                INTEGER,
        phaseWalk                  INTEGER,
        phasePedestrianClear       INTEGER,
        phaseMinimumGreen          INTEGER,
        phasePassage               INTEGER,
        phaseMaximum1              INTEGER,
        phaseMaximum2              INTEGER,
        phaseYellowChange          INTEGER,
        phaseRedClear              INTEGER,
        phaseRedRevert             INTEGER,
        phaseAddedInitial          INTEGER,
        phaseMaximumInitial        INTEGER,
        phaseTimeBeforeReduction   INTEGER,
        phaseCarsBeforeReduction   INTEGER,
        phaseTimeToReduce          INTEGER,
        phaseReduceBy              INTEGER,
        phaseMinimumGap            INTEGER,
        phaseDynamicMaxLimit       INTEGER,
        phaseDynamicMaxStep        INTEGER,
        phaseStartup               INTEGER,
        phaseOptions               INTEGER,
        phaseRing                  INTEGER,
        phaseConcurrency           OCTET STRING }
```

2.2.2.1 Phase Number

```
phaseNumber   OBJECT-TYPE
        SYNTAX    INTEGER (1..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The phase number for objects in this row. This value shall not exceed the maxPhases
            object value."
::= { phaseEntry 1 }
```

2.2.2.2 Phase Walk Parameter

```
phaseWalk   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Phase Walk Parameter in seconds. This shall control the amount of time the Walk
             indication shall be displayed."
        REFERENCE
             "NEMA TS 2 Clause 3.5.3.1 and 3.5.3.2.2.a"
::= { phaseEntry 2 }
```

2.2.2.3 Phase Pedestrian Clear Parameter

```
phasePedestrianClear   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Phase Pedestrian Clear Parameter in seconds. This shall control the duration of the
             Pedestrian Clearance output (if present) and the flashing period of the Don't Walk output. "
        REFERENCE
             "NEMA TS 2 Clause 3.5.3.1 and 3.5.3.2.2.b"
::= { phaseEntry 3 }
```

2.2.2.4 Phase Minimum Green Parameter

```
phaseMinimumGreen   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Phase Minimum Green Parameter in seconds (NEMA TS 2 range: 1-255 sec).  The first
             timed portion of the Green interval which may be set in consideration of the storage of
             vehicles between the zone of detection for the approach vehicle detector(s) and the stop
             line."
        REFERENCE
             "NEMA TS 2 Clause 3.5.3.1 and 3.5.3.2.1.a.(1)"
::= { phaseEntry 4 }
```

2.2.2.5 Phase Passage Parameter

```
phasePassage   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Phase Passage Parameter in tenth seconds (0-25.5 sec). Passage Time, Vehicle Interval,
             Preset Gap, Vehicle Extension: the extensible portion of the Green shall be a function of
             vehicle actuations that occur during the Green interval.  The phase shall remain in the
             extensible portion of the Green interval as long as the passage timer is not timed out.  The
             timing of this portion of the green interval shall be reset with each subsequent vehicle
             actuation and shall not commence to time again until the vehicle actuation is removed."
        REFERENCE
             "NEMA TS 2 Clause 3.5.3.1 and 3.5.3.2.1.a.(2)"
::= { phaseEntry 5 }
```

2.2.2.6 Phase Maximum Green 1 Parameter

```
phaseMaximum1   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Phase Maximum 1 Parameter in seconds (NEMA TS 2 range: 1-255 sec). This time setting
            shall determine the maximum length of time this phase may be held Green in the presence
            of a serviceable conflicting call. In the absence of a serviceable conflicting call the Maximum
            Green timer shall be held reset unless Max Vehicle Recall is enabled for this phase.  This is
            the default maximum value to use.  It may be overridden via an external input,
            coordMaximumMode or other method."
        REFERENCE
            "NEMA TS 2 Clause 3.5.3.1, 3.5.3.2.1.a.(3) and 3.5.3.5"
::= { phaseEntry 6 }
```

2.2.2.7 Phase Maximum Green 2 Parameter

```
phaseMaximum2   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Phase Maximum 2 Parameter in seconds (NEMA TS 2 range: 1-255 sec). This time setting
            shall determine the maximum length of time this phase may be held Green in the presence
            of a serviceable conflicting call. In the absence of a serviceable conflicting call the Maximum
            Green timer shall be held reset unless Max Vehicle Recall is enabled for this phase.  This
            may be implemented as the max green timer via an external input, coordMaximumMode or
            other method."
        REFERENCE
            "NEMA TS 2 Clause 3.5.3.1, 3.5.3.2.1.a.(3), 3.5.3.5 and 3.5.4.1 (7)"
::= { phaseEntry 7 }
```

2.2.2.8 Phase Yellow Change Parameter

```
phaseYellowChange   OBJECT-TYPE
        SYNTAX  INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Phase Yellow Change Parameter in tenth seconds (NEMA TS 2 range: 3-25.5 sec).
            Following the Green interval of each phase the CU shall provide a Yellow Change interval
            which is timed according to the Yellow Change parameter for that phase."
        REFERENCE
            "NEMA TS 2 Clause 3.5.3.1 and 3.5.3.2.5.a"
::= { phaseEntry 8 }
```

2.2.2.9 Phase Red Clear Parameter

```
phaseRedClear   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Phase Red Clearance Parameter in tenth seconds (0-25.5 sec).  Following the Yellow
            Change interval for each phase, the CU shall provide a Red Clearance interval which is
            timed according to the Red Clearance parameter for that phase."
        REFERENCE
            "NEMA TS 2 Clause 3.5.3.1 and 3.5.3.2.5.b"
::= { phaseEntry 9 }
```

2.2.2.10 Phase Red Revert

```
phaseRedRevert OBJECT-TYPE
        SYNTAX  INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "Red revert time parameter in tenth seconds .  A minimum Red indication to be timed
            following the Yellow Change interval and prior to the next display of Green on the same
            signal output driver group.
            The unitRedRevert parameter shall act as a minimum red revert time for all signal displays.
            The phaseRedRevert parameter may increase the red revert time for a specific phase.  If the
            phaseRedRevert parameter is less than the unitRedRevert the unitRedRevert time shall be
            used."
::= { phaseEntry 10 }
```

2.2.2.11 Phase Added Initial Parameter

```
phaseAddedInitial   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Phase Added Initial Parameter in tenths of seconds (0-25.5 sec). Added Initial parameter
            (Seconds / Actuation)  shall determine the time by which the variable initial time period will
            be increased from zero with each vehicle actuation received during the associated phase
            Yellow and Red intervals."
        REFERENCE
            "NEMA TS 2 Clause 3.5.3.1 and 3.5.3.2.1.b.(1).(b)"
::= { phaseEntry 11 }
```

2.2.2.12 Phase Maximum Initial Parameter

```
phaseMaximumInitial   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Phase Maximum Initial Parameter in seconds (0-255 sec).  The maximum value of the
             variable initial timing period.  Variable Initial timing shall equal the lesser of [added
             initial(seconds / actuation) * number of actuations]  or [ Max Initial ].  The variable initial time
             shall not be less than  Minimum Green."
        REFERENCE
             "NEMA TS 2 Clause 3.5.3.2.1.b.(1).(c)"
::= { phaseEntry 12 }
```

2.2.2.13 Phase Time Before Reduction Parameter

```
phaseTimeBeforeReduction   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Phase Time Before Reduction (TBR) Parameter in seconds (0-255 sec). The Time Before
             Reduction period shall begin when the phase is Green and there is a serviceable conflicting
             call. If the serviceable conflicting call is removed before completion of this time (or time to
             reduce), the timer shall reset.  Upon completion of the TBR period or the
             CarsBeforeReduction (CBR) parameter is satisfied, whichever occurs first, the linear
             reduction of the allowable gap from the Passage Time shall begin."
        REFERENCE
             "NEMA TS 2 Clause 3.5.3.1 and 3.5.3.2.1.b.(2)"
::= { phaseEntry 13 }
```

2.2.2.14 Phase Cars Before Reduction Parameter

```
phaseCarsBeforeReduction   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
             "Phase Cars Before Reduction (CBR) Parameter (0-255 vehicles). When the phase is Green
             and the sum of the cars waiting (vehicle actuations during Yellow & Red intervals) on
             serviceable conflicting phases equals or exceeds the CBR parameter or the Time Before
             Reduction (TBR) parameter is satisfied, whichever occurs first, the linear reduction of the
             allowable gap from the Passage Time shall begin."
::= { phaseEntry 14 }
```

2.2.2.15 Phase Time To Reduce Parameter

```
phaseTimeToReduce   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Phase Time To Reduce Parameter in seconds (0-255 sec). This parameter shall control the
            rate of reduction of the allowable gap between the Passage Time and Minimum Gap
            setting."
        REFERENCE
            "NEMA TS 2 Clause 3.5.3.1 and 3.5.3.2.1.b.(2)"
::= { phaseEntry 15 }
```

2.2.2.16 Phase Reduce By

```
phaseReduceBy OBJECT-TYPE
        SYNTAX  INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "This object may be used for volume density gap reduction as an alternate to the linear
            reduction defined by NEMA TS 1 and TS 2.  It contains the tenths of seconds to reduce the
            gap by (0.0 - 25.5  seconds).  The frequency of reduction shall produce the Minimum Gap
            after a time equal to the 'phaseTimeToReduce' object."
::= { phaseEntry 16 }
```

2.2.2.17 Phase Minimum Gap Parameter

```
phaseMinimumGap   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Phase Minimum Gap Parameter in tenth seconds (0-25.5 sec). The reduction of the
            allowable gap shall continue until the gap reaches a value equal to or less than the minimum
            gap as set on the Minimum Gap control after which the allowable gap shall remain fixed at
            the values set on the Minimum Gap control."
        REFERENCE
            "NEMA TS 2 Clause 3.5.3.1 and 3.5.3.2.1.b.(2)"
::= { phaseEntry 17 }
```

2.2.2.18 Phase Dynamic Max Limit

```
phaseDynamicMaxLimit  OBJECT-TYPE
        SYNTAX  INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "This object shall determine either the upper or lower limit of the running max in seconds (0-
            255) during dynamic max operation.
            The normal maximum (i.e. Max1, Max2, etc.) shall determine the other limit as follows:
                When dynamicMaxLimit is larger than the normal maximum, it shall become the upper
                limit.
                When dynamicMaxLimit is smaller than the normal maximum, it shall become the lower
                limit.
```

Setting dynamicMaxLimit greater than zero enables dynamic max operation with the normal maximum used as the initial maximum setting. See dynamicMaxStep for details on dynamic max operation.
Maximum recall or a failed detector that is assigned to the associated phase shall disable dynamic max operation for the phase."
::= { phaseEntry 18 }

2.2.2.19 Phase Dynamic Max Step

```
phaseDynamicMaxStep  OBJECT-TYPE
        SYNTAX  INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
```

"This object shall determine the automatic adjustment to the running max in tenth seconds (0-25.5).
When a phase maxes out twice in a row, and on each successive max out thereafter, one dynamic max step value shall be added to the running max until such addition would mean the running max was greater than the larger of normal max or dynamic max limit.
When a phase gaps out twice in a row, and on each successive gap out thereafter, one dynamic max step value shall be subtracted from the running max until such subtraction would mean the running max was less than the smaller of the normal max or the dynamic max limit.
If a phase gaps out in one cycle and maxes out in the next cycle, or vice versa, the running max will not change."
::= { phaseEntry 19 }

2.2.2.20 Phase Startup

```
phaseStartup OBJECT-TYPE
        SYNTAX INTEGER {  other (1),
                          phaseNotOn (2),
                          greenWalk (3),
                          greenNoWalk (4),
                          yellowChange (5),
                          redClear (6) }
        ACCESS read-write
        STATUS mandatory
        DESCRIPTION
```

"The Phase Startup parameter is an enumerated integer which selects the startup state for each phase after restoration of a defined power interruption or activation of the external start input. The following entries are defined:
other; this phase initializes in a state not defined by this standard.
phaseNotOn; this phase initializes in a Red state (the phase is not active and no intervals are timing).
greenWalk; this phase initializes at the beginning of the minimum green and walk timing intervals.
greenNoWalk; this phase initializes at the beginning of the minimum green timing interval.
yellowChange; this phase initializes at the beginning of the Yellow Change interval.
redClear; this phase initializes at the beginning of the Red Clearance interval."

REFERENCE
"NEMA TS 2 Clause 3.5.5.1 and 3.5.5.12"
::= { phaseEntry 20 }

2.2.2.21 Phase Options

phaseOptions OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"Optional phase functions (0 = False/Disabled, 1 = True/Enabled)

Bit Description

0 Enabled Phase - provide a means to define whether this phase is used in the current configuration. A disabled phase shall not provide any outputs nor respond to any phase inputs.

1 Automatic Flash Entry Phase - When Automatic Flash is called, the CU shall service the Entry Phase(s), clear to an All Red, then initiate flashing operation. Support is optional.
REFERENCE NEMA TS 2 Clause 3.9.1.2.1

2 Automatic Flash Exit Phase - The CU shall move immediately to the beginning of the phase(s) programmed as Exit Phase(s) when Automatic Flash terminates. Support is optional
REFERENCE NEMA TS 2 Clause 3.9.1.2.1

3 Non-Actuated 1 - when set to 1 causes a phase to respond to the Call To Non-Actuated 1 input (if present) or other method. Support is optional
REFERENCE NEMA TS 2 Clause 3.5.5.5.8

4 Non-Actuated 2 - when set to 1 causes a phase to respond to the Call To Non-Actuated 2 input (if present) or other method. Support is optional
REFERENCE NEMA TS 2 Clause 3.5.5.5.8

5 Non Lock Detector Memory - when set to 0 will cause the call to be locked at the beginning of the yellow interval. When set to 1 call locking will depend on the detectorOptions object.
REFERENCE NEMA TS 2 Clause 3.5.3.4

6 Min. Vehicle Recall - when set to 1 causes recurring demand for vehicle service on the phase when that phase is not in its Green interval.
REFERENCE NEMA TS 2 Clause 3.5.3.6

7 Max Vehicle Recall - when set to 1 causes a call on a phase such that the timing of the Green interval for that phase shall be extended to Maximum Green time.
REFERENCE NEMA TS 2 Clause 3.5.3.5

8 Ped. Recall - when set to 1 causes a recurring pedestrian demand which shall function in the same manner as an external pedestrian call except that it shall not recycle the pedestrian service until a conflicting phase is serviced
REFERENCE NEMA TS 2 Clause 3.5.3.7

9 Soft Vehicle Recall - when set to 1 causes a call on a phase when all conflicting phases are in green dwell or red dwell and there are no serviceable conflicting calls. Support is optional.

10 Dual Entry Phase - in multi-ring configurations when set to 1 causes the phase to become active upon entry into a concurrency group (crossing a barrier) when no calls exist in its ring within its concurrency group.
REFERENCE NEMA TS 2 Clause 3.5.5.3

11 Simultaneous Gap Disable - in multi-ring configurations when set to 1 disables a gapped out phase from reverting to the extensible portion. Support is optional
REFERENCE NEMA TS 2 Clause 3.5.5.3

12 Guaranteed Passage - when set to 1 enables an actuated phase operating in volume density mode (using gap reduction) to retain the right of way for the unexpired portion of the Passage time following the decision to terminate the green due to a reduced gap. Support is optional

13 Actuated Rest In Walk - when set to 1 causes an actuated phase to rest in Walk when there is no serviceable conflicting call at the end of Walk Timing.

14 Conditional Service Enable - in multi-ring configurations when set to 1 causes a gapped/maxed phase to conditionally service a preceding actuated vehicle phase when sufficient time remains before max time out of the phase(s) not prepared to terminate. Support is optional.
REFERENCE NEMA TS 2 Clause 3.5.3.9

15 AddedInitialCalculation - If set (1) the CU shall compare counts from all associated AddedInitial detectors and use the largest count value for the calculations. If clear (0) the CU shall sum all associated AddedInitial detector counts and use this sum for the calculations. The ability to modify the setting of this bit is optional."

::= { phaseEntry 21 }

2.2.2.22 Phase Ring Parameter

```
phaseRing OBJECT-TYPE
        SYNTAX  INTEGER (1..255)
        ACCESS read-write
        STATUS mandatory
        DESCRIPTION
            "Phase ring number (1..maxRings) that identified the ring which contains the associated
            phase.  This value must not exceed the maxRings object value."
::= { phaseEntry 22 }
```

2.2.2.23 Phase Concurrency

```
phaseConcurrency  OBJECT-TYPE
        SYNTAX  OCTET STRING
        ACCESS read-write
        STATUS mandatory
        DESCRIPTION
            "Each octet contains a phase number (binary value) that may run concurrently with the
            associated phase.  Phases that are contained in the same ring may NOT run concurrently."
::= { phaseEntry 23 }
```

2.2.3 Maximum Phase Groups

```
maxPhaseGroups   OBJECT-TYPE
        SYNTAX   INTEGER (1..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The Maximum Number of Phase Groups (8 Phases per group) this Actuated Controller Unit
            supports. This value is equal to TRUNCATE [(maxPhases + 7) / 8]. This object indicates the
            maximum rows which shall appear in the phaseStatusGroupTable and
            phaseControlGroupTable."
::= { phase 3 }
```

2.2.4 Phase Status Group Table

```
phaseStatusGroupTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF PhaseStatusGroupEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "A table containing Actuated Controller Unit Phase Output (Red, Yellow, & Green) and Call
            (vehicle & pedestrian) status in groups of eight Phases. The number of rows in this table is
            equal to the maxPhaseGroups object."
::= { phase 4 }
```

```
phaseStatusGroupEntry   OBJECT-TYPE
        SYNTAX   PhaseStatusGroupEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "Red, Yellow, & Green Output Status and Vehicle and Pedestrian Call for eight Actuated
             Controller Unit Phases."
        INDEX   { phaseStatusGroupNumber }
::= { phaseStatusGroupTable 1 }

PhaseStatusGroupEntry ::= SEQUENCE {
        phaseStatusGroupNumber              INTEGER,
        phaseStatusGroupReds                INTEGER,
        phaseStatusGroupYellows             INTEGER,
        phaseStatusGroupGreens              INTEGER,
        phaseStatusGroupDontWalks           INTEGER,
        phaseStatusGroupPedClears           INTEGER,
        phaseStatusGroupWalks               INTEGER,
        phaseStatusGroupVehCalls            INTEGER,
        phaseStatusGroupPedCalls            INTEGER,
        phaseStatusGroupPhaseOns            INTEGER,
        phaseStatusGroupPhaseNexts          INTEGER }
```

2.2.4.1 Phase Status Group Number

```
phaseStatusGroupNumber   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The Phase StatusGroup number for objects in this row. This value shall not exceed the
             maxPhaseGroups object value."
::= { phaseStatusGroupEntry 1 }
```

2.2.4.2 Phase Status Group Reds

```
phaseStatusGroupReds   OBJECT-TYPE
      SYNTAX   INTEGER (0..255)
      ACCESS   read-only
      STATUS   mandatory
      DESCRIPTION
           "Phase Red Output Status Mask, when a bit = 1, the Phase Red is currently active. When a bit
           = 0, the Phase Red is NOT currently active.
                Bit 7 = Phase number = (phaseStatusGroupNumber * 8)
                Bit 6 = Phase number = (phaseStatusGroupNumber * 8) - 1
                Bit 5 = Phase number = (phaseStatusGroupNumber * 8) - 2
                Bit 4 = Phase number = (phaseStatusGroupNumber * 8) - 3
                Bit 3 = Phase number = (phaseStatusGroupNumber * 8) - 4
                Bit 2 = Phase number = (phaseStatusGroupNumber * 8) - 5
                Bit 1 = Phase number = (phaseStatusGroupNumber * 8) - 6
                Bit 0 = Phase number = (phaseStatusGroupNumber * 8) - 7"
::= { phaseStatusGroupEntry 2 }
```

2.2.4.3 Phase Status Group Yellows

```
phaseStatusGroupYellows   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Phase Yellow Output Status Mask, when a bit = 1, the Phase Yellow is currently active.
             When a bit = 0, the Phase Yellow is NOT currently active.
                  Bit 7 = Phase number = (phaseStatusGroupNumber * 8)
                  Bit 6 = Phase number = (phaseStatusGroupNumber * 8) - 1
                  Bit 5 = Phase number = (phaseStatusGroupNumber * 8) - 2
                  Bit 4 = Phase number = (phaseStatusGroupNumber * 8) - 3
                  Bit 3 = Phase number = (phaseStatusGroupNumber * 8) - 4
                  Bit 2 = Phase number = (phaseStatusGroupNumber * 8) - 5
                  Bit 1 = Phase number = (phaseStatusGroupNumber * 8) - 6
                  Bit 0 = Phase number = (phaseStatusGroupNumber * 8) - 7"
::= { phaseStatusGroupEntry 3 }
```

2.2.4.4 Phase Status Group Greens

```
phaseStatusGroupGreens   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Phase Green Output Status Mask, when a bit = 1, the Phase Green is currently active.
             When a bit = 0, the Phase Green is NOT currently active.
                  Bit 7 = Phase number = (phaseStatusGroupNumber * 8)
                  Bit 6 = Phase number = (phaseStatusGroupNumber * 8) - 1
                  Bit 5 = Phase number = (phaseStatusGroupNumber * 8) - 2
                  Bit 4 = Phase number = (phaseStatusGroupNumber * 8) - 3
                  Bit 3 = Phase number = (phaseStatusGroupNumber * 8) - 4
                  Bit 2 = Phase number = (phaseStatusGroupNumber * 8) - 5
                  Bit 1 = Phase number = (phaseStatusGroupNumber * 8) - 6
                  Bit 0 = Phase number = (phaseStatusGroupNumber * 8) - 7"
::= { phaseStatusGroupEntry 4 }
```

2.2.4.5 Phase Status Group Dont Walks

```
phaseStatusGroupDontWalks   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Phase Dont Walk Output Status Mask, when a bit = 1, the Phase Dont Walk is currently
             active. When a bit = 0, the Phase Dont Walk is NOT currently active.
                  Bit 7 = Phase number = (phaseStatusGroupNumber * 8)
                  Bit 6 = Phase number = (phaseStatusGroupNumber * 8) - 1
                  Bit 5 = Phase number = (phaseStatusGroupNumber * 8) - 2
                  Bit 4 = Phase number = (phaseStatusGroupNumber * 8) - 3
                  Bit 3 = Phase number = (phaseStatusGroupNumber * 8) - 4
                  Bit 2 = Phase number = (phaseStatusGroupNumber * 8) - 5
                  Bit 1 = Phase number = (phaseStatusGroupNumber * 8) - 6
                  Bit 0 = Phase number = (phaseStatusGroupNumber * 8) - 7"
::= { phaseStatusGroupEntry 5 }
```

2.2.4.6 Phase Status Group Pedestrian clears

```
phaseStatusGroupPedClears   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Phase Ped. Clear Output Status Mask, when a bit = 1, the Phase Ped. Clear is currently
             active. When a bit = 0, the Phase Ped. Clear is NOT currently active.
                  Bit 7 = Phase number = (phaseStatusGroupNumber * 8)
                  Bit 6 = Phase number = (phaseStatusGroupNumber * 8) - 1
                  Bit 5 = Phase number = (phaseStatusGroupNumber * 8) - 2
                  Bit 4 = Phase number = (phaseStatusGroupNumber * 8) - 3
                  Bit 3 = Phase number = (phaseStatusGroupNumber * 8) - 4
                  Bit 2 = Phase number = (phaseStatusGroupNumber * 8) - 5
                  Bit 1 = Phase number = (phaseStatusGroupNumber * 8) - 6
                  Bit 0 = Phase number = (phaseStatusGroupNumber * 8) - 7"
::= { phaseStatusGroupEntry 6 }
```

2.2.4.7 Phase Status Group Walks

```
phaseStatusGroupWalks   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Phase Walk Output Status Mask, when a bit = 1, the Phase Walk is currently active. When
             a bit = 0, the Phase Walk is NOT currently active.
                  Bit 7 = Phase number = (phaseStatusGroupNumber * 8)
                  Bit 6 = Phase number = (phaseStatusGroupNumber * 8) - 1
                  Bit 5 = Phase number = (phaseStatusGroupNumber * 8) - 2
                  Bit 4 = Phase number = (phaseStatusGroupNumber * 8) - 3
                  Bit 3 = Phase number = (phaseStatusGroupNumber * 8) - 4
                  Bit 2 = Phase number = (phaseStatusGroupNumber * 8) - 5
                  Bit 1 = Phase number = (phaseStatusGroupNumber * 8) - 6
                  Bit 0 = Phase number = (phaseStatusGroupNumber * 8) - 7"
::= { phaseStatusGroupEntry 7 }
```

2.2.4.8 Phase Status Group Vehicle Calls

```
phaseStatusGroupVehCalls   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Phase Vehicle Call Status Mask, when a bit = 1, the Phase vehicle currently has a call for
             service. When a bit = 0, the Phase vehicle currently does NOT have a call for service.
                  Bit 7 = Phase number = (phaseStatusGroupNumber * 8)
                  Bit 6 = Phase number = (phaseStatusGroupNumber * 8) - 1
                  Bit 5 = Phase number = (phaseStatusGroupNumber * 8) - 2
                  Bit 4 = Phase number = (phaseStatusGroupNumber * 8) - 3
                  Bit 3 = Phase number = (phaseStatusGroupNumber * 8) - 4
                  Bit 2 = Phase number = (phaseStatusGroupNumber * 8) - 5
                  Bit 1 = Phase number = (phaseStatusGroupNumber * 8) - 6
                  Bit 0 = Phase number = (phaseStatusGroupNumber * 8) - 7"
::= { phaseStatusGroupEntry 8 }
```

2.2.4.9 Phase Status Group Pedestrian Calls

```
phaseStatusGroupPedCalls   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "Phase Pedestrian Call Status Mask, when a bit = 1, the Phase pedestrian currently has a
            call for service. When a bit = 0, the Phase pedestrian currently does NOT have a call for
            service.
                Bit 7 = Phase number = (phaseStatusGroupNumber * 8)
                Bit 6 = Phase number = (phaseStatusGroupNumber * 8) - 1
                Bit 5 = Phase number = (phaseStatusGroupNumber * 8) - 2
                Bit 4 = Phase number = (phaseStatusGroupNumber * 8) - 3
                Bit 3 = Phase number = (phaseStatusGroupNumber * 8) - 4
                Bit 2 = Phase number = (phaseStatusGroupNumber * 8) - 5
                Bit 1 = Phase number = (phaseStatusGroupNumber * 8) - 6
                Bit 0 = Phase number = (phaseStatusGroupNumber * 8) - 7"
::= { phaseStatusGroupEntry 9 }
```

2.2.4.10 Phase Status Group Phase Ons

```
phaseStatusGroupPhaseOns   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "Phase On Status Mask, when a bit = 1, the Phase is currently active. When a bit = 0, the
            Phase currently is NOT active. The phase is ON during the Green, Yellow, & Red Clearance
            intervals of that phase. It shall be permissible for this status to be True (bit=1) during the
            Red Dwell state.
                Bit 7 = Phase number = (phaseStatusGroupNumber * 8)
                Bit 6 = Phase number = (phaseStatusGroupNumber * 8) - 1
                Bit 5 = Phase number = (phaseStatusGroupNumber * 8) - 2
                Bit 4 = Phase number = (phaseStatusGroupNumber * 8) - 3
                Bit 3 = Phase number = (phaseStatusGroupNumber * 8) - 4
                Bit 2 = Phase number = (phaseStatusGroupNumber * 8) - 5
                Bit 1 = Phase number = (phaseStatusGroupNumber * 8) - 6
                Bit 0 = Phase number = (phaseStatusGroupNumber * 8) - 7"
::= { phaseStatusGroupEntry 10 }
```

2.2.4.11 Phase Status Group Phase Nexts

```
phaseStatusGroupPhaseNexts   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "Phase Next Status Mask, when a bit = 1, the Phase currently is committed to be NEXT in
            sequence & remains present until the phase becomes active (On/Timing). When a bit = 0,
            the Phase currently is NOT committed to be NEXT in sequence. The phase next to be
            serviced shall be determined at the end of the green interval of the terminating phase;
            except that if the decision cannot be made at the end of the Green interval, it shall not be
            made until after the end of all Vehicle Change & Clearance intervals.
```

```
                    Bit 7 = Phase number = (phaseStatusGroupNumber * 8)
                    Bit 6 = Phase number = (phaseStatusGroupNumber * 8) - 1
                    Bit 5 = Phase number = (phaseStatusGroupNumber * 8) - 2
                    Bit 4 = Phase number = (phaseStatusGroupNumber * 8) - 3
                    Bit 3 = Phase number = (phaseStatusGroupNumber * 8) - 4
                    Bit 2 = Phase number = (phaseStatusGroupNumber * 8) - 5
                    Bit 1 = Phase number = (phaseStatusGroupNumber * 8) - 6
                    Bit 0 = Phase number = (phaseStatusGroupNumber * 8) - 7"
::= { phaseStatusGroupEntry 11 }
```

2.2.5 Phase Control Table

```
phaseControlGroupTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF PhaseControlGroupEntry
        ACCESS   not-accessible
        STATUS   optional
        DESCRIPTION
            "A table containing Actuated Controller Unit Phase Control in groups of eight phases. The
            number of rows in this table is equal to the maxPhaseGroups object.
            This table is optional for Actuated Controller Units conforming to this specification.  If
            implemented then all objects in this table shall be implemented."
::= { phase 5 }

phaseControlGroupEntry   OBJECT-TYPE
        SYNTAX   PhaseControlGroupEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "Phase Control for eight Actuated Controller Unit phases."
        INDEX   { phaseControlGroupNumber }

::= { phaseControlGroupTable 1 }

PhaseControlGroupEntry ::= SEQUENCE {
        phaseControlGroupNumber             INTEGER,
        phaseControlGroupPhaseOmit          INTEGER,
        phaseControlGroupPedOmit            INTEGER,
        phaseControlGroupHold               INTEGER,
        phaseControlGroupForceOff           INTEGER,
        phaseControlGroupVehCall            INTEGER,
        phaseControlGroupPedCall            INTEGER }
```

2.2.5.1 Phase Control Group Number

```
phaseControlGroupNumber   OBJECT-TYPE
        SYNTAX   INTEGER (1..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The Phase Control Group number for objects in this row. This value shall not exceed the
            maxPhaseGroups object value."
::= { phaseControlGroupEntry 1 }
```

2.2.5.2 Phase Omit Control

```
phaseControlGroupPhaseOmit   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
                "This object is used to allow a remote entity to omit phases from being serviced in the device.
                When a bit = 1, the device shall activate the System Phase Omit control for that phase. When a
                bit = 0, the device shall not activate the System Phase Omit control for that phase.
                        Bit 7 = Phase number = (phaseControlGroupNumber * 8)
                        Bit 6 = Phase number = (phaseControlGroupNumber * 8) - 1
                        Bit 5 = Phase number = (phaseControlGroupNumber * 8) - 2
                        Bit 4 = Phase number = (phaseControlGroupNumber * 8) - 3
                        Bit 3 = Phase number = (phaseControlGroupNumber * 8) - 4
                        Bit 2 = Phase number = (phaseControlGroupNumber * 8) - 5
                        Bit 1 = Phase number = (phaseControlGroupNumber * 8) - 6
                        Bit 0 = Phase number = (phaseControlGroupNumber * 8) - 7

                The device shall reset this object to ZERO when in BACKUP Mode. A write to this object
                shall reset the Backup timer to ZERO."
        REFERENCE

                "NEMA TS 2 Clause 3.5.3.11.2"
::= { phaseControlGroupEntry 2 }
```

2.2.5.3 Pedestrian Omit Control

```
phaseControlGroupPedOmit   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
                "This object is used to allow a remote entity to omit peds from being serviced in the device.
                When a bit = 1, the device shall activate the System Ped Omit control for that phase. When
                a bit = 0, the device shall not activate the System Ped Omit control for that phase.
                        Bit 7 = Phase number = (phaseControlGroupNumber * 8)
                        Bit 6 = Phase number = (phaseControlGroupNumber * 8) - 1
                        Bit 5 = Phase number = (phaseControlGroupNumber * 8) - 2
                        Bit 4 = Phase number = (phaseControlGroupNumber * 8) - 3
                        Bit 3 = Phase number = (phaseControlGroupNumber * 8) - 4
                        Bit 2 = Phase number = (phaseControlGroupNumber * 8) - 5
                        Bit 1 = Phase number = (phaseControlGroupNumber * 8) - 6
                        Bit 0 = Phase number = (phaseControlGroupNumber * 8) - 7

                The device shall reset this object to ZERO when in BACKUP Mode. A write to this object
                shall reset the Backup timer to ZERO."
        REFERENCE
                "NEMA TS 2 Clause 3.5.3.11.3"
::= { phaseControlGroupEntry 3 }
```

2.2.5.4 Phase Hold Control

```
phaseControlGroupHold   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "This object is used to allow a remote entity to hold phases in the device. When a bit = 1, the
            device shall activate the System Phase Hold control for that phase. When a bit = 0, the
            device shall not activate the System Phase Hold control for that phase.
                Bit 7 = Phase number = (phaseControlGroupNumber * 8)
                Bit 6 = Phase number = (phaseControlGroupNumber * 8) - 1
                Bit 5 = Phase number = (phaseControlGroupNumber * 8) - 2
                Bit 4 = Phase number = (phaseControlGroupNumber * 8) - 3
                Bit 3 = Phase number = (phaseControlGroupNumber * 8) - 4
                Bit 2 = Phase number = (phaseControlGroupNumber * 8) - 5
                Bit 1 = Phase number = (phaseControlGroupNumber * 8) - 6
                Bit 0 = Phase number = (phaseControlGroupNumber * 8) - 7

            The device shall reset this object to ZERO when in BACKUP Mode. A write to this object
            shall reset the Backup timer to ZERO."
        REFERENCE
            "NEMA TS 2 Clause 3.5.3.11.1"
::= { phaseControlGroupEntry 4 }
```

2.2.5.5 Phase Force Off Control

```
phaseControlGroupForceOff   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "This object is used to apply force offs on a per phase basis. When a bit = 1, the device shall
            activate the System Phase Force Off control for that phase. When a bit = 0, the device shall
            not activate the System Phase Force Off control for that phase.  When the phase green
            terminates, the associated bit shall be reset to 0.
                Bit 7 = Phase number = (phaseControlGroupNumber * 8)
                Bit 6 = Phase number = (phaseControlGroupNumber * 8) - 1
                Bit 5 = Phase number = (phaseControlGroupNumber * 8) - 2
                Bit 4 = Phase number = (phaseControlGroupNumber * 8) - 3
                Bit 3 = Phase number = (phaseControlGroupNumber * 8) - 4
                Bit 2 = Phase number = (phaseControlGroupNumber * 8) - 5
                Bit 1 = Phase number = (phaseControlGroupNumber * 8) - 6
                Bit 0 = Phase number = (phaseControlGroupNumber * 8) - 7

            The device shall reset this object to ZERO when in BACKUP Mode. A write to this object
            shall reset the Backup timer to ZERO."
::= { phaseControlGroupEntry 5 }
```

2.2.5.6 Vehicle Call Control

```
phaseControlGroupVehCall   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "This object is used to allow a remote entity to place calls for vehicle service in the device.
            When a bit = 1, the device shall place a call for vehicle service on that phase. When a bit =
            0, the device shall not place a call for vehicle service on that phase.
                Bit 7 = Phase number = (phaseControlGroupNumber * 8)
                Bit 6 = Phase number = (phaseControlGroupNumber * 8) - 1
                Bit 5 = Phase number = (phaseControlGroupNumber * 8) - 2
                Bit 4 = Phase number = (phaseControlGroupNumber * 8) - 3
                Bit 3 = Phase number = (phaseControlGroupNumber * 8) - 4
                Bit 2 = Phase number = (phaseControlGroupNumber * 8) - 5
                Bit 1 = Phase number = (phaseControlGroupNumber * 8) - 6
                Bit 0 = Phase number = (phaseControlGroupNumber * 8) - 7

            The device shall reset this object to ZERO when in BACKUP Mode. A write to this object
            shall reset the Backup timer to ZERO."
::= { phaseControlGroupEntry 6 }
```

2.2.5.7 Pedestrian Call Control

```
phaseControlGroupPedCall   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "This object is used to allow a remote entity to place calls for ped service in the device.
            When a bit = 1, the device shall place a call for ped service on that phase. When a bit = 0,
            the device shall not place a call for ped service on that phase.
                Bit 7 = Phase number = (phaseControlGroupNumber * 8)
                Bit 6 = Phase number = (phaseControlGroupNumber * 8) - 1
                Bit 5 = Phase number = (phaseControlGroupNumber * 8) - 2
                Bit 4 = Phase number = (phaseControlGroupNumber * 8) - 3
                Bit 3 = Phase number = (phaseControlGroupNumber * 8) - 4
                Bit 2 = Phase number = (phaseControlGroupNumber * 8) - 5
                Bit 1 = Phase number = (phaseControlGroupNumber * 8) - 6
                Bit 0 = Phase number = (phaseControlGroupNumber * 8) - 7

            The device shall reset this object to ZERO when in BACKUP Mode. A write to this object
            shall reset the Backup timer to ZERO."
::= { phaseControlGroupEntry 7 }
```

2.3 DETECTOR PARAMETERS

```
detector OBJECT IDENTIFIER
::= { asc 2 }
```

-- This defines a node for supporting detector objects.

2.3.1 Maximum Vehicle Detectors

```
maxVehicleDetectors OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The Maximum Number of Vehicle Detectors this Actuated Controller Unit supports. This
            object indicates the maximum rows which shall appear in the vehicleDetectorTable object."
::= { detector 1 }
```

2.3.2 Vehicle Detector Parameter Table

```
vehicleDetectorTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF VehicleDetectorEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "A table containing Actuated Controller Unit vehicle detector parameters. The number of
            rows in this table is equal to the maxVehicleDetectors object."
::= { detector 2 }

vehicleDetectorEntry   OBJECT-TYPE
        SYNTAX   VehicleDetectorEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "Parameters for a specific Actuated Controller Unit detector."
        INDEX   { vehicleDetectorNumber }
::= { vehicleDetectorTable 1 }

        VehicleDetectorEntry ::= SEQUENCE {
        vehicleDetectorNumber               INTEGER ,
        vehicleDetectorOptions              INTEGER ,
        vehicleDetectorCallPhase            INTEGER ,
        vehicleDetectorSwitchPhase          INTEGER ,
        vehicleDetectorDelay                INTEGER ,
        vehicleDetectorExtend               INTEGER ,
        vehicleDetectorQueueLimit           INTEGER ,
        vehicleDetectorNoActivity           INTEGER ,
        vehicleDetectorMaxPresence          INTEGER ,
        vehicleDetectorErraticCounts        INTEGER ,
        vehicleDetectorFailTime             INTEGER ,
        vehicleDetectorAlarms               INTEGER ,
        vehicleDetectorReportedAlarms       INTEGER ,
        vehicleDetectorReset                INTEGER }
```

2.3.2.1 Vehicle Detector Number

```
vehicleDetectorNumber   OBJECT-TYPE
        SYNTAX   INTEGER (1..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
                "The vehicle detector number for objects in this row. The value shall not exceed the
                maxVehicleDetectors object value."
::= { vehicleDetectorEntry 1 }
```

2.3.2.2 Vehicle Detector Options Parameter

```
vehicleDetectorOptions   OBJECT-TYPE
        SYNTAX  INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION

                "Vehicle Detector Options Parameter as follows:
                   Bit   Function
                   7     Call - if set (1) the CU shall place a demand for vehicular service on the assigned
                         phase when the phase is not timing the green interval.
                   6     Queue - if set (1) the CU shall extend the green interval of the assigned phase until
                         a gap occurs (no actuation) or until the green has been active longer than the
                         vehicleDetectorQueueLimit time.  This is optional.
                   5     AddedInitial - if set (1) the CU shall accumulate detector actuation counts for use in
                         the added initial calculations.  Counts shall be accumulated from the beginning of
                         the yellow interval to the beginning of the green interval.
                   4     Passage - if set (1) the CU shall maintain a reset to the associated phase passage
                         timer for the duration of the detector actuation when the phase is green.
                   3     Red Lock Call - if set (1) the detector will lock a call to the assigned phase if an
                         actuation occurs while the phase is not timing Green or Yellow.  This mode is
                         optional.
                   2     Yellow Lock Call - if set (1) the detector will lock a call to the assigned phase if an
                         actuation occurs while the phase is not timing Green.
                   1     Occupancy Detector - if set (1) the detector collects data for the associated detector
                         occupancy object(s).  This capability may not be supported on all detector inputs to
                         a device.
                   0     Volume Detector - if set (1) the detector collects data for the associated detector
                         volume object(s).  This capability may not be supported on all detector inputs to a
                         device."
::= { vehicleDetectorEntry 2}
```

2.3.2.3 Vehicle Detector Call Phase Parameter

```
vehicleDetectorCallPhase   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
                "This object contains assigned phase number for the detector input associated with this row.
                The associated detector call capability is enabled when this object is set to a non-zero value.
                The value shall not exceed the value of maxPhases"
        REFERENCE
                "NEMA TS 2 Clause 3.5.5.5.4 and 3.5.5.5.5"
::= { vehicleDetectorEntry 4 }
```

2.3.2.4 Vehicle Detector Switch Phase Parameter

```
vehicleDetectorSwitchPhase   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Detector Switch Phase Parameter (i.e., Phase Number). The phase to which a vehicle
            detector actuation shall be switched when the assigned phase is Yellow or Red and the
            Switch Phase is Green"
        REFERENCE
            "NEMA TS 2 Clause 3.5.5.5.4.c"
::= { vehicleDetectorEntry 5 }
```

2.3.2.5 Vehicle Detector Delay Parameter

```
vehicleDetectorDelay   OBJECT-TYPE
        SYNTAX   INTEGER (0..65535)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Detector Delay Parameter in tenth seconds (0–255.0 sec). The period a detector actuation
            (input recognition) shall be delayed when the phase is not Green"
        REFERENCE
            "NEMA TS 2 Clause 3.5.5.5.4.a"
::= { vehicleDetectorEntry 6 }
```

2.3.2.6 Vehicle Detector Extend Parameter

```
vehicleDetectorExtend   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Detector Extend Parameter in tenth seconds (0–25.5 sec). The period a vehicle detector
            actuation (input duration) shall be extended from the point of termination , when the phase is
            Green"
        REFERENCE
            "NEMA TS 2 Clause 3.5.5.5.4.b"
::= { vehicleDetectorEntry 7 }
```

2.3.2.7 Vehicle Detector Queue Limit

```
vehicleDetectorQueueLimit   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "Detector Queue Limit parameter in  seconds (0-255 sec).  The length of time that an
            actuation from a queue detector may continue into the phase green.  This time begins when
            the phase becomes green and when it expires any associated detector inputs shall be
            ignored.  This time may be shorter due to other overriding device parameters (i.e. Maximum
            time, Force Off's, ...)."
::= { vehicleDetectorEntry 8 }
```

2.3.2.8 Vehicle Detector No Activity Parameter

```
vehicleDetectorNoActivity   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Detector No Activity diagnostic Parameter in minutes (0–255 min.) . If an active detector
            does not exhibit an actuation in the specified period, it is considered a fault by the
            diagnostics and the detector is classified as Failed. A value of 0 for this object shall disable
            this diagnostic for this detector."
        REFERENCE
            "NEMA TS 2 Clause 3.9.3.1.4.1"
::= { vehicleDetectorEntry 9 }
```

2.3.2.9 Vehicle Detector Maximum Presence Parameter

```
vehicleDetectorMaxPresence   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Detector Maximum Presence diagnostic Parameter in minutes (0-255 min.). If an active
            detector exhibits continuous detection for too long a period, it is considered a fault by the
            diagnostics and the detector is classified as Failed. A value of 0 for this object shall disable
            this diagnostic for this detector."
        REFERENCE
            "NEMA TS 2 Clause 3.9.3.1.4.2"
::= { vehicleDetectorEntry 10 }
```

2.3.2.10 Vehicle Detector Erratic Counts Parameter

```
vehicleDetectorErraticCounts   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Detector Erratic Counts diagnostic Parameter in counts/minute (0-255 cpm). If an active
            detector exhibits excessive actuations, it is considered a fault by the diagnostics and the
            detector is classified as Failed. A value of 0 for this object shall disable this diagnostic for
            this detector."
        REFERENCE
            "NEMA TS 2 Clause 3.9.3.1.4.3"
::= { vehicleDetectorEntry 11 }
```

2.3.2.11 Vehicle Detector Fail Time Parameter

```
vehicleDetectorFailTime   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "Detector Fail Time in seconds (0..255).  If a detector diagnostic indicates that the
            associated detector input is failed, then a call shall be placed on the associated phase
            during all non-green intervals.
            When each green interval begins the call shall be maintained for the length of time specified
            by this object and then removed.
```

If the value of this object equals the maximum value (255) then a constant call shall be placed on the associated phase (max recall).

If the value of this object equals zero then no call shall be placed on the associated phase for any interval (no recall).

Compliant devices may support a limited capability for this object (i.e. only max recall or max recall and no recall). At a minimum the max recall setting must be supported."

::= { vehicleDetectorEntry 12 }

2.3.2.12 Vehicle Detector Alarms

vehicleDetectorAlarms OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"This object shall return indications of detector alarms. Detector Alarms are indicated as follows:

Bit Definition
0 No Activity Fault: This detector has been flagged as non-operational due to lower than expected activity by the CU detector diagnostic.
1 Max Presence Fault: This detector has been flagged as non-operational due to a presence indicator that exceeded the maximum expected time by the CU detector diagnostic.
2 Erratic Output Fault: This detector has been flagged as non-operational due to erratic outputs (excessive counts) by the CU detector diagnostic.
3 Communications Fault: Communications to the device (if present) have failed.
4 Configuration Fault: Detector is assigned but is not supported.
5-6 Reserved.
7 Other Fault: The detector has failed due to some other cause.

Once set a bit shall maintain its state as long as the condition exists. The bit shall clear when the condition no longer exists."

::= { vehicleDetectorEntry 13 }

2.3.2.13 Vehicle Detector Reported Alarms

vehicleDetectorReportedAlarms OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS optional
DESCRIPTION
"This object shall return detector device reported alarms (via some communications mechanism). Inductive Loop Detector Alarms are indicated as follows:

Bit Definition
0 Other
1 Watchdog Fault: This detector has been flagged as non-operational due to a watchdog error.
2 Open Loop Fault: This detector has been flagged as non-operational due to an open loop (broken wire).
3 Shorted Loop Fault: This detector has been flagged as non-operational due to a shorted loop wire.
4 Excessive Change Fault: This detector has been flagged as non-operational due to an inductance change that exceeded expected values.
5-7 Reserved

Once set a bit shall maintain its state as long as the condition exists. The bit shall clear when the condition no longer exists."

::= { vehicleDetectorEntry 14 }

2.3.2.14 Vehicle Detector Reset

```
vehicleDetectorReset OBJECT-TYPE
        SYNTAX   INTEGER (0..1)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "This object when set to TRUE (non-zero) shall cause the CU to command the associated
             detector to reset.  This object shall automatically return to FALSE (zero)  after the CU has
             issued the reset command.

             NOTE: this may affect other detector (detector channels) that are physically attached to a
             common reset line."
::= { vehicleDetectorEntry 15 }
```

2.3.3 Maximum Vehicle Detector Status Groups

```
maxVehicleDetectorStatusGroups OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The maximum number of detector status groups (8 detectors per group) this device
             supports.  This value is equal to TRUNCATE [(maxVehicleDetectors + 7 ) / 8].  This object
             indicates the maximum number of rows which shall appear in the
             vehicleDetectorStatusGroupTable object."
::= { detector 3 }
```

2.3.4 Vehicle Detector Status Group Table

```
vehicleDetectorStatusGroupTable OBJECT-TYPE
        SYNTAX   SEQUENCE OF VehicleDetectorStatusGroupEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "A table containing detector status in groups of eight detectors.  The number of rows in this
             table is equal to the maxVehicleDetectorStatusGroups object."
::= { detector 4 }

vehicleDetectorStatusGroupEntry OBJECT-TYPE
        SYNTAX   VehicleDetectorStatusGroupEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "A group (row) of detector status."
        INDEX  { vehicleDetectorNumber }
::= { vehicleDetectorStatusGroupTable  1 }

VehicleDetectorStatusGroupEntry ::= SEQUENCE {
        vehicleDetectorStatusGroupNumber          INTEGER ,
        vehicleDetectorStatusGroupActive          INTEGER ,
        vehicleDetectorStatusGroupAlarms          INTEGER  }
```

2.3.4.1 Detector Status Group Number

```
vehicleDetectorStatusGroupNumber OBJECT-TYPE
        SYNTAX   INTEGER (1..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The detector status group number for objects in this row.  This value shall not exceed the
             maxVehicleDetectorStatusGroups object value."
::= { vehicleDetectorStatusGroupEntry 1 }
```

2.3.4.2 Detector Status Group Active

```
vehicleDetectorStatusGroupActive OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "This object shall return the detection status of each detector associated with the group.
             Each detector shall be represented as ON (detect) or OFF (no-detect) by individual bits in
             this object.  If a detector is ON then the associated bit shall be set (1).  If a detector is OFF
             then the associated bit shall be clear (0).
                Bit   Description
                7     Detector number = ( vehicleDetectorStatusGroupNumber * 8)
                6     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 1
                5     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 2
                4     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 3
                3     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 4
                2     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 5
                1     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 6
                0     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 7"
::= { vehicleDetectorStatusGroupEntry 2 }
```

2.3.4.3 Detector Alarm Status

```
vehicleDetectorStatusGroupAlarms OBJECT-TYPE
        SYNTAX  INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION

             "This object shall return the alarm status of the detectors associated with the group.  Each
             detector alarm status shall be represented as ON or OFF by individual bits in this object.  If
             any detector alarm (defined in the vehicleDetectorAlarm object) is active the associated bit
             shall be set (1).  If a detector alarm is not active the associated bit shall be clear (0).
                Bit   Description
                7     Detector number = ( vehicleDetectorStatusGroupNumber * 8)
                6     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 1
                5     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 2
                4     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 3
                3     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 4
                2     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 5
                1     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 6
                0     Detector number = ( vehicleDetectorStatusGroupNumber * 8) - 7"
::= { vehicleDetectorStatusGroupEntry 3 }
```

2.3.5 Volume / Occupancy report

volumeOccupancyReport OBJECT IDENTIFIER
::= { detector 5 }

-- This node contains the objects necessary to support volume / occupancy reporting .

2.3.5.1 Volume / Occupancy Sequence

```
volumeOccupancySequence   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "This object defines a Sequence Number for Volume / Occupancy data collection.  This
            object is used to detect duplicate or missing reports.  The value cycles within the limits of 0
            to 255.  This object is incremented by one at the expiration of the volumeOccupancyPeriod
            time."
::= { volumeOccupancyReport 1 }
```

2.3.5.2 Volume / Occupancy Period

```
volumeOccupancyPeriod   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "This object defines the number of seconds (0-255) that comprise the volume / occupancy
            collection period.  When the collection period expires the device shall increment the
            volumeOccupancySequence,  update the volumeOccupancyTable entries and reset the
            volume occupancy timer."
::= { volumeOccupancyReport 2 }
```

2.3.5.3 Active Volume / Occupancy Detectors

```
activeVolumeOccupancyDetectors   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The number of detectors in this device.  This object indicates how many rows are in the
            volumeOccupancyTable object.  There shall be a row for every detector that is collecting
            volume or occupancy data (refer to detectorOptions in the detectorTable)."
::= { volumeOccupancyReport 3 }
```

2.3.5.4 Volume / Occupancy Table

```
volumeOccupancyTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF VolumeOccupancyEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "A table containing Detector Volume and Occupancy data collected. The number of rows in
            this table is equal to the activeVolumeOccupancyDetectors object."
::= { volumeOccupancyReport 4 }
```

```
volumeOccupancyEntry   OBJECT-TYPE
        SYNTAX   VolumeOccupancyEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "The Volume and Occupancy data collected for one of the detectors in the device."
        INDEX   { vehicleDetectorNumber }
::= { volumeOccupancyTable 1 }

VolumeOccupancyEntry ::=   SEQUENCE {
        detectorVolume       INTEGER,
        detectorOccupancy    INTEGER  }
```

2.3.5.4.1 Volume data

```
detectorVolume   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Detector Volume data collected over the Volume / Occupancy Period.  This value shall
             range from 0 to 254 indicating the volume of traffic crossing the associated detectorNumber
             during the collection period.

             The value 255 shall indicate volume overflow."
::= { volumeOccupancyEntry 1 }
```

2.3.5.4.2 Occupancy data

```
detectorOccupancy   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Detector Occupancy data collected over the Volume / Occupancy Period or Detector Unit
             Diagnostic Information.  The value of the object shall indicate occupancy or detector
             diagnostic information as follows:
                Range       Meaning
                0-200       Detector Occupancy in 0.5% Increments
                201-209     Reserved
                210         Max Presence Fault
                211         No Activity Fault
                212         Open loop Fault
                213         Shorted loop Fault
                214         Excessive Change Fault
                215         Reserved
                216         Watchdog Fault
                217         Erratic Output Fault
                218-255     Reserved

             Faults shall be indicated for all collection periods during which a fault is detected if either
             occupancy data or volume data is being collected.  The highest numbered fault shall be
             presented if more than one fault is active (i.e. indicate OpenLoop rather than NoActivity)."
::= { volumeOccupancyEntry 2 }
```

2.3.6 Maximum Pedestrian Detectors

```
maxPedestrianDetectors OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The Maximum Number of Pedestrian Detectors this Actuated Controller Unit supports. This
             object indicates the maximum rows which shall appear in the pedestrianDetectorTable
             object."
::= { detector 6 }
```

2.3.7 Pedestrian Detector Parameter Table

```
pedestrianDetectorTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF PedestrianDetectorEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "A table containing Actuated Controller Unit pedestrian detector parameters. The number of
             rows in this table is equal to the maxPedestrianDetectors object."
::= { detector 7 }

pedestrianDetectorEntry   OBJECT-TYPE
        SYNTAX   PedestrianDetectorEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "Parameters for a specific Actuated Controller Unit pedestrian detector."
        INDEX   { pedestrianDetectorNumber }
::= { pedestrianDetectorTable 1 }

PedestrianDetectorEntry ::= SEQUENCE {
        pedestrianDetectorNumber          INTEGER,
        pedestrianDetectorCallPhase       INTEGER,
        pedestrianDetectorNoActivity      INTEGER,
        pedestrianDetectorMaxPresence     INTEGER,
        pedestrianDetectorErraticCounts   INTEGER,
        pedestrianDetectorAlarms          INTEGER }
```

2.3.7.1 Pedestrian Detector Number

```
pedestrianDetectorNumber   OBJECT-TYPE
        SYNTAX   INTEGER (1..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The pedestrianDetector number for objects in this row. The value shall not exceed the
             maxPedestrianDetectors object value."
::= { pedestrianDetectorEntry 1 }
```

2.3.7.2 Pedestrian Detector Call Phase Parameter

```
pedestrianDetectorCallPhase   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "This object contains assigned phase number for the pedestrian detector input associated
            with this row.  The associated detector call capability is enabled when this object is set to a
            non-zero value. The value shall not exceed the value of maxPhases."
::= { pedestrianDetectorEntry 2 }
```

2.3.7.3 Pedestrian Detector No Activity Parameter

```
pedestrianDetectorNoActivity   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Pedestrian Detector No Activity diagnostic Parameter in minutes (0–255 min.) . If an active
            detector does not exhibit an actuation in the specified period, it is considered a fault by the
            diagnostics and the detector is classified as Failed. A value of 0 for this object shall disable
            this diagnostic for this detector."
        REFERENCE
            "NEMA TS 2 Clause 3.9.3.1.4.1"
::= { pedestrianDetectorEntry 3 }
```

2.3.7.4 Pedestrian Detector Maximum Presence Parameter

```
pedestrianDetectorMaxPresence   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Pedestrian Detector Maximum Presence diagnostic Parameter in minutes (0-255 min.). If
            an active detector exhibits continuous detection for too long a period, it is considered a fault
            by the diagnostics and the detector is classified as Failed.  A value of 0 for this object shall
            disable this diagnostic for this detector."
        REFERENCE
            "NEMA TS 2 Clause 3.9.3.1.4.2"
::= { pedestrianDetectorEntry 4 }
```

2.3.7.5 Pedestrian Detector Erratic Counts Parameter

```
pedestrianDetectorErraticCounts   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Pedestrian Detector Erratic Counts diagnostic Parameter in counts/minute (0-255 cpm). If
            an active detector exhibits excessive actuations, it is considered a fault by the diagnostics
            and the detector is classified as Failed. A value of 0 for this object shall disable this
            diagnostic for this detector."
        REFERENCE
            "NEMA TS 2 Clause 3.9.3.1.4.3"
::= { pedestrianDetectorEntry 5 }
```

2.3.7.6 Pedestrian Detector Alarms

pedestrianDetectorAlarms OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"This object shall return indications of detector alarms. Detector Alarms are indicated as follows:

Bit	Definition
0	No Activity Fault: This detector has been flagged as non-operational due to lower than expected activity by the CU detector diagnostic.
1	Max Presence Fault: This detector has been flagged as non-operational due to a presence indicator that exceeded the maximum expected time by the CU detector diagnostic.
2	Erratic Output Fault: This detector has been flagged as non-operational due to erratic outputs (excessive counts) by the CU detector diagnostic.
3	Communications Fault: Communications to the device (if present) have failed.
4	Configuration Fault: Detector is assigned but is not supported.
5-6	Reserved.
7	Other Fault: The detector has failed due to some other cause.

Once set a bit shall maintain its state as long as the condition exists. The bit shall clear when the condition no longer exists."
::= { pedestrianDetectorEntry 6 }

2.4 UNIT PARAMETERS

unit OBJECT IDENTIFIER
::= { asc 3 }
--"This defines a node for supporting unit objects."

2.4.1 StartUp Flash Parameter

unitStartUpFlash OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"Unit Start up Flash time parameter in seconds (0 to 255 sec). The period/state (Start-Up Flash occurs when power is restored following a device defined power interruption. During the Start-Up Flash state, the Fault Monitor and Voltage Monitor outputs shall be inactive (if present)."
REFERENCE
"NEMA TS 2 Clause 3.9.1.1"
::= { unit 1 }

2.4.2 Automatic Ped Clear Parameter

```
unitAutoPedestrianClear   OBJECT-TYPE
        SYNTAX   INTEGER {   disable(1),
                             enable (2) }
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Unit Automatic Ped Clear parameter (1 = False/Disable 2=True/Enable). When enabled, the
             CU shall time the Pedestrian Clearance interval when Manual Control Enable is active and
             prevent the Pedestrian Clearance interval from being terminated by the Interval Advance
             input."
        REFERENCE
             "NEMA TS 2 Clause 3.5.3.10"
::= { unit 2 }
```

2.4.3 Backup Time Parameter

```
unitBackupTime   OBJECT-TYPE
        SYNTAX   INTEGER (0..65535)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "The Backup Time in seconds (0-65535). When one of the defined system control
             parameters is SET, the backup timer is reset and times the unitBackupTime interval.  If the
             unitBackupTime interval expires without a SET operation to one of the system control
             parameters, then the CU shall revert to Backup Mode.
             A value of zero (0) shall disable this feature.
             The system control parameters are:
             phaseControlGroupPhaseOmit, phaseControlGroupPedOmit, phaseControlGroupHold,
             phaseControlGroupForceOff, phaseControlGroupVehCall, phaseControlGroupPedCall,
             unitControl, systemPatternControl, systemSyncControl, preemptControlState,
             ringControlGroupStopTime, ringControlGroupForceOff, ringControlGroupMax2,
             ringControlGroupMaxInhibit, ringControlGroupPedRecycle, ringControlGroupRedRest,
             ringControlGroupOmitRedClear and unitControl."
::= { unit 3 }
```

2.4.4 Unit Red Revert Parameter

```
unitRedRevert   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "The red revert in tenth seconds ( 0.0 - 25.5 seconds).  This value shall provide the minimum
             red revert time for all phases (i.e. if it is greater than a phaseRedRevert object value, then
             this value shall be used as the red revert time for the affected phase).
             This object provides a minimum Red indication following the Yellow Change interval and
             prior to the next display of Green on the same signal output driver group."
::= { unit 4 }
```

2.4.5 Unit Control Status

```
unitControlStatus   OBJECT-TYPE
        SYNTAX  INTEGER {   other (1),
                            systemControl (2),
                            systemStandby (3),
                            backupMode(4),
                            manual (5),
                            timebase (6),
                            interconnect (7),
                            interconnectBackup (8)}
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The Control Mode for Pattern, Flash, or Free at the device:
               systemControl;        control by master or central commands.
               systemStandby;        control by local based on master or central command to use local
                                     control.
               backupMode;           Backup Mode (see Terms).
               Manual;               control by entry other than zero in coordOperationalMode.
               timebase;             control by the local Time Base.
               interconnect;         control by the local Interconnect inputs.
               interconnectBackup; control by local TBC due to invalid Interconnect inputs or loss of sync.
               other;                control by a source other than those listed above.
            The value of this object is ignored when in BACKUP Mode.
            A write to this object shall reset the BACKUP timer to ZERO."
::= { unit 5 }
```

2.4.6 Unit Flash Status

```
unitFlashStatus   OBJECT-TYPE
        SYNTAX   INTEGER {   other(1),
                             notFlash(2),
                             automatic(3),
                             localManual(4),
                             faultMonitor(5),
                             mmu(6),
                             startup(7) ,
                             preempt (8)}.
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The Flash modes:
               notFlash; the CU is not in Flash
               automatic; the CU is currently in an Automatic Flash state.
               localManual; the Controller Unit Local Flash input is active, MMU Flash input is not
                         active, and Flash is not commanded by the Master.
               faultMonitor; the CU is currently in a Fault Monitor State.
               mmu; the Controller Unit MMU Flash input is active and the CU is not in Start-Up Flash.
               startup; the CU is currently timing the Start-Up Flash period.
               preempt; the CU is currently timing the preempt Flash.
               other; the CU is in flash for some other reason."
::= { unit 6 }
```

2.4.7 Unit Alarm Status 2

```
unitAlarmStatus2   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Device Alarm Mask 2 ( 0 = False, 1 = True) as follows:
                 Bit 7 - Reserved.
                 Bit 6 - Reserved.
                 Bit 5 - Reserved.
                 Bit 4 - Stop Time - When either CU Stop Time Input becomes active.
                 Bit 3 - External Start - When the CU External Start becomes active.
                 Bit 2 - Response Fault - When any NEMA TS2 Port 1 response frame fault occurs.
                 Bit 1 - Low Battery - When any battery voltage falls below the required level.
                 Bit 0 - Power Restart - When power returns after a power interruption.
             Once set, a bit shall maintain it's state as long as the condition exists."
::= { unit 7 }
```

2.4.8 Unit Alarm Status 1

```
unitAlarmStatus1   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Device Alarm Mask 1 ( 0 = False, 1 = True) as follows:
                 Bit 7 - CoordActive - When coordination is active and not preempted or overridden.
                 Bit 6 - Local Free - When any of the Controller Unit inputs and/or programming cause it to
                         not respond to coordination control.
                 Bit 5 - Local Flash - When the Controller Unit Local Flash input becomes active, MMU
                         Flash input is not active, and Flash is not commanded by the system.
                 Bit 4 - MMU Flash - When the Controller Unit MMU Flash input remains active for a
                         period of time exceeding the Start-Up Flash time.
                 Bit 3 - Cycle Fail - When a local Controller Unit is operating in the non-coordinated mode,
                         whether the result of a Cycle Fault or Free being the current normal mode, and
                         cycling diagnostics indicate that a serviceable call exists that has not been
                         serviced for two cycles.
                 Bit 2 - Coord Fail - When a Coord Fault is in effect and a Cycle Fault occurs again within
                         two cycles of the coordination retry.
                 Bit 1 - Coord Fault - When a Cycle Fault is in effect and the serviceable call has been
                         serviced within two cycles after the Cycle Fault.
                 Bit 0 - Cycle Fault - When the Controller Unit is operating in the coordinated mode and
                         cycling diagnostics indicate that a serviceable call exists that has not been
                         serviced for two cycles.
             Once set, a bit shall maintain it's state as long as the condition exists."
::= { unit 8 }
```

2.4.9 Short Alarm Status

```
shortAlarmStatus   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Short Alarm Mask ( 0 = False, 1 = True) as follows:
```

Bit 7 - Critical Alarm; When the Stop Time input is active.
Bit 6 - Non-Critical Alarm; When an physical alarm input is active.
Bit 5 - Detector Fault; When any detectorAlarm fault occurs.
Bit 4 - Coordination Alarm; When the CU is not running the called pattern without offset correction within three cycles of the command. An offset correction requiring less than three cycles due to cycle overrun caused by servicing a pedestrian call shall not cause a Coordination Alarm.
Bit 3 - Local Override; When any external input or CU programming has prevented the device from responding to a system pattern command.
Bit 2 - Local Cycle Zero; When running coordinated and the local coord cycle timer has passed through zero.
Bit 1 - T&F Flash; When either the Local Flash or MMU Flash input becomes active.
Bit 0 - Preempt - When any of the CU Preempt inputs become active.
Once set, a bit shall maintain it's state as long as the condition exists."
::= { unit 9 }

2.4.10 Unit Control

unitControl OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"This object is used to allow a remote entity to activate unit functions in the device (0 = False / Disabled, 1 = True / Enabled) as follows:
Bit 7 = Dimming Enable - when set to 1, causes channel dimming to operate as configured.
REFERENCE NEMA TS 2 Clause 3.9.2
Bit 6 = Interconnect - when set to 1, shall cause the interconnect inputs to operate at a higher priority than the timebase control (TBC On Line).
REFERENCE NEMA TS 2 Clause 3.6.2.3 and 3.8.3
Bit 5 = Walk Rest Modifier - when set to 1, causes non-actuated phases to remain in the timed-out Walk state (rest in Walk) in the absence of a serviceable conflicting call.
REFERENCE NEMA TS 2 Clause 3.5.5.5.13
Bit 4 = Call to Non-Actuated 2 - when set to 1, causes any phase(s) appropriately programmed in the phaseOptions object to operate in the Non-Actuated Mode.
REFERENCE NEMA TS 2 Clause 3.5.5.5.8
Bit 3 = Call to Non-Actuated 1 - when set to 1, causes any phase(s) appropriately programmed in the phaseOptions object to operate in the Non-Actuated Mode.
REFERENCE NEMA TS 2 Clause 3.5.5.5.8
Bit 2 = External Minimum Recall - when set to 1, causes a recurring demand on all vehicle phases for a minimum vehicle service.
REFERENCE NEMA TS 2 Clause 3.5.5.5.9
Bit 1 = Reserved
Bit 0 = Reserved
When a bit = 1, the device shall activate the Unit control. When a bit = 0, the device shall not activate the Unit control.

The device shall reset this object to ZERO when in BACKUP Mode. A write to this object shall reset the BACKUP timer."
::= { unit 10 }

2.4.11 Maximum Alarm Groups

```
maxAlarmGroups OBJECT-TYPE
        SYNTAX  INTEGER(0..255)
        ACCESS   read-only
        STATUS   optional
        DESCRIPTION
             "This object contains the maximum number of alarm groups (8 alarm inputs per group) this
             device supports.  This object indicates the maximum rows which shall appear in the
             alarmGroupTable object."
::= { unit 11 }
```

2.4.12 Alarm Group Table

```
alarmGroupTable OBJECT-TYPE
        SYNTAX  SEQUENCE OF AlarmGroupEntry
        ACCESS   not-accessible
        STATUS   optional
        DESCRIPTION
             "This table contains alarm input status in groups of eight inputs.  The number of rows in this
             table is equal to the maxAlarmGroups object."
::= { unit 12 }

alarmGroupEntry OBJECT-TYPE
        SYNTAX  AlarmGroupEntry
        ACCESS  not-accessible
        STATUS   mandatory
        DESCRIPTION
             "Status for eight alarm inputs."
        INDEX  { alarmGroupNumber }
::= { alarmGroupTable 1 }

AlarmGroupEntry::= SEQUENCE {
        alarmGroupNumber  INTEGER,
        alarmGroupState      INTEGER}
```

2.4.12.1 Alarm Group Number

```
alarmGroupNumber OBJECT-TYPE
      SYNTAX  INTEGER (0..255)
      ACCESS   read-only
      STATUS   mandatory
      DESCRIPTION
           "The alarm group number for objects in this row.  This value shall not exceed the
           maxAlarmGroups object value."
::= { alarmGroupEntry 1 }
```

2.4.12.2 Alarm Group State

```
alarmGroupState OBJECT-TYPE
        SYNTAX  INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Alarm input state bit field.  When a bit = 1, the associated physical alarm input is active.
             When a bit = 0, the associated alarm input is NOT active.
```

Bit 7 = Alarm Input number = (alarmGroupNumber * 8)
Bit 6 = Alarm Input number = (alarmGroupNumber * 8) -1
Bit 5 = Alarm Input number = (alarmGroupNumber * 8) -2
Bit 4 = Alarm Input number = (alarmGroupNumber * 8) -3
Bit 3 = Alarm Input number = (alarmGroupNumber * 8) -4
Bit 2 = Alarm Input number = (alarmGroupNumber * 8) -5
Bit 1 = Alarm Input number = (alarmGroupNumber * 8) -6
Bit 0 = Alarm Input number = (alarmGroupNumber * 8) -7"
::= {alarmGroupEntry 2 }

2.4.13 Maximum Special Function Outputs

```
maxSpecialFunctionOutputs   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The Maximum Number of Special Functions this Actuated Controller Unit supports."
::= { unit 13 }
```

2.4.14 Special Function Output Table

```
specialFunctionOutputTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF SpecialFunctionOutputEntry
        ACCESS   not-accessible
        STATUS   optional
        DESCRIPTION
            "A table containing Actuated Controller Unit special function output objects. The number of
            rows in this table is equal to the maxSpecialFunctionOutputs object."
::= { unit 14 }

specialFunctionOutputEntry   OBJECT-TYPE
        SYNTAX   SpecialFunctionOutputEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "Control for  Actuated Controller Unit system special functions."
        INDEX   { specialFunctionOutputNumber }
::= { specialFunctionOutputTable 1 }

SpecialFunctionOutputEntry ::= SEQUENCE {
        specialFunctionOutputNumber             INTEGER,
        specialFunctionOutputState              INTEGER }
```

2.4.14.1 Special Function Output Number

```
specialFunctionOutputNumber OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "The special function output number associated with the  specialFunctionOutputState object
            in this row. This value shall not exceed the maxSpecialFunctionOutputs object value."
::= { specialFunctionOutputEntry 1 }
```

2.4.14.2 Special Function Output Control

```
specialFunctionOutputState OBJECT-TYPE
        SYNTAX   INTEGER (0..1)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "The special function output (logical or physical)on the device may be controlled by this
             object.  When this object is non-zero then the associated special function output signal shall
             be ON.  When this object is zero then the associated special function output signal shall be
             OFF  A read of this object shall reflect the current state of the special function output."
::= { specialFunctionOutputEntry  2 }
```

2.5 COORDINATION PARAMETERS

```
coord OBJECT IDENTIFIER
::= { asc  4 }
```

-- The coord node contains objects that support coordination configuration, status and control functions for -- the device.

2.5.1 Coord Operational Mode Parameter

```
coordOperationalMode   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "This object defines the operational mode for coordination.  The possible modes are:
                Value Description
                0        Automatic - this mode provides for coord operation, free, and flash to be
                         determined automatically by the possible sources (i.e. Interconnect, Time Base, or
                         System Commands).
                1-253 Manual Pattern - these modes provides for Coord operation running this pattern.
                         This selection of pattern overrides all other pattern commands.
                254    Manual Free - this mode provides for Free operation without coordination or
                         Automatic Flash from any source.
                255    Manual Flash - this mode provides for Automatic Flash without coordination or
                         Free from any source."
        REFERENCE
             "NEMA TS 2 Clause 3.6.2.4"
::= { coord 1 }
```

2.5.2 Coord Correction Mode Parameters

```
coordCorrectionMode   OBJECT-TYPE

        SYNTAX   INTEGER {   other (1),
                             dwell (2),
                             shortway (3),
                             addOnly (4) }
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "This object defines the Coord Correction Mode. The possible modes are:
                other; the coordinator establishes a new offset by a mechanism not defined in this
                       standard.
```

dwell; when changing offset, the coordinator shall establish a new offset by dwelling in the coord phase(s) until the desired offset is reached.
shortway (Smooth); when changing offset, the coordinator shall establish a new offset by adding or subtracting to/from the timings in a manner that limits the cycle change. This operation is performed in a device specific manner.
addOnly; when changing offset, the coordinator shall establish a new offset by adding to the timings in a manner that limits the cycle change. This operation is performed in a device specific manner."
::= { coord 2 }

2.5.3 Coord Maximum Mode Parameters

```
coordMaximumMode   OBJECT-TYPE
        SYNTAX   INTEGER {   other (1),
                             maximum1 (2),
                             maximum2 (3),
                             maxInhibit (4) }
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
          "This object defines the Coord Maximum Mode. The possible modes are:
                other; the maximum mode is determined by some other mechanism not defined in this
                        standard.
                maximum1; the internal Maximum 1 Timing shall be effective while coordination is
                        running a pattern.
                maximum2; the internal Maximum 2 Timing shall be effective while coordination is
                        running a pattern.
                maxInhibit; the internal Maximum Timing shall be inhibited while coordination is running a
                        pattern."
::= { coord 3 }
```

2.5.4 Coord Force Mode Parameters

```
coordForceMode   OBJECT-TYPE
        SYNTAX   INTEGER {   other(1),
                             floating (2),
                             fixed (3) }
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "This object defines the Pattern Force Mode. The possible modes are:
                other; the CU implements a mechanism not defined in this standard.
                floating; each phase will be forced the split time after it becomes active. This allows
                         unused split time to revert to the coord phase.
                fixed; each phase will be forced at a fixed position in the cycle. This allows unused split
                         time to revert to the following phase."
::= { coord 4 }
```

2.5.5 Maximum Patterns Parameters

```
maxPatterns   OBJECT-TYPE
        SYNTAX   INTEGER (0..253)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The maximum number of Patterns this Actuated Controller Unit supports. This object
            indicates how many rows are in the patternTable object. Pattern 254 is always Flash mode
            and pattern 255 is always Free mode."
::= { coord 5 }
```

2.5.6 Pattern Table Type

```
patternTableType  OBJECT-TYPE
        SYNTAX  INTEGER {    other (1),
                             patterns (2),
                             offset3 (3),
                             offset5 (4) }
        ACCESS  read-only
        STATUS  mandatory
        DESCRIPTION
            "This object provides information about any special organizational structure required for the
            pattern table.  The defined structures are as follows:
               other -     The pattern table setup is not described in this standard, refer to device
                           manual.
               patterns -  Each row of the pattern table represents a unique pattern and has no
                           dependencies on other rows.
               offset3 -   The pattern table is organized into plans which have three offsets.  Each plan
                           uses three consecutive rows.  Only the offsetTime value may vary between
                           each of the three rows.  Plan 1 is contained in rows 1,  2 and 3,  Plan 2 is
                           contained in rows 4, 5 and 6, Plan 3 is in rows 7, 8 and 9, etc..
               offset5 -   The pattern table is organized into plans which have five offsets.  Each plan
                           occupies five consecutive rows.  Only the offsetTime value may vary between
                           each of the rows.  Plan 1 is contained in rows 1, 2, 3, 4 and 5, Plan 2 is
                           contained in rows , 6,7, 8, 9 and 10, Plan 3 is contained in rows  11, 12, 13, 14
                           and 15, etc..."
        REFERENCE
            "NEMA TS 2 Clause 3.6.2.1 and 3.6.2.2"
::= { coord 6 }
```

2.5.7 Pattern Table

```
patternTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF PatternEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "A table containing Actuated Controller Unit coordination Pattern parameters. The number of
            rows in this table is equal to the maxPatterns object."
::= { coord 7 }
```

```
patternEntry   OBJECT-TYPE
        SYNTAX   PatternEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "Parameters for a specific Actuated Controller Unit pattern."
        INDEX   { patternNumber }
::= { patternTable 1 }

PatternEntry ::= SEQUENCE {
        patternNumber                          INTEGER,
        patternCycleTime                       INTEGER,
        patternOffsetTime                      INTEGER,
        patternSplitNumber                     INTEGER,
        patternSequenceNumber                  INTEGER }
```

2.5.7.1 Pattern Number Entry

```
patternNumber   OBJECT-TYPE
        SYNTAX   INTEGER (0..253)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The pattern number for objects in this row. This value shall not exceed the maxPatterns
             object value."
::= { patternEntry 1 }
```

2.5.7.2 Pattern Cycle Time

```
patternCycleTime   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "The patternCycleTime object specifies the length of the pattern cycle in seconds (NEMA TS
             2 range: 30-255).  A pattern cycle time less than adequate to service the minimum
             requirements of all phases shall result in Free mode.  If the pattern cycle time is zero  and
             the associated split table (if any)  contains values greater than zero then the CU shall utilize
             the split time values as maximum values for each phase."
        REFERENCE
             "NEMA TS 2 Clause 3.6.2.1.1"
::= { patternEntry 2 }
```

2.5.7.3 Pattern Offset Time Parameter

```
patternOffsetTime   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "The patternOffsetTime defines by how many seconds (NEMA TS 2 range: 0-254) the local
             time zero shall lag the system time zero (synchronization pulse) for this pattern.. An offset
             value equal to or greater than the cycle time shall result in Free being the operational mode.
             While this condition exists, the Local Free bit of unitAlarmStatus and the LocalOverride bit of
             shortAlarmStatus shall be set to one (1)."
        REFERENCE
             "NEMA TS 2 Clause 3.6.2.2"
```

```
::= { patternEntry 3 }
```

2.5.7.4 Pattern Split Number Parameter

```
patternSplitNumber   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "This object is used to locate information in the splitTable to use for this pattern. This value
            shall not exceed the maxSplits object value."
::= { patternEntry 4 }
```

2.5.7.5 Pattern Sequence Number Parameter

```
patternSequenceNumber   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "This object is used to locate information in the sequenceTable to use with this pattern. This
            value shall not exceed the maxSequences object value."
::= { patternEntry 5 }
```

2.5.8 Maximum Splits

```
maxSplits   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The maximum number of Split Plans this Actuated Controller Unit supports. This object
            indicates how many Split plans are in the splitTable object."
::= { coord 8 }
```

2.5.9 Split Table

```
splitTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF SplitEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "A table containing Actuated Controller Unit coordination split parameters. The number of
            rows in this table is equal to maxSplits."
::= { coord 9 }

splitEntry   OBJECT-TYPE
        SYNTAX   SplitEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "Split type Parameters for a specific Actuated Controller Unit phase."
        INDEX   { splitNumber, splitPhase }
::= { splitTable 1 }
```

```
SplitEntry ::= SEQUENCE {
        splitNumber             INTEGER,
        splitPhase              INTEGER,
        splitTime               INTEGER,
        splitMode               INTEGER,
        splitCoordPhase         INTEGER }
```

2.5.9.1 Split Number

```
splitNumber   OBJECT-TYPE
        SYNTAX   INTEGER (1..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
                "The object defines which rows of the split table comprise a split group. All rows that have
                the same splitNumber are in the same split group. The value of this object shall not exceed
                the maxSplits object value."
::= { splitEntry 1 }
```

2.5.9.2 Split Phase Number

```
splitPhase   OBJECT-TYPE
        SYNTAX   INTEGER (1..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
                "The phase number for objects in this row. The value of this object shall not exceed the
                maxPhases object value."
::= { splitEntry 2 }
```

2.5.9.3 Split Time Parameter

```
splitTime   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
                "The time in seconds the splitPhase is allowed to receive (i.e. before a Force Off is applied)
                when constant demands exist on all phases.  In floating coordForceMode, this is always the
                maximum time a non-coordinated phase is allowed to receive.  In fixed coordForceMode, the
                actual allowed time may be longer if a previous phase gapped out.
                The splitTime includes all phase clearance times for the associated phase.  The split time
                shall be longer than the sum of the phase minimum service requirements (Minimum Green,
                Yellow Change, Red Clearance, Walk, Pedestrian Clearance, etc.) for the phase.  When the
                time is NOT adequate to service the minimum service requirements of the phase, Free
                Mode shall be the result.
                If the cycleTime entry of the associated patternTable entry is zero (i.e. the device is in Free
                Mode), then the value of this object shall be applied as a maximum time for the associated
                phase.
                If the critical path through the phase diagram is less than the cycleTime entry of the
                associated patternTable entry, all extra time is allotted to the coordination phase in each
                ring.
                If the critical path through the phase diagram is greater than the cycleTime entry of the
                associated patternTable entry (and the cycleTime is not zero) the device shall operate in the
                Free Mode.
```

```
            While the Free Mode condition exists, the Local Override bit of shortAlarm shall be set to
            one (1)."
        REFERENCE
            "NEMA TS 2 Clause 3.6.2.1.2"
::= { splitEntry 3 }
```

2.5.9.4 Split Mode Parameter

```
splitMode   OBJECT-TYPE
        SYNTAX   INTEGER {   other(1),
                             none (2),
                             minimumVehicleRecall (3),
                             maximumVehicleRecall (4),
                             pedestrianRecall (5),
                             maximumVehicleAndPedestrianRecall (6),
                             phaseOmitted (7) }
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "This object defines operational characteristics of the phase. The following options are
            available:
                other; the operation is not specified in this standard
                none; no split mode control.
                minimumVehicleRecall; this phase operates with a minimum vehicle recall.
                maximumVehicleRecall; this phase operates with a maximum vehicle recall.
                pedestrianRecall; this phase operates with a pedestrian recall.
                maximumVehicleAndPedestrianRecall; this phase operates with a maximum vehicle &
                        pedestrian recall.
                phaseOmitted; this phase is omitted."
::= { splitEntry 4 }
```

2.5.9.5 Split Coordinated Phase

```
splitCoordPhase  OBJECT-TYPE
        SYNTAX   INTEGER (0..1)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "To select the associated phase as a coordinated phase this object shall be set to TRUE
            (non zero)."
::= { splitEntry 5 }
```

2.5.10 Coordination Pattern Status

```
coordPatternStatus   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "This object defines the running coordination pattern / mode in the device.  The possible
            values are:
                Value    Description
                0        Not used
                1-253    Pattern, indicates the currently running pattern
                254      Free, indicates Free operation without coordination.
                255      Flash, indicates Automatic Flash without coordination."
::= { coord 10 }
```

2.5.11 Local Free Status

```
localFreeStatus   OBJECT-TYPE
        SYNTAX   INTEGER {   other(1),
                             notFree(2),
                             commandFree(3),
                             transitionFree(4),
                             inputFree(5),
                             coordFree(6),
                             badPlan(7),
                             badCycleTime(8),
                             splitOverrun (9),
                             invalidOffset (10),
                             failed(11) }
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The Free modes:
                notFree - The unit is not running in free mode.
                commandFree - the current pattern command is the Free mode pattern.
                transitionFree - the CU has a pattern command but is cycling to a point to begin
                        coordination.
                inputFree - one of the CU inputs cause it to not respond to coordination.
                coordFree - the CU programming for the called pattern is to run Free.
                badPlan - Free - the called pattern is invalid.
                badCycleTimeFree - the specified cycle time is not adequate to service the all phase
                        minimum service requirements.
                splitOverrun - Free - the sum of the critical path splitTime's exceed the programmed
                        patternCycleTime value..
                invalidOffset - Free - the programmed patternOffsetTime value exceeds the programmed
                        patternCycleTime value.
                failedFree - cycling diagnostics have called for Free.
                other - Some other condition has caused the device to run in free mode."
::= { coord 11 }
```

2.5.12 Coordination Cycle Status

```
coordCycleStatus   OBJECT-TYPE
        SYNTAX   INTEGER (0..65535)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The Local Cycle Timer position for the running pattern in the device. Value 0 to 510. Count
             down from current cycle's Cycle Length to ZERO.  This value may exceed the cycleTime
             value during correction cycle's (cycleTime + dwell )."
::= { coord 12 }
```

2.5.13 Coordination Sync Status

```
coordSyncStatus   OBJECT-TYPE
        SYNTAX   INTEGER (0..65536)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The Sync Cycle Timer position for the running pattern in the device. Value 0 to 510.  It
             represents the time that has elapsed since system time zero."
::= { coord 13 }
```

2.5.14 System Pattern Control

systemPatternControl OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"This object is used to establish the Called System Pattern / Mode for the device. The possible values are:

Value	Description
0	Standby - the system relinquishes control of the device.
1-253	Pattern - these values indicate the system commanded pattern
254	Free - this value indicates a call for Free
255	Flash - this value indicates a call for Automatic Flash

If an unsupported / invalid pattern is called, Free shall be the operational mode.
The value of this object is ignored in BACKUP mode.
A write to this object shall reset the BACKUP timer to ZERO."
::= { coord 14 }

2.5.15 System Sync Control

systemSyncControl OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"This object is used to set the current System Sync Cycle Timer in the Unit to a Value 0 to 255. The device shall recognize a write to this object as a command to set the timer equal to the value in the object. The Sync Cycle Timer counts up from 0. When the value in the object is 255, the System Sync Cycle Timer shall be referenced to the local Time Base in accordance with its programming.
This CU must maintain an accuracy of 0.1 seconds based on the receipt of the SET packet.
The value of this object is ignored when in BACKUP Mode.
A write to this object shall reset the BACKUP timer to ZERO."
::= { coord 15 }

2.6 TIME BASE PARAMETERS

timebase OBJECT IDENTIFIER
::= { asc 5 }

-- "This object is an identifier used to group all objects for support of timebase functions. If a device
-- implements timebase functions then these objects shall be supported."

2.6.1 Time Base Pattern Sync Parameter

timebasePatternSync OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"Pattern Sync Reference in minutes past midnight. When the value is 0xFFFF, the controller unit shall use the Action time as the Sync Reference for that pattern."
REFERENCE
"NEMA TS 2 Clause 3.8.2"
::= { timebase 1 }

2.6.2 Maximum Time Base Actions

```
maxTimebaseAscActions  OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The Maximum Number of Actions this device supports. This object indicates the maximum
             rows which shall appear in the timebaseAscActionTable object."
::= { timebase 2 }
```

2.6.3 Time Base ASC Action Table

```
timebaseAscActionTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF TimebaseAscActionEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "A table containing Actuated Controller Unit Time Base action parameters. The number of
             rows in this table is equal to the maxTimebaseAscActions object."
::= { timebase 3 }

timebaseAscActionEntry   OBJECT-TYPE
        SYNTAX   TimebaseAscActionEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "Action Parameters for a Actuated Controller Unit Time Base Program."
        INDEX   { timebaseAscActionNumber }
::= { timebaseAscActionTable 1 }

TimebaseAscActionEntry ::= SEQUENCE {
        timebaseAscActionNumber          INTEGER,
        timebaseActionPattern            INTEGER,
        timebaseActionAuxillaryFunction  INTEGER,
        timebaseActionSpecialFunction    INTEGER }
```

2.6.3.1 Time Base Action Number Entry

```
timebaseAscActionNumber   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The time base Action number for objects in this row. This value shall not exceed the
             maxTimebaseAscActions object value."
::= { timebaseAscActionEntry 1 }
```

2.6.3.2 Time Base Action Pattern Parameter

```
timebaseActionPattern   OBJECT-TYPE
          SYNTAX   INTEGER (0..255)
          ACCESS   read-write
          STATUS   mandatory
          DESCRIPTION
                "The Pattern that shall be active when this Action is active.  The value shall not exceed the
                value of maxPatterns.  A pattern of zero indicates that no pattern is being selected."
::= { timebaseAscActionEntry 2 }
```

2.6.3.3 Time Base Action Auxiliary Function Parameter

```
timebaseActionAuxillaryFunction   OBJECT-TYPE
          SYNTAX   INTEGER (0..255)
          ACCESS   read-write
          STATUS   mandatory
          DESCRIPTION
                "The Auxiliary functions that shall be active when this Action is active.
                    Bit   Function
                    0     Auxiliary function 1 enabled if set (non-zero), disabled if clear (zero).
                    1     Auxiliary function 2 enabled if set (non-zero), disabled if clear (zero).
                    2     Auxiliary function 3 enabled if set (non-zero), disabled if clear (zero).
                    3-7   Reserved"
::= { timebaseAscActionEntry 3 }
```

2.6.3.4 Time Base Action Special Function Parameter

```
timebaseActionSpecialFunction   OBJECT-TYPE
          SYNTAX   INTEGER (0..255)
          ACCESS   read-write
          STATUS   mandatory
          DESCRIPTION
                "The Special Functions that shall be active when this Action is active.
                    Bit 7 - Special Function 8 (0 =False / Disabled, 1 = True /  Enabled)
                    Bit 6 - Special Function 7 (0 =False / Disabled, 1 = True /  Enabled)
                    Bit 5 - Special Function 6 (0 =False / Disabled, 1 = True /  Enabled)
                    Bit 4 - Special Function 5 (0 =False / Disabled, 1 = True /  Enabled)
                    Bit 3 - Special Function 4 (0 =False / Disabled, 1 = True /  Enabled)
                    Bit 2 - Special Function 3 (0 =False / Disabled, 1 = True /  Enabled)
                    Bit 1 - Special Function 2 (0 =False / Disabled, 1 = True /  Enabled)
                    Bit 0 - Special Function 1 (0 =False / Disabled, 1 = True /  Enabled)"
::= { timebaseAscActionEntry 4 }
```

2.6.4 Time Base ASC Action Status

```
timebaseAscActionStatus  OBJECT-TYPE
          SYNTAX  INTEGER(0..255)
          ACCESS  read-only
          STATUS  mandatory
          DESCRIPTION
                "This object indicates the current time base Action Table row that will be used when the CU
                is in Time Base operation.  A value of zero indicates that no time base Action is selected."
::= { timebase 4 }
```

2.7 PREEMPT PARAMETERS

```
preempt OBJECT IDENTIFIER
        ::= { asc 6 }
-- The preempt node contains objects that support preempt input functions for the device.
```

2.7.1 Maximum Preempts

```
maxPreempts   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The Maximum Number of Preempts this Actuated Controller Unit supports. This object
            indicates the maximum rows which shall appear in the preemptTable object."
        REFERENCE
            "NEMA TS 2 Clause 3.7"
::= { preempt 1 }
```

2.7.2 Preempt Table

```
preemptTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF PreemptEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "A table containing Actuated Controller Unit preemption parameters. The number of rows in
            this table is equal to the maxPreempts object."
::={ preempt 2 }

preemptEntry   OBJECT-TYPE
        SYNTAX   PreemptEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "Parameters for a specific Actuated Controller Unit preemptor."
        INDEX    { preemptNumber }

::={ preemptTable 1}

PreemptEntry ::= SEQUENCE {
        preemptNumber              INTEGER,
        preemptControl             INTEGER,
        preemptLink                INTEGER,
        preemptDelay               INTEGER,
        preemptMinimumDuration     INTEGER,
        preemptMinimumGreen        INTEGER,
        preemptMinimumWalk         INTEGER,
        preemptEnterPedClear       INTEGER,
        preemptTrackGreen          INTEGER,
        preemptDwellGreen          INTEGER,
        preemptMaximumPresence     INTEGER,
        preemptTrackPhase          OCTET STRING,
        preemptDwellPhase          OCTET STRING,
        preemptDwellPed            OCTET STRING,
        preemptExitPhase           OCTET STRING ,
        preemptState               INTEGER }
```

2.7.2.1 Preempt Number

```
preemptNumber   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The preempt number for objects in this row. The value shall not exceed the maxPreempts
             object value."
::= { preemptEntry 1 }
```

2.7.2.2 Preempt Control Parameter

```
preemptControl   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Preempt Miscellaneous Control Parameter Mask ( 0 = False / Disabled, 1 = True /
             Enabled) as follows:
                Bit   Function
                7-4
                3     Flash Dwell - the CU shall cause the phases listed in the preemptDwellPhase object
                      to flash Yellow during the Dwell phase.  All active phases not listed in the
                      preemptDwellPhase shall flash Red.  If any conflicting phase numbers are listed in
                      the preemptDwellPhase then all active phases shall flash Red.
                      This control is optional.
                2     Preempt Override preemptNumber + 1 - provide a means to define whether this
                      preempt shall NOT override the next higher numbered Preempt.  When set (1) this
                      preempt shall not override the next higher numbered preempt.  This parameter shall
                      be ignored when preemptNumber equals maxPreempts.
                1     Preempt Override Flash - provide a means to define whether this preempt shall NOT
                      override Automatic Flash.  When set (1) this preempt shall not override Automatic
                      Flash.
                0     Non-Locking Memory - provide a means to enable an operation which does not
                      require detector memory. When set (1) a preempt sequence shall not occur if the
                      preempt input terminates prior to expiration of the preemptDelay time."
        REFERENCE
             "NEMA TS 2 Clause 3.7.2.1 and 3.7.2.2"
::= { preemptEntry 2 }
```

2.7.2.3 Preempt Link Parameter

```
preemptLink   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "This object provides a means to define a higher priority preempt to be combined (linked)
             with this preempt. At the end of Dwell time, the linked preempt shall receive an automatic
             call which shall be maintained as long as the demand for this preempt is active. Any value
             that is not a higher priority preempt or a valid preempt shall be ignored. The value shall not
             exceed the maxPreempts object value."
::= { preemptEntry 3 }
```

2.7.2.4 Preempt Delay Parameter

```
preemptDelay   OBJECT-TYPE
        SYNTAX   INTEGER (0..65535)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Preempt Delay Time in seconds ( 0-600 sec). This value determines the time the preempt
            input shall be active prior to initiating any preempt sequence.  A non-locking preempt input
            which is removed prior to the completion of this time shall not cause a preempt sequence to
            occur."
::= { preemptEntry 4 }
```

2.7.2.5 Preempt Duration Parameter

```
preemptMinimumDuration   OBJECT-TYPE
        SYNTAX   INTEGER (0..65535)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Preempt Minimum Duration Time in seconds (0..65535). This value determines the
            minimum time during which the preempt is active.  Duration begins timing at the end of
            Preempt Delay (if non zero) and will prevent an exit from the Dwell state until this time has
            elapsed."
::= { preemptEntry 5 }
```

2.7.2.6 Preempt Minimum Green Parameter

```
preemptMinimumGreen   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "Preempt Minimum Green Time in seconds (0-255 sec). A preempt initiated transition shall
            not cause the termination of an existing Green prior to its display for lesser of the phase’s
            Minimum Green time or this period."
::= { preemptEntry 6 }
```

2.7.2.7 Preempt Minimum Walk Parameter

```
preemptMinimumWalk   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "Preempt Minimum Walk Time in seconds (0-255 sec). A preempt initiated transition shall
            not cause the termination of an existing Walk prior to its display for the lesser of the phase’s
            Minimum Walk time or this period."
::= { preemptEntry 7 }
```

2.7.2.8 Preempt Enter Pedestrian Clear Parameter

```
preemptEnterPedClear   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
             "Enter Ped ClearTime in seconds (0-255 sec). This parameter controls the ped clear timing
             for a normal Walk signal terminated by a preempt initiated transition.  A preempt initiated
             transition shall not cause the termination of a Pedestrian Clearance prior to its display for the
             lesser of the phase's Pedestrian Clearance time or this period."
::= { preemptEntry 8 }
```

2.7.2.9 Preempt Track Green Parameter

```
preemptTrackGreen   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Track Clear Green Time in seconds (0-255 sec). This parameter controls the green timing
             for the track clearance movement. The phase(s) active during the Track Green interval are
             enabled in preemptTrackPhase object."
::= { preemptEntry 9 }
```

2.7.2.10 Preempt Minimum Dwell Parameter

```
preemptDwellGreen   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Minimum Dwell Time in seconds (1-255 sec). This parameter controls the minimum timing
             for the dwell movement. The phase(s) active during the Dwell interval are enabled in
             preemptDwellPhase object.

             The Dwell interval shall not terminate prior to the completion of Preempt Duration Time,
             Preempt Dwell Time, & the call is no longer present."
::= { preemptEntry 10 }
```

2.7.2.11 Preempt Maximum Presence Parameter

```
preemptMaximumPresence OBJECT-TYPE
        SYNTAX   INTEGER (0..65535)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Preempt Maximum Presence time in seconds (0-65535 sec).  This value determines the
             maximum time which a preempt call may remain active and be considered valid.  When the
             preempt call has been active for this time period, the CU shall return to normal operation.
             This preempt call shall be considered invalid until such time as a change in state occurs (no
             longer active).  When set to zero the preempt maximum presence time is disabled."
::= { preemptEntry 11 }
```

2.7.2.12 Preempt Track Phase Parameter

```
preemptTrackPhase   OBJECT-TYPE
        SYNTAX   OCTET STRING
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Each octet within the octet string contains a phaseNumber(binary value) that shall be active
            during the Preempt Track Green interval."
::= { preemptEntry 12 }
```

2.7.2.13 Preempt Dwell Phase Parameters

```
preemptDwellPhase   OBJECT-TYPE
        SYNTAX   OCTET STRING
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Each octet within the octet string contains a phaseNumber (binary value)that is allowed
            during the Preempt Dwell interval."
::= { preemptEntry 13 }
```

2.7.2.14 Preempt Dwell Ped Parameters

```
preemptDwellPed   OBJECT-TYPE
        SYNTAX   OCTET STRING
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "Each octet within the octet string contains a phaseNumber (binary value)indicating a
            pedestrian movement that is allowed during the Preempt Dwell interval."
::= { preemptEntry 14 }
```

2.7.2.15 Preempt Exit Phase Parameters

```
preemptExitPhase   OBJECT-TYPE
        SYNTAX   OCTET STRING
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Each octet within the octet string contains a phaseNumber (binary value)that shall be active
            following Preempt."
::= { preemptEntry 15 }
```

2.7.2.16 Preempt State

```
preemptState OBJECT-TYPE
        SYNTAX  INTEGER {   other (1),
                            notActive (2),
                            notActiveWithCall (3),
                            entryStarted (4),
                            trackService (5),
                            dwell (6),
                            linkActive (7),
                            exitStarted (8),
                            maxPresence (9) }
        ACCESS  read-only
        STATUS  optional
        DESCRIPTION
            "Preempt State provides status on which state the associated preempt is in.  The states are
            as follows:
                State               Description
                notActive           preempt input is not active, this preempt is not active.
                notActiveWithCall   preempt input is active, preempt service has not started.
                entryStarted        preempt service is timing the entry intervals.
                trackService        preempt service is timing the track intervals.
                dwell               preempt service is timing the dwell intervals.
                linkActive          preempt service is performing linked operation.
                exitStarted         preempt service is timing the exit intervals.
                maxPresence         preempt input has exceeded maxPresence time
                other               preempt service is not specified in this standard."
::= { preemptEntry 16}
```

2.7.3 Preempt Control Table

```
preemptControlTable OBJECT-TYPE
        SYNTAX SEQUENCE OF PreemptControlEntry
        ACCESS not-accessible
        STATUS optional
        DESCRIPTION
            "This table contains the control objects that allow the preempts to be activated remotely.
            There shall be one control object for each preempt input supported by the device.  The
            number of rows in this table shall be equal to maxPreempts."
::= { preempt 3 }

preemptControlEntry   OBJECT-TYPE
        SYNTAX   PreemptControlEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "Control objects for each preempt input. These objects allow the system to activate preempt
            functions remotely."
        INDEX   { preemptControlNumber }
::= { preemptControlTable 1 }

PreemptControlEntry ::= SEQUENCE {
        preemptControlNumber                    INTEGER,
        preemptControlState                     INTEGER}
```

2.7.3.1 Preempt Control Number

```
preemptControlNumber  OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "This object shall indicate the preempt input number controlled by the associated
             preemptControlState object in this row."
::= { preemptControlEntry  1 }
```

2.7.3.2 Preempt Control State

```
preemptControlState OBJECT-TYPE
        SYNTAX   INTEGER (0..1)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "This object when set to ON (non-zero) shall cause the associated preempt actions to occur
             unless the actions have already been started by the physical preempt input.  The preempt
             shall remain active as long as this object is ON or the physical preempt input is ON.  This
             object when set to OFF (zero) shall cause the physical preempt input to control the
             associated preempt actions.
             The value of this object is ignored in BACKUP mode.  A write to this object shall reset the
             BACKUP timer."
::= { preemptControlEntry  2 }
```

2.8 RING PARAMETERS

```
ring  OBJECT IDENTIFIER
      ::= { asc  7 }
--The ring node contains objects that support ring configuration, status and control functions in the device.
```

2.8.1 Maximum Rings

```
maxRings   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The value of this object shall specify the maximum number of rings this device supports."
::= { ring 1 }
```

2.8.2 Maximum Sequences

```
maxSequences  OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The value of this object shall specify the maximum number of sequence plans this device
             supports."
::= { ring 2 }
```

2.8.3 Sequence Table

```
sequenceTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF SequenceEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "This table contains all the sequence plans for the controller.  A sequence plan shall consist
             of one row for each ring that the CU supports.  Each row defines the phase service order for
             that ring."
::= { ring 3 }

sequenceEntry   OBJECT-TYPE
        SYNTAX   SequenceEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "Phase Sequence Parameters for an Actuated Controller Unit."
        INDEX   { sequenceNumber, sequenceRingNumber }
::= { sequenceTable 1 }

SequenceEntry ::= SEQUENCE {
        sequenceNumber                          INTEGER,
        sequenceRingNumber                      INTEGER,
        sequenceData                            OCTET STRING }
```

2.8.3.1 Sequence Number

```
sequenceNumber  OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS  read-only
        STATUS  mandatory
        DESCRIPTION
             "This number identifies a sequence plan.  Each row of the table contains the phase
             sequence for a ring.  A sequence plan shall consist of one row for each ring that defines the
             phase sequences for that ring."
::= { sequenceEntry 1 }
```

2.8.3.2 Sequence Ring Number

```
sequenceRingNumber  OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS  read-write
        STATUS  mandatory
        DESCRIPTION
             "This number identifies the ring number this phase sequence applies to."
::= { sequenceEntry 2 }
```

2.8.3.3 SequenceData

```
sequenceData   OBJECT-TYPE
        SYNTAX   OCTET STRING
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Each octet is a Phase Number (binary value) within the associated ring number.  The phase
            number value shall not exceed the maxPhases object value.  The order of phase numbers
            determines the phase sequence for the ring.  The phase numbers shall not be ordered in a
            manner that would violate the devices compatibility group."
::= { sequenceEntry 3 }
```

2.8.4 Maximum Ring Control Groups

```
maxRingControlGroups OBJECT-TYPE
        SYNTAX          INTEGER (0..255)
        ACCESS          read-only
        STATUS          mandatory
        DESCRIPTION
            "The maximum number of Ring Control Groups (8 rings per group) this Actuated Controller
            Unit supports.  This value is equal to TRUNCATE[(maxRings + 7) / 8]. This object indicates
            the maximum rows which shall appear in the ringControlGroupTable object."
::= { ring 4 }
```

2.8.5 Ring Control Group Table

```
ringControlGroupTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF RingControlGroupEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "A table containing Actuated Controller Unit Ring Control in groups of eight rings. The
            number of rows in this table is equal to the maxRingControlGroups object."
::= { ring 5 }

ringControlGroupEntry   OBJECT-TYPE
        SYNTAX   RingControlGroupEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "Ring Control for eight Actuated Controller Unit rings."
        INDEX   { ringControlGroupNumber }
::= { ringControlGroupTable 1 }

RingControlGroupEntry ::= SEQUENCE {
        ringControlGroupNumber              INTEGER,
        ringControlGroupStopTime            INTEGER,
        ringControlGroupForceOff            INTEGER,
        ringControlGroupMax2                INTEGER,
        ringControlGroupMaxInhibit          INTEGER,
        ringControlGroupPedRecycle          INTEGER,
        ringControlGroupRedRest             INTEGER,
        ringControlGroupOmitRedClear        INTEGER }
```

2.8.5.1 Ring Control Group Number

```
ringControlGroupNumber   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The Ring Control Group number for objects in this row. This value shall not exceed the
            maxRingControlGroups object value."
::= { ringControlGroupEntry 1 }
```

2.8.5.2 Ring Stop Time Control

```
ringControlGroupStopTime   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "This object is used to allow a remote entity to stop timing in the device. When a bit = 1, the
            device shall activate the System Stop Time control for that ring.
                Bit 7 = Ring number = (ringControlGroupNumber * 8)
                Bit 6 = Ring number = (ringControlGroupNumber * 8) - 1
                Bit 5 = Ring number = (ringControlGroupNumber * 8) - 2
                Bit 4 = Ring number = (ringControlGroupNumber * 8) - 3
                Bit 3 = Ring number = (ringControlGroupNumber * 8) - 4
                Bit 2 = Ring number = (ringControlGroupNumber * 8) - 5
                Bit 1 = Ring number = (ringControlGroupNumber * 8) - 6
                Bit 0 = Ring number = (ringControlGroupNumber * 8) - 7

            The value of this object is ignored in BACKUP Mode. A write to this object shall reset the
            Backup timer."
        REFERENCE
            "NEMA TS 2 Clause 3.5.4.1.6"
::= { ringControlGroupEntry 2 }
```

2.8.5.3 Ring Force Off Control

```
ringControlGroupForceOff   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "This object is used to allow a remote entity to terminate phases via a force off command in
            the device. When a bit = 1, the device shall activate the System Force Off control for that
            ring.
                Bit 7 = Ring number = (ringControlGroupNumber * 8)
                Bit 6 = Ring number = (ringControlGroupNumber * 8) - 1
                Bit 5 = Ring number = (ringControlGroupNumber * 8) - 2
                Bit 4 = Ring number = (ringControlGroupNumber * 8) - 3
                Bit 3 = Ring number = (ringControlGroupNumber * 8) - 4
                Bit 2 = Ring number = (ringControlGroupNumber * 8) - 5
                Bit 1 = Ring number = (ringControlGroupNumber * 8) - 6
                Bit 0 = Ring number = (ringControlGroupNumber * 8) - 7
```

The value of this object is ignored in BACKUP Mode. A write to this object shall reset the Backup timer."
REFERENCE
"NEMA TS 2 Clause 3.5.4.1.1"
::= { ringControlGroupEntry 3 }

2.8.5.4 Ring Max 2 Control

```
ringControlGroupMax2   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "This object is used to allow a remote entity to request maximum 2 timings in the device.
            When a bit = 1, the device shall activate the System Maximum 2 control for that ring.
                Bit 7 = Ring number = (ringControlGroupNumber * 8)
                Bit 6 = Ring number = (ringControlGroupNumber * 8) - 1
                Bit 5 = Ring number = (ringControlGroupNumber * 8) - 2
                Bit 4 = Ring number = (ringControlGroupNumber * 8) - 3
                Bit 3 = Ring number = (ringControlGroupNumber * 8) - 4
                Bit 2 = Ring number = (ringControlGroupNumber * 8) - 5
                Bit 1 = Ring number = (ringControlGroupNumber * 8) - 6
                Bit 0 = Ring number = (ringControlGroupNumber * 8) - 7
            The value of this object is ignored in BACKUP Mode. A write to this object shall reset the
            Backup timer."
        REFERENCE
            "NEMA TS 2 Clause 3.5.4.1.7"
::= { ringControlGroupEntry 4 }
```

2.8.5.5 Ring Max Inhibit Control

```
ringControlGroupMaxInhibit   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "This object is used to allow a remote entity to request internal maximum timings be inhibited
            in the device. When a bit = 1, the device shall activate the System Max Inhibit control for that
            ring.
                Bit 7 = Ring number = (ringControlGroupNumber * 8)
                Bit 6 = Ring number = (ringControlGroupNumber * 8) - 1
                Bit 5 = Ring number = (ringControlGroupNumber * 8) - 2
                Bit 4 = Ring number = (ringControlGroupNumber * 8) - 3
                Bit 3 = Ring number = (ringControlGroupNumber * 8) - 4
                Bit 2 = Ring number = (ringControlGroupNumber * 8) - 5
                Bit 1 = Ring number = (ringControlGroupNumber * 8) - 6
                Bit 0 = Ring number = (ringControlGroupNumber * 8) - 7

            The value of this object is ignored in BACKUP Mode. A write to this object shall reset the
            Backup timer."
        REFERENCE
            "NEMA TS 2 Clause 3.5.4.1.3"
::= { ringControlGroupEntry 5 }
```

2.8.5.6 Ring Ped Recycle Control

```
ringControlGroupPedRecycle   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
              "This object is used to allow a remote entity to request a pedestrian recycle in the device.
              When a bit = 1, the device shall activate the System Ped Recycle control for that ring.
                 Bit 7 = Ring number = (ringControlGroupNumber * 8)
                 Bit 6 = Ring number = (ringControlGroupNumber * 8) - 1
                 Bit 5 = Ring number = (ringControlGroupNumber * 8) - 2
                 Bit 4 = Ring number = (ringControlGroupNumber * 8) - 3
                 Bit 3 = Ring number = (ringControlGroupNumber * 8) - 4
                 Bit 2 = Ring number = (ringControlGroupNumber * 8) - 5
                 Bit 1 = Ring number = (ringControlGroupNumber * 8) - 6
                 Bit 0 = Ring number = (ringControlGroupNumber * 8) - 7

              The value of this object is ignored in BACKUP Mode. A write to this object shall reset the
              Backup timer."
        REFERENCE
              "NEMA TS 2 Clause 3.5.4.1.5"
::= { ringControlGroupEntry 6 }
```

2.8.5.7 Ring Red Rest Control

```
ringControlGroupRedRest   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
              "This object is used to allow a remote entity to request red rest in the device. When a bit = 1,
              the device shall activate the System Red Rest control for that ring.
                 Bit 7 = Ring number = (ringControlGroupNumber * 8)
                 Bit 6 = Ring number = (ringControlGroupNumber * 8) - 1
                 Bit 5 = Ring number = (ringControlGroupNumber * 8) - 2
                 Bit 4 = Ring number = (ringControlGroupNumber * 8) - 3
                 Bit 3 = Ring number = (ringControlGroupNumber * 8) - 4
                 Bit 2 = Ring number = (ringControlGroupNumber * 8) - 5
                 Bit 1 = Ring number = (ringControlGroupNumber * 8) - 6
                 Bit 0 = Ring number = (ringControlGroupNumber * 8) - 7

              The value of this object is ignored when in BACKUP Mode. A write to this object shall reset
              the Backup timer."
        REFERENCE
              "NEMA TS 2 Clause 3.5.4.1.2"
::= { ringControlGroupEntry 7 }
```

2.8.5.8 Ring Omit Red Control

```
ringControlGroupOmitRedClear   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   optional
        DESCRIPTION
            "This object is used to allow a remote entity to omit red clearances in the device. When a bit
            = 1, the device shall activate the System Omit Red Clear control for that ring.
                Bit 7 = Ring number = (ringControlGroupNumber * 8)
                Bit 6 = Ring number = (ringControlGroupNumber * 8) - 1
                Bit 5 = Ring number = (ringControlGroupNumber * 8) - 2
                Bit 4 = Ring number = (ringControlGroupNumber * 8) - 3
                Bit 3 = Ring number = (ringControlGroupNumber * 8) - 4
                Bit 2 = Ring number = (ringControlGroupNumber * 8) - 5
                Bit 1 = Ring number = (ringControlGroupNumber * 8) - 6
                Bit 0 = Ring number = (ringControlGroupNumber * 8) - 7

            The value of this object is ignored in BACKUP Mode. A write to this object shall reset the
            Backup timer."
        REFERENCE
            "NEMA TS 2 Clause 3.5.4.1.4"
::= { ringControlGroupEntry 8 }
```

2.9 CHANNEL PARAMETERS

```
channel OBJECT IDENTIFIER
::= { asc 8 }
```

--This defines a node for supporting channel objects.

2.9.1 Maximum Channels

```
maxChannels   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The Maximum Number of Channels this Actuated Controller Unit supports. This object
            indicates the maximum rows which shall appear in the channelTable object."
::= { channel 1 }
```

2.9.2 Channel Table

```
channelTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF ChannelEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "A table containing Actuated Controller Unit channel parameters. The number of rows in this
            table is equal to the maxChannels object."
::= { channel 2 }
```

```
channelEntry   OBJECT-TYPE
        SYNTAX   ChannelEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "Parameters for a specific Actuated Controller Unit channel."
        INDEX   { channelNumber }
::= { channelTable 1 }

ChannelEntry ::= SEQUENCE {
        channelNumber         INTEGER,
        channelControlSource  INTEGER,
        channelControlType    INTEGER,
        channelFlash          INTEGER,
        channelDim            INTEGER }
```

2.9.2.1 Channel Number

```
channelNumber   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The channel number for objects in this row. This value shall not exceed the maxChannels
            object value."
::= { channelEntry 1 }
```

2.9.2.2 Channel Control Source Parameters

```
channelControlSource   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "This object defines the channel control source (which Phase or Overlap). The value shall
            not exceed maxPhases or maxOverlaps as determined by channelControlType object:
                  Value 00 = No Control (Not In Use)
                  Value 01 = Phase 01 or Overlap A
                  Value 02 = Phase 02 or Overlap B
                          ||
                  Value 15 = Phase 15 or Overlap O
                  Value 16 = Phase 16 or Overlap P
                          etc."
::= { channelEntry 2 }
```

2.9.2.3 Channel Control Type Parameters

```
channelControlType   OBJECT-TYPE
        SYNTAX   INTEGER {   other (1),
                             phaseVehicle (2),
                             phasePedestrian (3),
                             overlap (4) }
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "This object defines the channel control type (Vehicle Phase, Pedestrian Phase, or Overlap):
               phaseVehicle - The channel controls a vehicle phase display.
```

phase Pedestrian - The channel controls a pedestrian phase display.
overlap - The channel controls an overlap display.
other - The channel controls an other type of display."
::= { channelEntry 3 }

2.9.2.4 Channel Flash Parameters

```
channelFlash   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "This object defines the channel state during Automatic Flash.
               Bit   Function
               7-4   Reserved
               3     Flash Alternate Half Hertz (Bit 0 = Off / Disabled & 1 = On / Enabled)
               2     Flash Red (Bit 0 = Off / Red Dark & 1 = On / Flash Red)
               1     Flash Yellow  (Bit 0 = Off / Yellow Dark & 1 = On / Flash Yellow)
               0     Reserved"
::= { channelEntry 4 }
```

2.9.2.5 Channel Dim Parameters

```
channelDim   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "This object defines the channel state during Dimming. Dimming shall be accomplished by
            the elimination of alternate one-half segments from the AC sinusoid applied to the field
            terminals.
               Bit   Function
               7-4   Reserved
               3     Dim Alternate Half Line Cycle (Bit 0 = Off / + half cycle & 1 = On / - half cycle)
               2     Dim Red - Bit 0 = Off / Red Not Dimmed & 1 = On / Dimmed Red
               1     Dim Yellow - Bit 0 = Off / Yellow Not Dimmed & 1 = On / Dimmed Yellow
               0     Dim Green - Bit 0 = Off / Green Not Dimmed & 1 = On / Dimmed Green"
::= { channelEntry 5 }
```

2.9.3 Maximum Channel Status Groups

```
maxChannelStatusGroups   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The maximum number of Channel Status Groups (8 channels per group) this Actuated
            Controller Unit supports. This value is equal to TRUNCATE [(maxChannels + 7) / 8]. This
            object indicates the maximum rows which shall appear in the channelStatusGroupTable
            object."
::= { channel 3 }
```

2.9.4 Channel Status Group Table

```
channelStatusGroupTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF ChannelStatusGroupEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "A table containing Actuated Controller Unit channel output (Red, Yellow, & Green) status in
            groups of eight channels. The number of rows in this table is equal to the
            maxChannelStatusGroups object."
::= { channel 4 }

channelStatusGroupEntry   OBJECT-TYPE
        SYNTAX   ChannelStatusGroupEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
            "Red, Yellow, & Green Output Status for eight Actuated Controller Unit channels."
        INDEX   { channelStatusGroupNumber }
::= { channelStatusGroupTable 1 }

ChannelStatusGroupEntry ::= SEQUENCE {
        channelStatusGroupNumber            INTEGER,
        channelStatusGroupReds              INTEGER,
        channelStatusGroupYellows           INTEGER,
        channelStatusGroupGreens            INTEGER }
```

2.9.4.1 Channel Status Group Number

```
channelStatusGroupNumber   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The channelStatusGroup number for objects in this row. This value shall not exceed the
            maxChannelStatusGroups object value."
::= { channelStatusGroupEntry 1 }
```

2.9.4.2 Channel Status Group Reds

```
channelStatusGroupReds   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "Channel Red Output Status Mask, when a bit = 1, the Channel Red is currently active.
            When a bit = 0, the Channel Red is NOT currently active.
               Bit 7 = Channel number = (channelStatusGroupNumber * 8)
               Bit 6 = Channel number = (channelStatusGroupNumber * 8) - 1
               Bit 5 = Channel number = (channelStatusGroupNumber * 8) - 2
               Bit 4 = Channel number = (channelStatusGroupNumber * 8) - 3
               Bit 3 = Channel number = (channelStatusGroupNumber * 8) - 4
               Bit 2 = Channel number = (channelStatusGroupNumber * 8) - 5
               Bit 1 = Channel number = (channelStatusGroupNumber * 8) - 6
               Bit 0 = Channel number = (channelStatusGroupNumber * 8) - 7"
::= { channelStatusGroupEntry 2 }
```

2.9.4.3 Channel Status Group Yellows

```
channelStatusGroupYellows   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Channel Yellow Output Status Mask, when a bit = 1, the Channel Yellow is currently active.
             When a bit = 0, the Channel Yellow is NOT currently active.
                Bit 7 = Channel number = (channelStatusGroupNumber * 8)
                Bit 6 = Channel number = (channelStatusGroupNumber * 8) - 1
                Bit 5 = Channel number = (channelStatusGroupNumber * 8) - 2
                Bit 4 = Channel number = (channelStatusGroupNumber * 8) - 3
                Bit 3 = Channel number = (channelStatusGroupNumber * 8) - 4
                Bit 2 = Channel number = (channelStatusGroupNumber * 8) - 5
                Bit 1 = Channel number = (channelStatusGroupNumber * 8) - 6
                Bit 0 = Channel number = (channelStatusGroupNumber * 8) - 7"
::= { channelStatusGroupEntry 3 }
```

2.9.4.4 Channel Status Group Greens

```
channelStatusGroupGreens   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Channel Green Output Status Mask, when a bit = 1, the Channel Green is currently active.
             When a bit = 0, the Channel Green is NOT currently active.
                Bit 7 = Channel number = (channelStatusGroupNumber * 8)
                Bit 6 = Channel number = (channelStatusGroupNumber * 8) - 1
                Bit 5 = Channel number = (channelStatusGroupNumber * 8) - 2
                Bit 4 = Channel number = (channelStatusGroupNumber * 8) - 3
                Bit 3 = Channel number = (channelStatusGroupNumber * 8) - 4
                Bit 2 = Channel number = (channelStatusGroupNumber * 8) - 5
                Bit 1 = Channel number = (channelStatusGroupNumber * 8) - 6
                Bit 0 = Channel number = (channelStatusGroupNumber * 8) - 7"
::= { channelStatusGroupEntry 4 }
```

2.10 OVERLAP PARAMETERS

```
overlap   OBJECT IDENTIFIER
     ::= { asc 9 }
--"This node contains objects that configure, monitor and control overlap functions."
```

2.10.1 Maximum Overlaps

```
maxOverlaps   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The Maximum Number of Overlaps this Actuated Controller Unit supports. This object
             indicates the maximum number of rows which shall appear in the overlapTable object."
::= { overlap 1 }
```

2.10.2 Overlap Table

```
overlapTable   OBJECT-TYPE
          SYNTAX   SEQUENCE OF OverlapEntry
          ACCESS   not-accessible
          STATUS   mandatory
          DESCRIPTION
                "A table containing Actuated Controller Unit overlap parameters. The number of rows in this
                table is equal to the maxOverlaps object."
::= { overlap 2 }

overlapEntry   OBJECT-TYPE
          SYNTAX   OverlapEntry
          ACCESS   not-accessible
          STATUS   mandatory
          DESCRIPTION
                "Parameters for a specific Actuated Controller Unit overlap."
          INDEX   { overlapNumber }
::= { overlapTable 1 }

OverlapEntry ::= SEQUENCE {
          overlapNumber            INTEGER,
          overlapType              INTEGER,
          overlapIncludedPhases    OCTET STRING,
          overlapModifierPhases    OCTET STRING,
          overlapTrailGreen        INTEGER,
          overlapTrailYellow       INTEGER,
          overlapTrailRed          INTEGER }
```

2.10.2.1 Overlap Number

```
overlapNumber   OBJECT-TYPE
          SYNTAX  INTEGER (0..255)
          ACCESS   read-only
          STATUS   mandatory
          DESCRIPTION
                "The overlap number for objects in this row. The value shall not exceed the maxOverlaps
                object. The value maps to the Overlap as follows: 1 = Overlap A, 2 = Overlap B etc."
::= { overlapEntry 1 }
```

2.10.2.2 Overlap Type

```
overlapType   OBJECT-TYPE
          SYNTAX  INTEGER {    other(1),
                               normal (2),
                               minusGreenYellow (3) }
          ACCESS   read-write
          STATUS   mandatory
          DESCRIPTION
                "The type of overlap operation for this row.  The types are as follows:
                   normal - The overlap output shall be controlled by the overlapIncludedPhases when this
                           type is selected.  The overlap output shall be green in the following situations:
                           (1) when an overlap included phase is green.
                           (2) when an overlap included phase is yellow (or red clearance) and an overlap
                           included phase is next.

                           The overlap output shall be yellow when an included phase is yellow and an
```

overlap included phase is not next.
The overlap output shall be red whenever the overlap green and yellow are not ON.
minusGreenYellow - The overlap output shall be controlled by the overlapIncludedPhases and the overlapModifierPhases if this type is selected.
The overlap output shall be green in the following situations:
(1) when an overlap included phase is green and an overlap modifier phase is NOT green.
(2) when an overlap included phase is yellow (or red clearance) and an overlap included phase is next and an overlap modifier phase is NOT green.

The overlap output shall be yellow when an overlap included phase is yellow and an overlap modifier phase is NOT yellow and an overlap included phase is not next.
The overlap output shall be red whenever the overlap green and yellow are not ON.
other - The overlap operates in another mode than those described above."
::= { overlapEntry 2 }

2.10.2.3 Overlap Included Phase Parameters

```
overlapIncludedPhases   OBJECT-TYPE
        SYNTAX   OCTET STRING
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Each octet is a Phase (number) that shall be an included phase for the overlap. The phase
            number value shall not exceed the maxPhases object value. When an included phase
            output is green or when the CU is cycling between included phases, the overlap output shall
            be green."
::= { overlapEntry 3 }
```

2.10.2.4 Overlap Modifier Phase Parameters

```
overlapModifierPhases   OBJECT-TYPE
        SYNTAX   OCTET STRING
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
            "Each octet is a Phase (number) that shall be a modifier phase for the overlap. The phase
            number value shall not exceed the maxPhases object value.  The function of the modifier
            phase(s) is defined by the overlapType selected."
::= { overlapEntry 4 }
```

2.10.2.5 Overlap Trailing Green Parameter

```
overlapTrailGreen   OBJECT-TYPE
SYNTAX   INTEGER (0..255)
ACCESS   read-write
STATUS   mandatory
DESCRIPTION
        "Overlap Trailing Green Parameter in  seconds (0-255 sec). When this value is greater than
        zero and the overlap green would normally terminate, the overlap green shall be extended by
        this additional time."
::= { overlapEntry 5 }
```

2.10.2.6 Overlap Trailing Yellow Change Parameter

```
overlapTrailYellow   OBJECT-TYPE
        SYNTAX  INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Overlap Trailing Yellow Change Parameter in tenth seconds (NEMA range: 3.0-25.5)
             seconds. When the overlap green has been extended (Trailing Green), this value shall
             determine the current length of the Yellow Change interval for the overlap."
::= { overlapEntry 6 }
```

2.10.2.7 Overlap Trailing Red Clear Parameter

```
overlapTrailRed   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-write
        STATUS   mandatory
        DESCRIPTION
             "Overlap Trailing Red Clear Parameter in tenth seconds (0-25.5 sec).  When the overlap
             green has been extended (Trailing Green), this value shall determine the current length of
             the Red Clearance interval for the overlap."
::= { overlapEntry 7 }
```

2.10.3 Maximum Overlap Status Groups

```
maxOverlapStatusGroups   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The Maximum Number of Overlap Status Groups (8 overlaps per group) this Actuated
             Controller Unit supports. This value is equal to TRUNCATE [(maxOverlaps + 7) / 8]. This
             object indicates the maximum rows which shall appear in the overlapStatusGroupTable
             object."
::= { overlap 3 }
```

2.10.4 Overlap Status Group Table

```
overlapStatusGroupTable   OBJECT-TYPE
        SYNTAX   SEQUENCE OF OverlapStatusGroupEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "A table containing Actuated Controller Unit overlap output (Red, Yellow, & Green) status in
             groups of eight overlaps. The number of rows in this table is equal to the
             maxOverlapStatusGroups object."
::= { overlap 4 }

overlapStatusGroupEntry   OBJECT-TYPE
        SYNTAX   OverlapStatusGroupEntry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "Red, Yellow, & Green Output Status for eight Actuated Controller Unit overlaps."
        INDEX   { overlapStatusGroupNumber }
::= { overlapStatusGroupTable 1 }
```

```
OverlapStatusGroupEntry ::= SEQUENCE {
        overlapStatusGroupNumber              INTEGER,
        overlapStatusGroupReds                INTEGER,
        overlapStatusGroupYellows             INTEGER,
        overlapStatusGroupGreens              INTEGER }
```

2.10.4.1 Overlap Status Group Number

```
overlapStatusGroupNumber   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The overlap StatusGroup number for objects in this row. This value shall not exceed the
            maxOverlapStatusGroups object value."
::= { overlapStatusGroupEntry 1 }
```

2.10.4.2 Overlap Status Group Reds

```
overlapStatusGroupReds   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "Overlap Red Output Status Mask, when a bit = 1, the Overlap Red is currently active. When
            a bit = 0, the Overlap Red is NOT currently active.
                Bit 7 = Overlap number = (overlapStatusGroupNumber * 8)
                Bit 6 = Overlap number = (overlapStatusGroupNumber * 8) - 1
                Bit 5 = Overlap number = (overlapStatusGroupNumber * 8) - 2
                Bit 4 = Overlap number = (overlapStatusGroupNumber * 8) - 3
                Bit 3 = Overlap number = (overlapStatusGroupNumber * 8) - 4
                Bit 2 = Overlap number = (overlapStatusGroupNumber * 8) - 5
                Bit 1 = Overlap number = (overlapStatusGroupNumber * 8) - 6
                Bit 0 = Overlap number = (overlapStatusGroupNumber * 8) - 7"
::= { overlapStatusGroupEntry 2 }
```

2.10.4.3 Overlap Status Group Yellows

```
overlapStatusGroupYellows   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "Overlap Yellow Output Status Mask, when a bit = 1, the Overlap Yellow is currently active.
            When a bit = 0, the Overlap Yellow is NOT currently active.
                Bit 7 = Overlap number = (overlapStatusGroupNumber * 8)
                Bit 6 = Overlap number = (overlapStatusGroupNumber * 8) - 1
                Bit 5 = Overlap number = (overlapStatusGroupNumber * 8) - 2
                Bit 4 = Overlap number = (overlapStatusGroupNumber * 8) - 3
                Bit 3 = Overlap number = (overlapStatusGroupNumber * 8) - 4
                Bit 2 = Overlap number = (overlapStatusGroupNumber * 8) - 5
                Bit 1 = Overlap number = (overlapStatusGroupNumber * 8) - 6
                Bit 0 = Overlap number = (overlapStatusGroupNumber * 8) - 7"
::= { overlapStatusGroupEntry 3 }
```

2.10.4.4 Overlap Status Group Greens

```
overlapStatusGroupGreens   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "Overlap Green Output Status Mask, when a bit = 1, the Overlap Green is currently active.
             When a bit = 0, the Overlap Green is NOT currently active.
                Bit 7 = Overlap number = (overlapStatusGroupNumber * 8)
                Bit 6 = Overlap number = (overlapStatusGroupNumber * 8) - 1
                Bit 5 = Overlap number = (overlapStatusGroupNumber * 8) - 2
                Bit 4 = Overlap number = (overlapStatusGroupNumber * 8) - 3
                Bit 3 = Overlap number = (overlapStatusGroupNumber * 8) - 4
                Bit 2 = Overlap number = (overlapStatusGroupNumber * 8) - 5
                Bit 1 = Overlap number = (overlapStatusGroupNumber * 8) - 6
                Bit 0 = Overlap number = (overlapStatusGroupNumber * 8) - 7"
::= { overlapStatusGroupEntry 4 }
```

2.11 TS2 PORT 1 PARAMETERS

```
ts2port1  OBJECT IDENTIFIER
::= { asc 10 }
```

-- This object is an identifier used to group all objects for support of TS 2 port1 activities.

2.11.1 Maximum Port 1 Addresses

```
maxPort1Addresses   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
             "The Maximum Number of Port 1 addresses this Actuated Controller Unit supports. This
             object indicates the maximum rows which shall appear in the port1Table object."
::= { ts2port1 1 }
```

2.11.2 Port 1 Table

```
port1Table   OBJECT-TYPE
        SYNTAX   SEQUENCE OF Port1Entry
        ACCESS   not-accessible
        STATUS   mandatory
        DESCRIPTION
             "A table containing Actuated Controller Unit port 1 parameters. The number of rows in this
             table is equal to the maxPort1Addresses object."
::= { ts2port1 2 }

port1Entry  OBJECT-TYPE
        SYNTAX  Port1Entry
        ACCESS  not-accessible
        STATUS  mandatory
        DESCRIPTION
             "This object defines a conceptual row in the port 1 Table."
        INDEX { port1Number }
::= { port1Table 1 }
```

```
Port1Entry ::= SEQUENCE {
        port1Number           INTEGER,
        port1DevicePresent    INTEGER,
        port1Frame40Enable    INTEGER,
        port1Status           INTEGER,
        port1FaultFrame       INTEGER }
```

2.11.2.1 Port 1 Number

```
port1Number   OBJECT-TYPE
        SYNTAX   INTEGER (0..255)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The Port 1 address for objects in this row. This value shall not exceed the
            maxPort1Addresses object value."
::= { port1Entry 1 }
```

2.11.2.2 Port 1 Device Present

```
port1DevicePresent   OBJECT-TYPE
        SYNTAX   INTEGER (0..1)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "The presence or absence of a device for this port 1 address. Command Frames shall be
            transmitted only to those devices that are present as determined by this programming.  If the
            object is TRUE (non-zero) then the device is present.  If the object is FALSE (zero) then the
            device is not present."
        REFERENCE
            "NEMA TS 2 Clause 3.3.1.4"
::= { port1Entry 2 }
```

2.11.2.3 Port 1 Frame 40 Enable

```
port1Frame40Enable   OBJECT-TYPE
        SYNTAX   INTEGER (0..1)
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION
            "To enable or disable Frame 40 messages to the device at this port 1 address. Frame 40 is
            used to poll the secondary stations for a secondary to secondary message exchange.
            Command 40 series frames shall be transmitted only to those devices that are enabled, as
            determined by this programming.
                TRUE (non-zero) - Enable frame 40 messages for this device.
                FALSE (zero) - Disable frame 40 messages for this device."
        REFERENCE
            "NEMA TS 2 Clause 3.3.1.4.1"
::= { port1Entry 3 }
```

2.11.2.4 Port 1 Status

```
port1Status OBJECT-TYPE
        SYNTAX INTEGER {    other (1),
                            online (2),
                            responseFault (3) }
        ACCESS read-write
        STATUS mandatory
        DESCRIPTION
            "This object indicates the communications status with the associated device:
            online - This indicates that at least five of the most recent 10 response transfers were
                    received correctly
            responseFault - This indicates that more than 5 of the most recent 10 response transfers
                    were received incorrectly.
            other - This indicates that some other communications fault has been detected."
::= { port1Entry 4 }
```

2.11.2.5 Port 1 Fault Frame

```
port1FaultFrame OBJECT-TYPE
        SYNTAX INTEGER  (0..255)
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
            "This object indicates the frame number that caused the most recent fault."
::= { port1Entry 5 }

END
```

Section 3
Group Definitions

A Conformance Group is defined in NEMA TS 3.2 Clause 3.3.5.

Conformance Groups are defined as either mandatory or optional. If a Conformance Group is mandatory, all of the objects with STATUS "mandatory" that are part of the Conformance Group shall be present for a device to claim conformance to the Group. If a Conformance Group is optional, all of the objects that are part of the Conformance Group with the STATUS "mandatory" shall be present if the device supports the Conformance Group. Objects with the STATUS "optional" may be supported.

When a table is included in a Conformance Group, all objects contained in the table are included by reference. This is because a table is defined as a SEQUENCE OF {SEQUENCE}. Thus, all objects listed in the sequence are defined as an integral part of the table. Tables are defined as either mandatory or optional. If a table is mandatory, all of the objects with STATUS "mandatory" shall be present. If a table is optional, all of the objects with the STATUS "mandatory" shall be present if the device supports the table. Objects in the table with the STATUS "optional" may be supported.

Table 3-1
OBJECT SUPPORT REQUIREMENTS

Object Status	Table Status	Group Status	Object Support
mandatory	mandatory	mandatory	mandatory
mandatory	mandatory	optional	mandatory, if group is supported
mandatory	optional	mandatory	mandatory, if table is supported
mandatory	optional	optional	mandatory, if both the group and table are supported
optional	mandatory	mandatory	optional
optional	mandatory	optional	optional
optional	optional	mandatory	optional
optional	optional	optional	optional

The Conformance Group definitions for actuated signal controllers are defined in this section. An actuated signal controller has multiple functions; thus, Conformance Groups are defined for each function.

3.1 PHASE CONFORMANCE GROUP

The Phase Conformance Group consists of the phase timing parameters, and phase status variables. The Phase Group shall consist of the following objects:

Object or Group Name	Reference
maxPhases	TS 3.5
phaseTable	TS 3.5
maxPhaseGroups	TS 3.5
phaseStatusGroupTable	TS 3.5

3.2 DETECTOR CONFORMANCE GROUP

The Detector Conformance Group consists of the detector configuration parameters, and the detector status variables. The Detector Group consists of the following objects:

Object or Group Name	Reference
maxVehicleDetectors	TS 3.5
vehicleDetectorTable	TS 3.5
maxVehicleDetectorStatusGroups	TS 3.5
vehicleDetectorStatusGroupTable	TS 3.5
maxPedestrianDetectors	TS 3.5
pedestrianDetectorTable	TS 3.5

3.3 VOLUME OCCUPANCY REPORT CONFORMANCE GROUP

The Volume Occupancy Report Group shall consist of the following objects:

Object or Group Name	Reference
volumeOccupancySequence	TS 3.5
volumeOccupancyPeriod	TS 3.5
activeVolumeOccupancyDetectors	TS 3.5
volumeOccupancyTable	TS 3.5

3.4 UNIT CONFORMANCE GROUP

The Unit Group consists of objects related to overall controller configuration and state. The Unit Group shall consist of the following objects:

Object or Group Name	Reference
unitStartUpFlash	TS 3.5
unitBackupTime	TS 3.5
unitRedRevert	TS 3.5
unitControlStatus	TS 3.5
unitFlashStatus	TS 3.5
unitAlarmStatus2	TS 3.5
unitAlarmStatus1	TS 3.5
shortAlarmStatus	TS 3.5
unitControl	TS 3.5
maxAlarmGroups	TS 3.5
alarmGroupTable	TS 3.5

3.5 SPECIAL FUNCTION CONFORMANCE GROUP

The Special Function Conformance Group consists of those objects related to control of special function outputs.

Object or Group Name	Reference
maxSpecialFunctionOutputs	TS 3.5
specialFunctionOutputTable	TS 3.5

3.6 COORDINATION CONFORMANCE GROUP

The Coordination Group consists of those objects related to signal coordination. The Coordination Group shall consist of the following objects:

Object or Group Name	Reference
coordOperationalMode	TS 3.5
coordCorrectionMode	TS 3.5
coordMaximumMode	TS 3.5
coordForceMode	TS 3.5
maxPatterns	TS 3.5
patternTableType	TS 3.5
patternTable	TS 3.5
maxSplits	TS 3.5
splitTable	TS 3.5
coordPatternStatus	TS 3.5
localFreeStatus	TS 3.5
coordCycleStatus	TS 3.5
coordSyncStatus	TS 3.5
systemPatternControl	TS 3.5
systemSyncControl	TS 3.5

3.7 TIME BASE CONFORMANCE GROUP

The Time Base Group consists of the asc specific objects related to time base operation. The Time Base Group shall consist of the following objects:

Object or Group Name	Reference
Time Management Conf. Group	TS 3.4
timebasePatternSync	TS 3.5
maxTimebaseAscActions	TS 3.5
timebaseAscActionTable	TS 3.5
timebaseAscActionStatus	TS 3.5

3.8 PREEMPT CONFORMANCE GROUP

The Preempt Group consists of the preempt configuration parameters, and the preempt status variables. The Preempt Conformance Group shall consist of the following objects:

Object or Group Name	Reference
maxPreempts	TS 3.5
preemptTable	TS 3.5

3.9 RING CONFORMANCE GROUP

The Ring Group consists of the ring configuration parameters, status variables. The Ring Conformance Group shall consist of the following objects:

Object or Group Name	Reference
maxRings	TS 3.5
maxSequences	TS 3.5
sequenceTable	TS 3.5

3.10 CHANNEL CONFORMANCE GROUP

The Channel Group consists of the channel configuration parameters, and status variables. The Channel Group shall consist of the following objects:

Object or Group Name	Reference
maxChannels	TS 3.5
channelTable	TS 3.5
maxChannelStatusGroups	TS 3.5
channelStatusGroupTable	TS 3.5

3.11 OVERLAP CONFORMANCE GROUP

The Overlap Group consists of the overlap configuration parameters, and status variables. The Overlap Group shall consist of the following objects:

Object or Group Name	Reference
maxOverlaps	TS 3.5
overlapTable	TS 3.5
maxOverlapStatusGroups	TS 3.5
overlapStatusGroupTable	TS 3.5

3.12 TS-2 PORT1 CONFORMANCE GROUP

The TS-2 Port1 Conformance Group consists of the TS-2 port 1 configuration parameters, status variables, and control objects. The TS-2 Group shall consist of the following objects:

Object or Group Name	Reference
maxPort1Addresses	TS 3.5
port1Table	TS 3.5

Section 4
CONFORMANCE STATEMENTS

Actuated Signal Controller (ASC) devices shall adhere to the conformance requirements specified in Table 4-1 as a minimum to claim compliance to this standard. Additional objects or groups may be supported without being non-compliant with ASC objects or NTCIP.

Minimum and maximum ranges of objects that differ from the values of the object's SYNTAX field may be enforced by an application running on a device.

A device which enforces range limits within the bounds specified by the values of the object's SYNTAX field shall not be categorized as being non-compliant with ASC objects or NTCIP.

A device which supports a subset of objects with enumerated values shall not be categorized as being non-compliant with ASC objects or NTCIP.

Table 4-1
CONFORMANCE TABLE

Conformance Group	Reference	Conformance Requirement
Configuration	TS 3.4	mandatory
Database Management	TS 3.4	optional
Time Management	TS 3.4	optional
Timebase Event Schedule	TS 3.4	optional
Report	TS 3.4	optional
STMP	TS 3.4	optional
PMPP	TS 3.4	optional
Phase	TS 3.5	mandatory
Detector	TS 3.5	mandatory
Volume Occupancy Report	TS 3.5	optional
Unit	TS 3.5	optional
Special Function	TS 3.5	optional
Coordination	TS 3.5	optional
Time Base	TS 3.5	optional
Preempt	TS 3.5	optional
Ring	TS 3.5	optional
Channel	TS 3.5	optional
Overlap	TS 3.5	optional
TS 2 Port 1	TS 3.5	optional

A Joint Standard of AASHTO, ITE, and NEMA

NTCIP 1204:1998 v01.13

National Transportation Communications for ITS Protocol

Object Definitions for Environmental Sensor Stations (ESS)

November 23, 2001

Includes Jointly Approved NTCIP 1204 Amendment 1 v02

This Adobe® PDF copy of an NTCIP standard is available at no-cost for a limited time through support from the U.S. DOT / Federal Highway Administration, whose assistance is gratefully acknowledged.

Published by

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ACKNOWLEDGEMENTS

This publication was prepared by the NTCIP Environmental Sensor Station Working Group, which is a subdivision of the Joint Committee on the NTCIP. The Joint Committee is organized under a Memorandum of Understanding among the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the National Electrical Manufacturers Association (NEMA). The Joint Committee on the NTCIP consists of six representatives from each of the standards organizations, and provides guidance for NTCIP development.

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In addition to the many volunteer efforts, recognition is also given to those organizations who supported the efforts of the working groups by providing comments and funding for the standard, including:

- Aanderaa Instruments
- AURORA
- California Department of Transportation
- Castle Rock Consultants
- Coastal Environmental Systems
- Colorado Department of Transportation
- Federal Highway Administration
- Georgia Institute of Technology
- Idaho Department of Transportation
- Illinois Department of Transportation
- Iowa Department of Transportation
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- Maine Department of Transportation
- Minnesota Department of Transportation
- New York Department of Transportation

- Odetics ITS
- Ontario Ministry of Transportation
- Office of the Federal Coordinator for Meteorology
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- Texas Transportation Institute
- University of North Dakota
- Vaisala, Inc.
- Viggen Corporation
- Virginia Department of Transportation
- Weather Solutions Group
- WELS Research Corporation
- Wisconsin Department of Transportation

FOREWORD

This document uses only metric units.

This publication defines the data elements and conformance requirements for environmental sensor stations. It defines requirements that are applicable to all NTCIP environmental sensor stations and it also contains optional and conditional clauses that are applicable to specific environments for which they are intended. There are no annexes to this document.

This document is an NTCIP Data Dictionary Standard. Data Dictionary Standards provide formal definitions of data elements for use within NTCIP systems; they are formally approved by AASHTO, ITE, and NEMA through a ballot process, after a formal recommendation by the NTCIP Joint Committee.

For more information about NTCIP standards, visit the NTCIP Web Site at http://www.ntcip.org. For a hardcopy summary of NTCIP information, contact the NTCIP coordinator at the above address.

In preparation of this NTCIP document, input of users and other interested parties was sought and evaluated. Inquires, comments, and proposed or recommended revisions should be submitted to:

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Approvals

This document was separately balloted and approved by AASHTO, ITE, and NEMA after recommendation by the Joint Committee on the NTCIP. Each organization has approved this standard as the following standard type, as of the date:

> AASHTO – Standard Specification; 1998
> ITE – Software Standard; June 1998
> NEMA – Standard; August 1998

History

From 1996 to 1998, this document was referenced as NEMA TS 3.7. However, to provide an organized numbering scheme for the NTCIP documents, this document is now referenced as NTCIP 1204. The technical specifications of NTCIP 1204 are identical to the former references, except as noted in the development history below:

> TS 3.7 version 97.01.11. November 1997 – Approved by AASHTO, ITE, and NEMA in 1998.
>
> TS 3.7 Amendment 1, version 98.01.02. September 1998 – Approved by AASHTO and NEMA in 1999 and approved by ITE in 2001.
>
> NTCIP 1204:1998 v01.12. September 1998 – Combined version 01.11 and Amendment 1 version 02, converted to revised standard numbering scheme, and made changes to the front matter. Added underline and strikethrough to indicate changes in Subclauses 3.2.2, 3.3.1, 3.8.11, 3.8.12, 3.11.2.10, 3.11.2.11, 3.11.2.12, 3.11.4.3, 3.11.4.4, 3.14.1 through 3.14.7, and 4.2.1.

NTCIP 1204:1998 v01.13. November 2001 – Reformatted for printing: incremented version number and updated date. Updated document to NTCIP 8002 v04 Template format, added approvals and history to Foreword, and converted references to TS 3 Standards to renumbered NTCIP Standards. The underline and strikethrough format used to indicate the amendment changes was removed. The normative reference to WMO BUFR was corrected and References were updated.

INTRODUCTION

This publication provides definitions of data elements for use with environmental sensor stations (ESS). The data is defined using the Simple Network Management Protocol (SNMP) object-type format as defined in RFC 1212 and would typically be exchanged using one of the NTCIP recognized Application Layers (e.g., SNMP).

This standard defines requirements that are applicable to all NTCIP environments and the standard also contains optional and conditional clauses that are applicable to specific environments for which they are intended.

The following keywords apply to this document: AASHTO, ITE, NEMA, NTCIP, ESS, RWIS, data, data dictionary, object, road weather, air quality.

In 1992, the NEMA 3-TS Transportation Management Systems and Associated Control Devices Section began the effort to develop the NTCIP. The Transportation Section's purpose was to respond to user needs to include standardized systems communication in the NEMA TS 2 standard, Traffic Controller Assemblies. Under the guidance of the Federal Highway Administration's NTCIP Steering Group, the NEMA effort was expanded to include the development of communications standards for all transportation field devices that could be used in an Intelligent Transportation Systems (ITS) network.

In September 1996, an agreement was executed among AASHTO, ITE, and NEMA to jointly develop, approve, and maintain the NTCIP standards. One of the first tasks of the joint effort was to establish the Environmental Sensor Station Working Group to standardize ESS equipment communication. The first ESS WG meeting was held in November 1996 to begin the development of this document.

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Joint AASHTO, ITE, and NEMA
NTCIP Management Information Base and Data Dictionary

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CONTENTS

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Section 1
INTRODUCTION

1.1 INTRODUCTION

Environmental sensors include a wide array of sensors, including those which monitor weather, roadway surface, and air/water quality conditions. These sensors are typically connected to a nearby field device/microprocessor termed a Remote Processor Unit (RPU). An Environmental Sensor Station (ESS) consists of the RPU plus its suite of sensors. In the transportation community, these devices are frequently used in order to improve roadway maintenance and traffic operations.

Unfortunately, there have not been standards defining how these devices communicate with other related equipment. As a result, each manufacturer has developed its own protocol to meet its particular needs. To integrate systems manufactured by different companies, considerable extra work must be performed resulting in increased costs. This shortcoming limits interchangeability of components between different vendors' and restricts information sharing within and between user organizations.

These problems have not been limited to weather and environmental monitoring. Many other devices also need to exchange information. In surface transportation, examples include traffic signal controllers, dynamic message signs, bus priority sensors, etc. To address these problems, the NTCIP is developing a family of open standards for communications among field devices and between field devices and central management stations, known as Information Management Subsystems (IMS).

1.2 WEATHER IMPACTS

Weather has a profound effect on driving condition. More generally, all modes of transportation can be severely affected by adverse weather events. Timely and reliable information on developing weather situations can help support highway maintenance, transit operations, trip planning and route selection. Transportation and meteorological agencies have common interests in improved coordination of surface transportation and weather information systems.

1.2.1 Transportation Facilities Maintenance

Several state transportation agencies already have a network of ESS in operation for road maintenance purposes; these systems have traditionally been called Road/Weather Information Systems (RWIS). At present, however, these systems often include proprietary elements which limit opportunities for effective information exchange.

The data from RWIS can be used to more accurately predict the start times, end times, and strength of storms. This information can then be used by maintenance agencies to better manage their staff and materials.

A study for the Strategic Highway Research Program (SHRP) showed that about two billion dollars are spent each year in North America on snow and ice control [1]. An estimated 10-12% of this total could be saved with better road and weather condition information. RWIS installed to date have proven highly cost effective.

The development of the NTCIP will allow a more open-systems approach, not only among RWIS equipment, but also with a wide variety of other field devices. It is expected that this open-systems approach will result in lower deployment and equipment costs similar to the PC industry. This in turn will allow for more devices to be deployed resulting in better decision-support to decrease maintenance costs.

1.2.2 Transportation Management

Intelligent Transportation Systems (ITS) are currently applying the benefits of information technology more broadly within surface transportation. One of the key goals of ITS is to improve the management of the existing surface transportation infrastructure. Weather is a key component which should be considered when making such management decisions. For example, start-up green times at traffic signals may need to be lengthened under icy conditions, and traffic flows can be redirected to avoid areas which are experiencing air quality or other problems. These benefits cut across all modes of surface transportation, e.g. highways, rail, and transit.

1.2.3 Commercial Vehicle Operator / Traveler Information

Another important area of ITS applications reside in the area of traveler information. By providing travelers with various environmental information, they can make more informed choices on their mode, route, and time of travel; this in turn will result in improved safety and increased convenience for travelers.

1.2.4 Meteorological Analysis and Forecasting

In meteorology, advancements in analysis and forecasting have been equally rapid. Besides conventional data sources, geostationary satellite observations give frequent worldwide updates on global weather patterns. Sophisticated Doppler radar can track the movement of severe storms. Improved Automated Surface Observing Systems (ASOS) are currently being installed at more than 850 locations throughout the United States. Also, many ships and aircraft now serve as mobile data collection platforms, extending weather observations beyond the reach of surface sites. These new weather data sources can greatly add to the output from ESS (RWIS) locations.

More accurate and precise weather forecasts are also of interest to travelers and highway maintenance managers. New, supercomputer 'meso-scale' weather forecasting models will soon become widely available under the multi-billion dollar National Weather Service (NWS) modernization program. Collectively, these systems and models will support much more detailed weather predictions than has previously been possible.

1.2.5 Integration of Systems

To make best use of these advancements, RWIS should be seen as a part of broader ITS and meteorological information systems. In Europe, integration has cut costs through accident reductions, lowered insurance premiums, improved snow removal efforts, and reduced traffic congestion. Information sharing across traditional system boundaries offers a win-win situation. RWIS data contribute to better weather forecasts which in turn support more efficient highway maintenance and more accurate traveler information. The key to these benefits is open standards, allowing agencies to share data and avoid getting locked into proprietary systems.

1.2.6 Informational References

1) SHRP project H-207, “Road Weather Information Systems, Volume 1”, Research Report, SHRP-H-350, 1993.

1.3 BENEFITS OF STANDARDIZATION

As transportation systems become more sophisticated, planners, users, and equipment manufacturers recognize the need for system interoperability and integration. Currently, there is no common protocol with which different types of equipment can communicate. If RWIS are to be integrated with ITS and the wider field of meteorology, common communications standards must be established.

Before the NTCIP development started, each vendor of electronic devices used in transportation adopted a different protocol for data communications. This made it very difficult to mix equipment from different vendors in the same system, and to communicate between systems operated by adjacent agencies. The NTCIP is now providing a common standard that can be used by all vendors.

The NTCIP offers increased flexibility and choice for agencies operating transportation information systems such as RWIS (ESS). It removes barriers to interjurisdictional coordination and allows equipment of different types and manufacturers to be mixed on the same communications line. For these reasons, operating agencies will benefit from specifying that the NTCIP is included in all future purchases and upgrades.

Benefits of adopting open standards based on the NTCIP include:

- *Avoiding Early Obsolescence*: Though it may not be practical to retrofit NTCIP support in some old equipment, most ESS (RWIS) vendors will offer NTCIP support in current and future products. An operating agency can ensure that its equipment remains useful and compatible long into the future by requiring NTCIP support for all future purchases and upgrades. This will include central computers and field stations for Environmental Sensor Station, traffic control, or traveler information devices.
- *Providing Choice of Vendor*: Once an agency has a weather information system that includes support for NTCIP it can buy field stations from any manufacturer offering NTCIP-compatible products, and they will communicate with the agency's "Information Management Subsystem" ('IMS', typically termed CPU).
- *Allowing Interjurisdictional Coordination*: In the future, an agency may want to communicate with ESS devices owned by other users and/or procured from different vendors. Under NTCIP, these various devices can be added onto an existing communications channel and mixed with different types of devices on the same line.
- *Using one Communications Network for All Devices*: NTCIP also allows a central computer to communicate with a range of field devices on the same communications channel. For example, if a dynamic message sign is installed near an ESS, the central computer could communicate with the sign controller using the communications channel already in place for the ESS. The communications network is usually the most expensive component of a transportation management system and use of the NTCIP maximizes that investment.

1.4 EXISTING STANDARDS

There are great benefits of adopting existing standards where possible. These include:
- reuse of software modules during development
- faster implementations
- reducing risks
- ability to integrate components from different manufacturers
- unambiguous meanings of terminology
- building on proven technologies

1.4.1 BUFR

The World Meteorological Organization (WMO) is the international organization which establishes and maintains standards, guidelines and procedures for meteorology, oceanography and hydrology. These documents have been developed over the last 100 years and they continue to evolve as technology advances and needs arise. BUFR and GRIB are the WMO standard binary codes which have been developed to take advantage of automated systems in meteorology, oceanography and hydrology. GRIB (Gridded Binary) is used for encoding gridded fields of data whereas BUFR is used for all other types of data. BUFR is the most applicable WMO standard on which to base the definition of ESS data elements.

1.4.2 Internet Standards

The Internet Engineering Task Force (IETF) is responsible for developing and maintaining the standards, guidelines and procedures for communications over the Internet. This group has become increasingly important over the last few years as the Internet has gained popularity. A wide range of Internet standards exist, including:

- Point-to-Point Protocol (PPP) - which may be used for NTCIP dial-up links
- Internet Protocol (IP) - which may be used for NTCIP communications over networks
- Transport Control Protocol (TCP) - which may be used to provide connection-oriented services over NTCIP networks
- User Datagram Protocol (UDP) - which may be used to provide connectionless transport services over NTCIP networks
- Simple Network Management Protocol (SNMP) - which may be used to exchange NTCIP data elements such as those defined within this document.

1.4.3 International Standards Organization Standards

The International Standards Organization (ISO) also develops various communication standards among a wide variety of other standards. The Open Systems Interconnect Reference Model (OSI) is a widely referenced ISO standard which defines the standard seven-layered communications model. While most implementations do not strictly conform to this standard, virtually all modern communications schemes, including the NTCIP, use many of the concepts defined within the standard. In addition, NTCIP communications may use the High Level Data Link Control Protocol (HDLC), another ISO standard, in specifying how to send a message over a single communications link.

1.4.4 NTCIP

To support ITS developments, US DOT funded the design of a National ITS Architecture. This architecture defines major ITS subsystems and the needs for information exchange among them. The National Transportation Communications for ITS Protocol (NTCIP) group is now developing standards for these information exchanges. NTCIP – a joint initiative of AASHTO, ITE, and NEMA – recognizes that weather and road condition information are vital for efficient highway maintenance and safer traffic operations. The family of NTCIP standards will support ESS (that is, RWIS) procurement and support information sharing between the various data users. The development of the NTCIP, including this ESS standard, makes use of existing standards as appropriate.

1.5 NTCIP SYSTEM DESIGN

NTCIP was initially designed to support traffic signal controllers because that was seen by the FHWA as an area of most pressing need. However, the development process planned that the protocol would be extended to other transportation environments (e.g., ITS) and, where appropriate, to other environments such as meteorology.

The NTCIP family of protocols is continually expanding to address additional needs. Work is in progress on additional protocols for computer-to-computer or center-to-center data exchange, transit communications, and communications with or between moving vehicles. The NTCIP along with other US DOT standards efforts will eventually provide a comprehensive family of communications protocols covering all appropriate ITS applications.

There may also be a future demand to use the system for communications to field devices that are not transportation related; for example air quality monitors for the Environmental Protection Agency (EPA), weather stations for the National Weather Service, or reservoir monitoring systems for the Corps of Engineers. The ultimate scope of NTCIP cannot be rigidly determined. The key is to determine how those changes might affect the system design and to provide flexible standards to accommodate these changes.

Where possible, NTCIP uses existing telecommunications and computer industry standards. That part of NTCIP addressing Environmental Sensor Stations (ESS) has also sought to follow worldwide standards used in meteorological data exchanges, such as BUFR (Binary Universal Format for the Representation of meteorological data). Sometimes, BUFR and NTCIP adopt different solutions, however, the aim has been to maintain compatibility with BUFR and NTCIP, so that data can be easily converted from one format to the other.

Section 2
GENERAL

2.1 SCOPE

The communications between an ITS Management Center or portable computer and an Environmental Sensor Station (ESS) is accomplished by using the NTCIP Application Layer services to convey requests to access or modify values of ESS objects resident in the device via an NTCIP network. An NTCIP message consists of a specific Application Layer service and a set of data objects. An NTCIP message may be conveyed using any NTCIP defined class of service which has been specified to be compatible with the Simple Transportation Management Framework (STMF).

The scope of this document is limited to the functionality related to ESS within a transportation environment. This publication defines objects which are specific to ESS and also defines standardized object Groups which can be used for conformance statements.

2.2 REFERENCES

For approved revisions, contact:

NTCIP Coordinator
National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209-3801

For proposed revisions, which are under discussion by the relevant NTCIP Working Group, and revisions recommended by the NTCIP Joint Committee are available on the World Wide Web at http://www.ntcip.org.

The following standards (normative references) contain provisions which, through reference in this text, constitute provisions of this Standard. Other documents and standards (other references) are referenced in these documents, which might provide a complete understanding of the entire protocol and the relations between all parts of the protocol. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standard listed below.

2.2.1 Normative References

ISO/IEC 8824-1:1995	Information Technology - Abstract Syntax Notation One (ASN.1): Specification of Basic Notation.
ISO/IEC 8824-2:1995	Information Technology -- Abstract Syntax Notation One (ASN.1): Information Object Specification.
RFC1155	Structure and Identification of Management Information for TCP/IP-based Internets. K. McCloghrie; M. Rose; 05/10/1990
RFC1212	Concise MIB Definitions. K. McCloghrie; M. Rose; 03/26/1991

WMO No. 306, Manual on Codes, International Codes, Vol. I.2 (Annex II to WMO Technical Regulations), Part B - Binary Codes, FM 94-X Ext. BUFR (Binary Universal Form for the Representation of meteorological data), 1995 edition.

2.2.2 Other References

2.2.2.1 NEMA Standards

NTCIP 1101:1996 National Transportation Communications and ITS Protocol - STMF

NTCIP 2001:1996 National Transportation Communications and ITS Protocol - Class B Profile

2.2.2.2 World Meteorology Organization and American Meteorological Society

Glossary of Meteorology (fifth printing), American Meteorological Society, 1989.

2.2.2.3 Office of the Federal Coordinator for Meteorology

A Guide to WMO Code Form FM-94 BUFR, Office of the Federal Coordinator for Meteorology (OFCM). March 1995.

2.2.3 Contact Information

2.2.3.1 ISO/IEC Standards

Members of the ISO maintain registers of currently valid ISO/IEC International Standards. For the USA, the member of ISO is the American National Standards Institute (ANSI), which may be contacted as follows:

ANSI
11 West 42nd Street, 13th Floor
New York, NY 10036
(212) 642-4900

2.2.3.2 RFC Documents

Electronic copies of RFC documents may be obtained using “anonymous” FTP to the host nic.ddn.mil or ds.internic.net. Printed copies are available from:

DDN Network Information Center
14200 Park Meadow Drive
Suite 200
Chantilly, VA 22021
(800) 365-3642
(703) 802-4535

2.2.3.3 American Meteorological Society and World Meteorological Organization Documents

Prepayment is required prior to shipment of these documents. Printed copies are available from:

American Meteorological Society
45 Beacon Street
Boston, MA 02108
(617) 227-2425

2.2.3.4 OFCM Documents

Office of the Federal Coordinator for Meteorology
8455 Colesville Rd., Suite 1500
Silver Spring, MD 20910
(301) 427-2002

2.3 GENERAL STATEMENTS

For all bitmapped objects, if a bit is zero (0), then the referenced function is disabled or not supported, and if a bit is one (1), then the referenced function is enabled or supported.

The format of this document is unlike other NTCIP Standards. The format for this standard groups the objects by device and purpose irrespective of the tree structure within the environmental sensor station node. Therefore the object definition identifiers indicate either the NTCIP node or the BUFR node. The groupings of these objects are indicated by title. The tree structure is shown beginning from the devices node within the NEMA node and maps this to the section structure.

This document is managed by the Joint AASHTO/ITE/NEMA Committee on the NTCIP and proprietary features should be defined through vendor-specific nodes or vendor-specific extensions to this Management Information Base (MIB).

2.4 ENVIRONMENTAL SENSOR STATION TERMS

For a better understanding of this standard, here are some terms and definitions.

BITMAP	A subset of the SYNTAX type OCTET STRING where every bit is a representation of a part or function (e.g. lamp 1 = bit 1, lamp 2 = bit 2).
BITMAP8	BITMAP with 8 bits
BITMAP16	BITMAP with 16 bits
BITMAP32	BITMAP with 32 bits
Binary Universal Form for the Representation of meteorological data (BUFR)	BUFR is the name of the WMO standard binary code for the exchange and storage of non-gridded meteorological data.
Checksum	Result of an algorithm used to detect errors.
Communication Failure	When a computer (central/master/portable/maintenance) cannot communicate with a specific station for any reason.
Communication Interface	The serial communication port on the controller used to communicate with another device.
Controller Address	See Physical Address.
Cyclical Redundancy Check (CRC)	A data error-detection scheme. A polynomial algorithm is performed on a block of data. There are different algorithms involving a different number of bits and bytes in the calculation such as CRC-16 and CRC-32.
Download	To transfer information into the referenced device.
Environmental Analysis Package	The component within a management subsystem which performs advanced processing of the collected environmental data. This would include the analysis, forecasting and packaging of weather and road condition information for resource management.
Surface Transportation Environmental Market Package	A set of components which perform all operations related to sensing, collecting, processing and exchanging environmental related information, including the exchange of data among the dispersely located equipment.
Environmental Sensor Station (ESS)	A location that includes a remote processor unit (RPU) connected to one or more sensors for the collection of environmental or meteorological data.
Information Management Subsystem (IMS)	A generic reference to any one of the management subsystems identified in the National Architecture; these include Traffic Management Subsystems, Transit Management Subsystems, Emergency Management Subsystems, etc. These management subsystems are responsible for collecting and processing information from remote devices, controlling

	remote devices, and/or disseminating this information to other subsystems or devices. These devices may include, but are not limited to, ESS.
Intelligent Transportation Systems (ITS)	The application of advanced information processing and communications, sensing, and control technologies to surface transportation with the objective of promoting more efficient use of the existing highway and transportation network, increasing safety and mobility, and decreasing the environmental cost of travel.
ITS Management Center	The physical location of an Information Management Subsystem(s).
Management Information Base (MIB)	Management information of object definitions so that devices on a network can be remotely monitored, configured and controlled. The information is provided in a format called Abstract Syntax Notation.1 (ASN.1), which is an international standard for defining objects.
National Transportation Communications for ITS Protocol (NTCIP)	The NTCIP is a family of protocols that provide common control and data collection services as well as accommodating various system topologies and data routing duties. The NTCIP will support not only currently deployed systems, but new systems and technologies as they become available.
Physical Address	The Data Link identifier which differentiates a field device in a multidrop- or point-to-point communication circuit, to allow the central computer to communicate with a specific field device.
Point-To-Point	A form of communications where data is transmitted between two devices without any other devices existing on the communication circuit.
Protocol	A specific set of rules, procedures and conventions defining the format and timing of data transmissions between devices that must be accepted and used to understand each other.
Remote Processor Unit (RPU)	A field processor which collects data from sensors and can communicate the collected data to other computers; the processor may also process the collected data and/or control equipment.
Road/Weather Information System (RWIS)	The collection of RPUs and sensors connected to a central system for analysis and use by maintenance personnel.
Sensor	A device which is capable of detecting a condition and reporting the result to an RPU.
Simple Network Management Protocol (SNMP)	A communications protocol developed by the IETF, used for configuration and monitoring of network devices.
Simple Transportation Management Framework (STMF)	Describes the organization of the information within devices and the methods of retrieving or modifying any information within the device. STMF also explains how to generate and utilize computer readable information organization descriptions.
Simple Transportation Management Protocol (STMP)	A variation of SNMP developed by NEMA to address low bandwidth communication links and real time device monitoring.
Upload	To transfer information from the referenced device to the central computer or an attached portable computer.

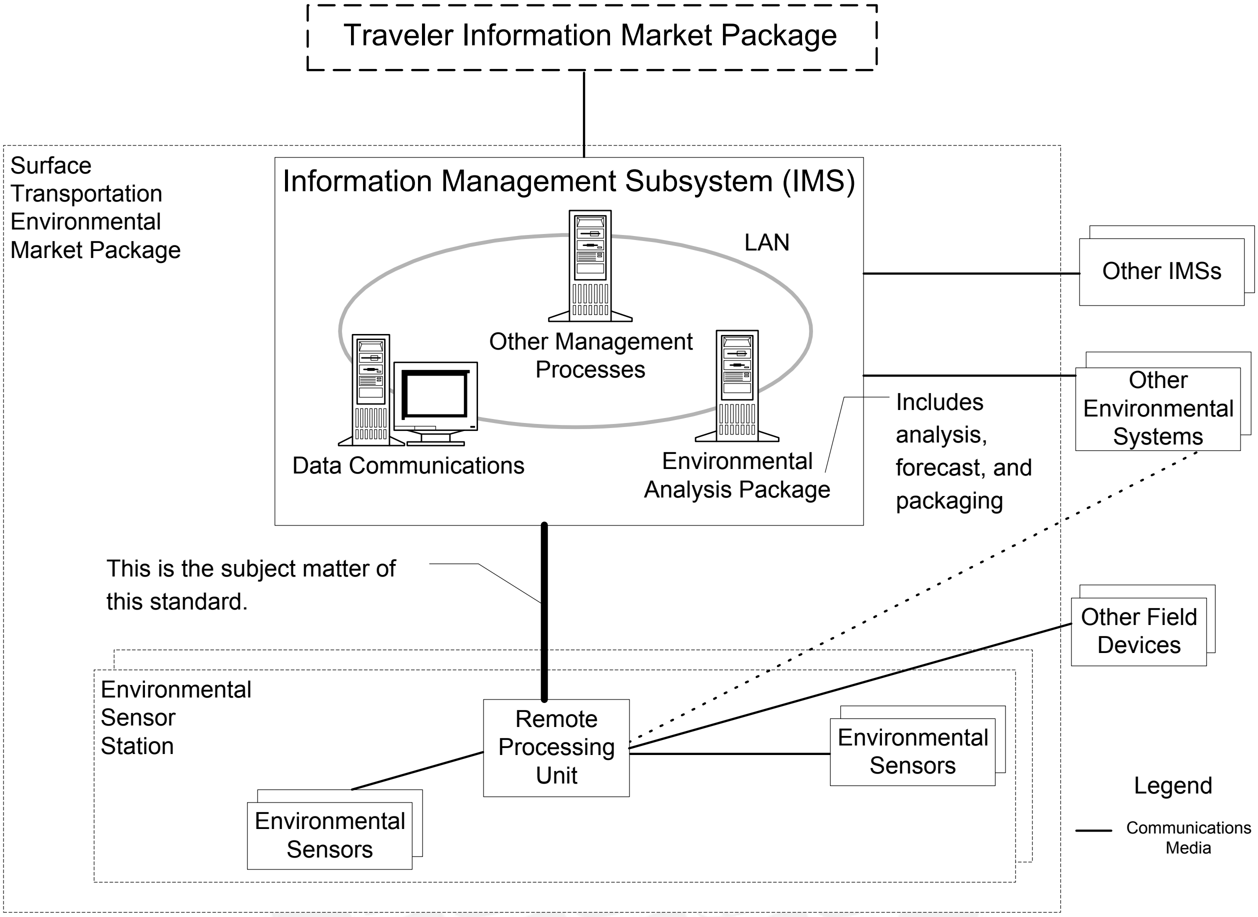
For a definition of meteorological terms, see the *Glossary of Meteorology*.

2.5 ACRONYMS

BUFR	Binary Universal Form for the Representation of meteorological data
CRC	Cyclical Redundancy Check
ESS	Environmental Sensor Station
IMS	Information Management Subsystem
ITS	Intelligent Transportation Systems
MIB	Management Information Base
NTCIP	National Transportation Communications for ITS Protocol
RPU	Remote Processor Unit
RWIS	Road/Weather Information System
SNMP	Simple Network Management Protocol
STMF	Simple Transportation Management Framework
STMP	Simple Transportation Management Protocol

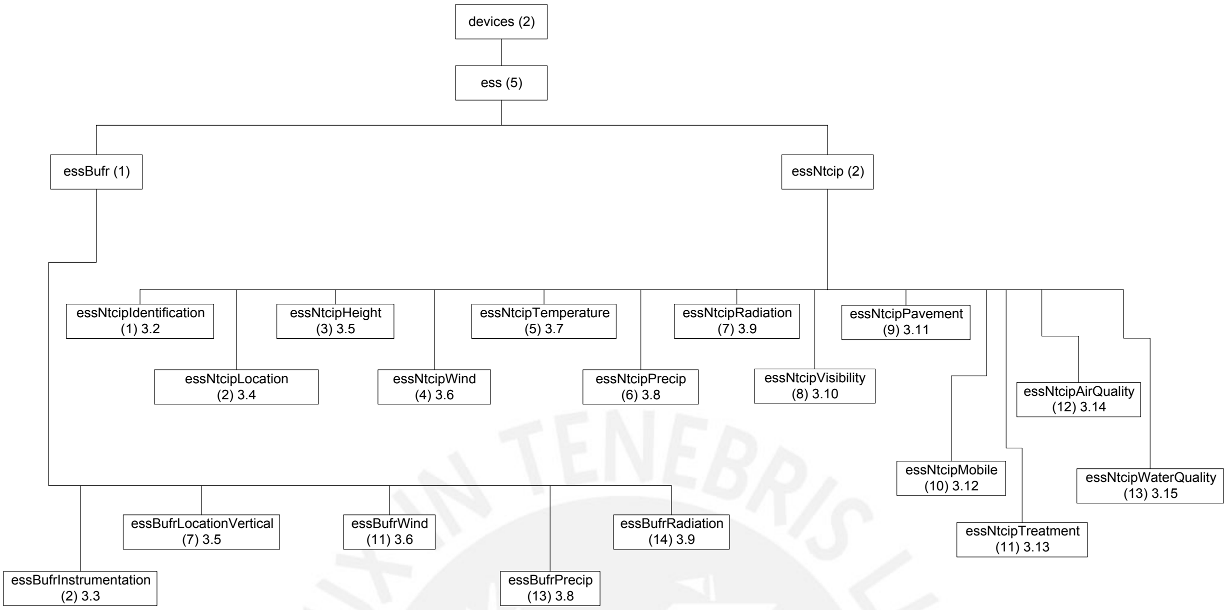
2.6 SUPPLEMENTAL FIGURES

The following two figures provide a pictorial representation of the ESS architecture and the Environmental Sensor Station Tree Structure. This is an architecture that is a proposed component for the National Architecture. The architecture diagram identifies some of the terms and acronyms described above and identifies the focus of this standard. The tree structure identifies how the object definitions are combined under specific nodes.



Architectural Terminology Diagram

Environmental Sensor Station Tree Branch of the Devices Tree



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Section 3
OBJECT DEFINITIONS

This section defines those objects which are specifically used by Environmental Sensor Stations (ESS). The objects are defined using the OBJECT-TYPE macro as specified in RFC 1212. The text provided from Clause 3.1 through the end of the section (except the clause headings) constitutes the standard ESSMIB1.

All of the objects defined in this document reside under the "ess" node of the global naming tree. To aid in object management, the "ess" node has been subdivided into logical categories, each defined by a node under the "ess" node. The individual objects are then located under the appropriate node.

Nodes should not be confused with Conformance Groups, which are defined in Section 4. A Conformance Group is a logical grouping of objects which is used for conformance statements. While Conformance Groups will frequently correspond to the nodal structure, a Conformance Group may contain objects which are not lexicographically ordered.

3.1 ENVIRONMENTAL SENSOR STATION (ESS) MIB HEADER INFORMATION

```
ESS-MIB DEFINITIONS ::= BEGIN
IMPORTS
  IpAddress, Counter
          FROM RFC1155-SMI
  DisplayString
          FROM RFC1158-SMI
  OBJECT-TYPE
          FROM RFC-1212
  experimental
          FROM NEMA_SMI
  devices
          FROM TMIB;
-- For the purpose of this section, the following OBJECT IDENTIFIERS are used:
ess OBJECT IDENTIFIER ::={devices 5}

essBufr OBJECT IDENTIFIER ::= {ess 1}
-- This node contains objects that describe BUFR information based on the BUFR Standards.

essNtcip OBJECT IDENTIFIER ::= {ess 2}
-- This node contains objects that describe surface transportation environmental information
-- which deviate from the BUFR Standards.
```

3.2 IDENTIFICATION OBJECTS

```
-- These are objects used to describe the identification of the environmental sensor station.
essNtcipIdentification  OBJECT IDENTIFIER ::= {essNtcip 1 }
```

3.2.1 Station Category

essNtcipCategory OBJECT-TYPE

```
SYNTAX          INTEGER { other (1),
                          permanent (2),
                          transportable (3),
                          mobile (4)}
```

ACCESS read-only
STATUS mandatory
DESCRIPTION "Indicates the type of station.

value	description
other	of a design not listed in this standard.
permanent	not designed to be relocated.
transportable	able to be relocated, but does not take readings while moving.
mobile	capable of taking readings while moving."

::= {essNtcipIdentification 1}

3.2.2 Station Site Description

essNtcipSiteDescription OBJECT-TYPE
SYNTAX DisplayString (SIZE (0..255))
ACCESS read-write
STATUS mandatory
DESCRIPTION "A textual description of the station's location."
::= {essNtcipIdentification 2}

-- it is also recognized that there would be a great value of an object to indicate the quality of data;
-- however, this is a very complex topic and thus we have not determined an appropriate mechanism.

3.3 DATA INSTRUMENTATION OBJECTS

-- Contains objects used to describe the type of data and the type of instrumentation used to
-- collect the data being received from the ess.
essBufrInstrumentation OBJECT IDENTIFIER ::= {essBufr 2 }

3.3.1 Type of Station

essTypeofStation OBJECT-TYPE
SYNTAX INTEGER (0..3)
ACCESS read-only
STATUS mandatory
DESCRIPTION "Integer value that indicates the type of station. If the station is a hybrid station, it shall be defined as two stations, one staffed and one automatic.

value	description
0 - automatic	the data is collected electronically/mechanically
1 - staffed	the data is collected by humans
3 - missingValue	the type of station is unknown."

REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 02 001."
::= {essBufrInstrumentation 1}

-- The definition of the type, make, model, and version of the various sensors connected to the ESS shall
-- be defined in the Global Module Table.

3.4 LOCATION OBJECTS

-- Contains objects used to describe the location of the ess that is transmitting the collected data.

essNtcipLocation OBJECT IDENTIFIER ::= {essNtcip 2 }

3.4.1 Latitude

essLatitude OBJECT-TYPE

SYNTAX INTEGER (-90000000..90000001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The latitude in 10^-6 degrees of the ESS station. The *essLatitude* at the North Pole is 90,000,000. The *essLatitude* at the South Pole is -90,000,000. The value 90,000,001 shall indicate a missing value."
REFERENCE "Resolution based on on-going location referencing activities; the WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 05 001 can be obtained by dividing this value by 10."
::= {essNtcipLocation 1}

3.4.2 Longitude

essLongitude OBJECT-TYPE
SYNTAX INTEGER (-180000000..180000001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The east longitude in 10^-6 degrees from the Prime Meridian of the ESS location. The *essLongitude* of 180 degrees West shall be -180,000,000. The *essLongitude* of 180 degrees East shall be 180,000,000. The value 180,000,001 shall indicate a missing value."
REFERENCE "Resolution based on on-going location referencing activities; the WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 06 001 can be obtained by dividing this value by 10."
::= {essNtcipLocation 2}

3.4.3 Vehicle Speed

essVehicleSpeed OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION "Indicates the current speed being reported by the vehicle in kilometers per hour. The value 255 shall indicate an error condition or missing value."
::= { essNtcipLocation 3}

3.4.4 Vehicle Bearing

essVehicleBearing OBJECT-TYPE
SYNTAX INTEGER (0..361)
ACCESS read-only
STATUS mandatory
DESCRIPTION "Indicates the current bearing of the vehicle in degrees, measured clockwise from True North. The value 361 shall indicate an error condition or missing value."
::= { essNtcipLocation 4 }

3.4.5 Odometer

essOdometer OBJECT-TYPE
SYNTAX Counter
ACCESS read-only
STATUS mandatory
DESCRIPTION "Indicates the current odometer reading of the vehicle in meters."
::= { essNtcipLocation 5 }

3.5 STATION ELEVATION OBJECTS

-- Contains objects used to describe the elevation and atmospheric pressure at the ess that is
-- transmitting the collected data.
essNtcipHeight OBJECT IDENTIFIER ::= {essNtcip 3 }
essBufrLocationVertical OBJECT IDENTIFIER ::= {essBufr 7 }

3.5.1 Reference Height

essReferenceHeight OBJECT-TYPE
SYNTAX INTEGER (-400..8001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The reference elevation of the ESS in meters above mean sea level. For a permanent station, this height shall be measured to the base of the structure; for transportable stations, this height shall be measured to the ground surface upon which the station resides; and for mobile, this height shall be measured to the surface under the vehicle. The value 8001 shall indicate an missing value."
REFERENCE "Resolution based on WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 07 001."
::= {essNtcipHeight 1}

3.5.2 Pressure Height

essPressureHeight OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The height of the pressure sensor with respect to the essReferenceHeight in meters. The value 1001 shall indicate a missing value."
REFERENCE "essRefernceHeight plus this value equals the WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 07 001."
::= {essNtcipHeight 2}

3.5.3 Wind Sensor Height

essWindSensorHeight OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The height of the wind sensor with respect to the essReferenceHeight in meters. The value 1001 shall indicate a missing value."
::= {essNtcipHeight 3}

3.5.4 Atmospheric Pressure Parameter

essAtmosphericPressure OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The force per unit area exerted by the atmosphere in 1/10ths of millibars, a.k.a. tenths of hectoPascals. A value of 65535 shall indicate an error condition or missing value."
REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 07 004."
::= { essBufrLocationVertical 4}

3.6 WIND DATA SECTION

-- Contains objects used to describe the wind data that is collected at the ess.
essNtcipWind OBJECT IDENTIFIER ::= {essNtcip 4 }
essBufrWind OBJECT IDENTIFIER ::= {essBufr 11 }

3.6.1 Average Wind Direction

essAvgWindDirection OBJECT-TYPE
SYNTAX INTEGER (0..361)
ACCESS read-only

STATUS mandatory
DESCRIPTION "A two minute average of the direction from which the wind is blowing measured clockwise in degrees from true North and measured at a height as indicated by essWindSensorHeight. A value of 361 shall indicate an error condition or missing value."
REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 11 001."
::= {essBufrWind 1}

3.6.2 Average Wind Speed

essAvgWindSpeed OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "A two minute average of the wind speed in tenths of meters per second measured at a height as indicated by essWindSensorHeight. A value of 65535 shall indicate an error condition or missing value."
REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 11 002."
::= {essBufrWind 2}

3.6.3 Spot Wind Direction

essSpotWindDirection OBJECT-TYPE
SYNTAX INTEGER (0..361)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The direction from which the wind is blowing measured in degrees clockwise from true North and measured at a height as indicated by essWindSensorHeight. A value of 361 shall indicate an error condition or missing value. For mobile platforms, the wind direction shall be corrected for vehicle movement."
::= { essNtcipWind 1}

3.6.4 Spot Wind Speed

essSpotWindSpeed OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The wind speed in tenths of meters per second measured at a height as indicated by essWindSensorHeight. A value of 65535 shall indicate an error condition or missing value. For mobile platforms, the wind speed shall be corrected for vehicle movement."
::= {essNtcipWind 2}

3.6.5 Wind Situation

essWindSituation OBJECT-TYPE
SYNTAX INTEGER { other (1),
unknown (2),
calm (3),
lightBreeze (4),
moderateBreeze (5),
strongBreeze (6),
gale (7),
moderateGale (8),
strongGale (9),
stormWinds (10),
hurricaneForceWinds (11),
gustyWinds (12)}
ACCESS read-only

STATUS mandatory
DESCRIPTION “Describes the weather and travel situation in terms of wind from staffed stations only. Specific ranges for these values are defined in the Glossary of Meteorology. Defined values are:

Range	Meaning
other	not defined within this standard, consult manufacturers documentation
unknown	Unknown conditions
calm	Calm
lightBreeze	Light breeze
moderateBreeze	Moderate breeze
strongBreeze	Strong breeze
gale	Gale
moderateGale	Moderate gale
strongGale	Strong gale
stormWinds	Storm winds
hurricaneForceWinds	Hurricane force winds
gustyWinds	Gusty winds – defined by a peak and a lull of greater than 46.3 tenths of meters per second within a 2 minute period.”

::= {essNtcipWind 3}

3.6.6 Maximum Wind Gust Speed

essMaxWindGustSpeed OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION “The maximum wind gust recorded during the 10 minutes preceding the observation at a height as indicated by essWindSensorHeight and measured in tenths of meters per second. The value 65535 shall indicate an error condition or missing value.”
REFERENCE “WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 11 041.”
::= {essBufrWind 41}

3.6.7 Maximum Wind Gust Direction

essMaxWindGustDir OBJECT-TYPE
SYNTAX INTEGER (0..361)
ACCESS read-only
STATUS mandatory
DESCRIPTION “The direction of the maximum wind gust recorded during the 10 minutes preceding the observation at a height as indicated by essWindSensorHeight; measured in degrees clockwise from true North. The value 361 shall indicate an error condition or missing value.”
REFERENCE “WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 11 043.”
::= {essBufrWind 43}

3.7 TEMPERATURE DATA OBJECTS

-- Contains objects used to describe the temperature data that is collected at the ess.
essNtcipTemperature OBJECT IDENTIFIER ::= {essNtcip 5 }

3.7.1 Number of Temperature Sensors

essNumTemperatureSensors OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION “Indicates the number of entries in the temperature sensor table.”
::= {essNtcipTemperature 1}

3.7.2 Temperature Sensor Table

essTemperatureSensorTable OBJECT-TYPE
SYNTAX SEQUENCE OF EssTemperatureSensorEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION "Table containing the temperature sensor data fields."
::= {essNtcipTemperature 2}

essTemperatureSensorEntry OBJECT-TYPE
SYNTAX EssTemperatureSensorEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION "Parameters for specific temperature sensor data fields."
INDEX {essTemperatureSensorIndex}
::= {essTemperatureSensorTable 1}

*Ess*Temperature*SensorEntry* ::= SEQUENCE {
essTemperatureSensorIndex INTEGER,
essTemperatureSensorHeight INTEGER,
essAirTemperature INTEGER }

3.7.2.1 Temperature Sensor Index

essTemperatureSensorIndex OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION "Enumerated list of row entries that will provide temperature sensor data."
::= {essTemperatureSensorEntry 1}

3.7.2.2 Temperature Sensor Height

essTemperatureSensorHeight OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The height of the temperature sensor as measured in meters above essReferenceHeight."
::= { essTemperatureSensorEntry 2}

3.7.2.3 Air Temperature

essAirTemperature OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The dry-bulb temperature in tenths of degrees Celsius. The temperature is an instantaneous reading at the height specified by *essTemperatureSensorHeight*. The value 1001 shall indicate an error condition or missing value."
REFERENCE "Resolution is based on WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 12 001; temperature in kelvin is determined by adding 273.15 to this value."
::= { essTemperatureSensorEntry 3}

3.7.3 Wet-Bulb Temperature

essWetbulbTemp OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS mandatory

DESCRIPTION "The wet-bulb temperature in tenths of degrees Celsius. The temperature is an instantaneous reading at the height specified by the *essTemperatureSensorHeight* as specified in the first row of the essTemperatureTable. The value 1001 shall indicate an error condition or missing value."
REFERENCE "Resolution is based on WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 12 002; temperature in kelvin is determined by adding 273.15 to this value."
::= {essNtcipTemperature 3}

3.7.4 Dew-Point Temperature

essDewpointTemp OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The dewpoint temperature in tenths of degrees Celsius. The temperature is an instantaneous reading at the height specified by the *essTemperatureSensorHeight* as specified in the first row of the essTemperatureTable. The value 1001 shall indicate an error condition or missing value."
REFERENCE "Resolution is based on WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 12 003; temperature in kelvin is determined by adding 273.15 to this value."
::= {essNtcipTemperature 4}

3.7.5 Maximum Temperature

essMaxTemp OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The maximum temperature in tenths of degrees Celsius recorded during the 24 hours preceding the observation at the height specified by the *essTemperatureSensorHeight* as specified in the first row of the essTemperatureTable. The value 1001 shall indicate an error condition or missing value."
REFERENCE "Resolution is based on WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 12 011; temperature in kelvin is determined by adding 273.15 to this value."
::= {essNtcipTemperature 5}

3.7.6 Minimum Temperature

essMinTemp OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The minimum temperature in tenths of degrees Celsius recorded during the 24 hours preceding the observation at the height specified by the *essTemperatureSensorHeight* as specified in the first row of the essTemperatureTable. The value 1001 shall indicate an error condition or missing value."
REFERENCE "Resolution is based on WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 12 012; temperature in kelvin is determined by adding 273.15 to this value."
::= {essNtcipTemperature 6}

3.8 HUMIDITY AND PRECIPITATION DATA OBJECTS

-- Contains objects used to describe the humidity and precipitation data that is collected by the
-- ess.
essBufrPrecip OBJECT IDENTIFIER ::= {essBufr 13 }
essNtcipPrecip OBJECT IDENTIFIER ::= {essNtcip 6 }

3.8.1 Relative Humidity

essRelativeHumidity OBJECT-TYPE
SYNTAX INTEGER (0..101)
ACCESS read-only
STATUS mandatory

DESCRIPTION “The relative humidity in percent. The value of 101 shall indicate an error condition or missing value.”
REFERENCE “WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 13 003.”
::= {essBufrPrecip 3}

3.8.2 Water Depth

essWaterDepth OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS optional
DESCRIPTION “Indicates the depth of the water from a user defined point in centimeters. The value of 65535 shall indicate an error condition or missing value. This may be used for stream depth, depth of water over a roadway, reservoir depth, or other such uses.”
::= {essNtcipPrecip 1}

3.8.3 Adjacent Snow Depth

essAdjacentSnowDepth OBJECT-TYPE
SYNTAX INTEGER (0..3001)
ACCESS read-only
STATUS mandatory
DESCRIPTION “The depth of snow in centimeters on representative areas other than the highway pavement, avoiding drifts and plowed areas. The value 3001 shall indicate an error condition or missing value.”
::={ essNtcipPrecip 2}

3.8.4 Roadway Snow Depth

essRoadwaySnowDepth OBJECT-TYPE
SYNTAX INTEGER (0..3001)
ACCESS read-only
STATUS mandatory
DESCRIPTION “The current depth of unpacked snow in centimeters on the driving surface. The value 3001 shall indicate an error condition or missing value.”
::={essNtcipPrecip 3}

3.8.5 Roadway Snow Pack Depth

essRoadwaySnowPackDepth OBJECT-TYPE
SYNTAX INTEGER (0..3001)
ACCESS read-only
STATUS mandatory
DESCRIPTION “The current depth of packed snow in centimeters on the roadway surface. The value 3001 shall indicate an error condition or missing value.”
::={ essNtcipPrecip 4}

3.8.6 Precipitation Indicator

essPrecipYesNo OBJECT-TYPE
SYNTAX INTEGER { precip (1),
noPrecip (2),
error (3)}
ACCESS read-only
STATUS mandatory
DESCRIPTION “Indicates whether or not moisture is detected by the sensor.”
::={ essNtcipPrecip 5}

3.8.7 Rainfall or Water Equivalent of Snow

essPrecipRate OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The rainfall, or water equivalent of snow, rate in tenths of grams per square meter per second (for rain, this is approximately to 0.36 mm/hr). A value of 65535 shall indicate an error condition or missing value."
REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 13 014."
::= { essBufrPrecip 14}

3.8.8 Snowfall Accumulation Rate

essSnowfallAccumRate OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The snowfall accumulation rate in 10^-7 meters per second (this is equivalent to 0.36 mm/hr). The value 65535 shall indicate an error condition or missing value."
REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 13 015."
::= { essBufrPrecip 15}

3.8.9 Precipitation Situation

essPrecipSituation OBJECT-TYPE
SYNTAX INTEGER { other (1),
unknown (2),
noPrecipitation (3),
unidentifiedSlight (4),
unidentifiedModerate (5),
unidentifiedHeavy (6),
snowSlight (7),
snowModerate (8),
snowHeavy (9),
rainSlight (10),
rainModerate (11),
rainHeavy (12),
frozenPrecipitationSlight (13),
frozenPrecipitationModerate (14),
frozenPrecipitationHeavy (15)}
ACCESS read-only
STATUS mandatory

DESCRIPTION "Describes the weather situation in terms of precipitation. Defined values of intensity are:

Intensity	Meaning
slight	< 2mm/h water equivalent
moderate	>= 2 and < 8 mm/h water equivalent
heavy	>= 8 mm/h water equivalent

If one exists, the corresponding BUFR value is indicated for staffed (BUFRs) and automated (BUFRa) stations. The indicated value can be found in the BUFR Table referenced below. Defined values are:

Range	BUFRa	BUFRs	Meaning
1			other
2			unknown
3			no precipitation
4			unidentified slight
5			unidentified moderate
6			unidentified heavy
7	171	85	snow slight
8	172	86	snow moderate
9	173	86	snow heavy
10		61	rain slight
11	165	63	rain moderate
12	163	65	rain heavy
13			frozen precipitation slight
14			frozen precipitation moderate
15			frozen precipitation heavy"

REFERENCE "The values identified in the above table for BUFRa and BUFRs can be found in WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 20 003."
::= { essNtcipPrecip 6}

3.8.10 Ice Deposit (Thickness)

essIceThickness OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS optional
DESCRIPTION "Indicates the thickness of the ice in millimeters. The value 65535 shall indicate an error condition or missing value."
::= {essNtcipPrecip 7}

3.8.11 Precipitation Start Time

essPrecipitationStartTime OBJECT-TYPE
SYNTAX INTEGER (0..4294967295)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The time at which the most recent precipitation event began, measured in seconds since 00:00:00 January 1, 1970 UTC. As this standard has been developed long after 1970, a value of 0 for the time should indicate to the management station that the data received is suspect."
::= { essNtcipPrecip 8}

3.8.12 Precipitation End Time

essPrecipitationEndTime OBJECT-TYPE
SYNTAX INTEGER (0..4294967295)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The time at which the most recently completed precipitation event ended, measured in seconds since 00:00:00 January 1, 1970 UTC. As this standard has been developed long after 1970, a value of 0 for the time should indicate to the management station that the data received is suspect."
::= { essNtcipPrecip 9}

3.8.13 Total Precipitation Past One Hour

essPrecipitationOneHour OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The total water equivalent precipitation over the hour preceding the observation in tenths of kilograms per square meter (for rain, this is approximately tenths of millimeters). A value of 65535 shall indicate an error condition or missing value."
REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 13 019."
::= { essBufrPrecip 19}

3.8.14 Total Precipitation Past Three Hours

essPrecipitationThreeHours OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The total water equivalent precipitation over the three hours preceding the observation in tenths of kilograms per square meter (for rain, this is approximately tenths of millimeters). A value of 65535 shall indicate an error condition or missing value."
REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 13 020."
::= { essBufrPrecip 20}

3.8.15 Total Precipitation Past Six Hours

essPrecipitationSixHours OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The total water equivalent precipitation over the six hours preceding the observation in tenths of kilograms per square meter (for rain, this is approximately tenths of millimeters). A value of 65535 shall indicate an error condition or missing value."
REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 13 021."
::= { essBufrPrecip 21}

3.8.16 Total Precipitation Past Twelve Hours

essPrecipitationTwelveHours OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The total water equivalent precipitation over the twelve hours preceding the observation in tenths of kilograms per square meter (for rain, this is approximately to tenths of millimeters). A value of 65535 shall indicate an error condition or missing value."
REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 13 022."
::= { essBufrPrecip 22}

3.8.17 Total Precipitation Past Twenty-Four Hours

essPrecipitation24Hours OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The total water equivalent precipitation over the twenty-four hours preceding the observation in tenths of kilograms per square meter (for rain, this is equivalent to tenths of millimeters). A value of 65535 shall indicate an error condition or missing value."

REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 13 023."
::= { essBufrPrecip 23}

3.9 RADIATION OBJECTS

-- Contains objects used to describe the data that is collected by the pavement surface sensor.
essBufrRadiation OBJECT IDENTIFIER ::= {essBufr 14 }
essNtcipRadiation OBJECT IDENTIFIER ::= {essNtcip 7}

3.9.1.1 Solar Radiation

essSolarRadiation OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The direct solar radiation integrated over the 24 hours preceding the observation in Joules per square meter. A value of 65535 shall indicate a missing value."
REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 14 024."
::= {essBufrRadiation 24}

3.9.1.2 Total Sun

essTotalSun OBJECT-TYPE
SYNTAX INTEGER (0..1441)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The total amount of sunshine in minutes over the 24 hour period preceding the observation. A value of 1441 shall indicate a missing value."
REFERENCE "WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 14 031."
::= {essBufrRadiation 31}

3.9.2 Cloud Cover Situation

essCloudSituation OBJECT-TYPE
SYNTAX INTEGER { overcast (1),
cloudy (2),
partlyCloudy (3),
mostlyClear (4),
clear (5)}
ACCESS read-only
STATUS mandatory
DESCRIPTION "Describes the amount of cloud cover. The associated percentages of cloud cover are indicated to identify the differences between the defined values. Defined values are:

Value	Meaning	Percent Cloud Cover
1	Overcast	100 %
2	Mostly cloudy	62.5 % - 99 %
3	Partly cloudy	37.5 % - 62.4 %
4	Mostly sunny	1 % - 37.4 %
5	Clear skies	0 %"

::= {essNtcipRadiation 1}

3.10 VISIBILITY DATA OBJECTS

-- Contains objects used to describe the visibility data that is collected by the ess.
essNtcipVisibility OBJECT IDENTIFIER ::= {essNtcip 8 }

3.10.1 Visibility Parameter

essVisibility OBJECT-TYPE

SYNTAX INTEGER (0..1000001)
ACCESS read-only
STATUS mandatory
DESCRIPTION “Surface visibility measured in one tenth of a meter. The value 1000001 shall indicate an error condition or missing value.”
REFERENCE “The value for WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 20 001 is given by this value divided by 100.”
::= { essNtcipVisibility 1}

3.10.2 Visibility Situation

essVisibilitySituation OBJECT-TYPE
SYNTAX INTEGER { other (1),
unknown (2),
clear (3),
fogNotPatchy (4),
patchyFog (5),
blowingSnow (6),
smoke (7),
seaSpray (8),
vehicleSpray (9),
blowingDustOrSand (10),
sunGlare (11),
swarmsOfInsects (12)}
ACCESS read-only
STATUS mandatory
DESCRIPTION “Describes the travel environment in terms of visibility. If one exists, the corresponding BUFR value is indicated for staffed (BUFRs) and automated (BUFRa) stations. The indicated value can be found in the BUFR Table referenced below. Defined values are:

Range	BUFRs	BUFRa	Meaning
1			other visibility anomaly
2			unknown
3	0	100	clear
4	44	130	Fog - not patchy
5	41	131	Patchy fog
6	36	127	Blowing snow
7	04	104	Smoke
8	07	207	Sea Spray
9			Vehicle Spray
10	31	127	Blowing dust or sand
11			sun glare
12			Swarms of insects”

REFERENCE “The values identified in the above table for BUFRa and BUFRs can be found in WMO Binary Code form FM 94 BUFR Table B table reference descriptor 0 20 003.”
::= {essNtcipVisibility 3}

3.11 PAVEMENT SENSOR OBJECTS

-- Contains objects used to describe the data that is collected by the pavement surface sensor.
essNtcipPavement OBJECT IDENTIFIER ::= {essNtcip 9}

3.11.1 Number of Pavement Sensors

numEssPavementSensors OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory

DESCRIPTION "Indicates the number of entries in the pavement sensor table."
::= {essNtcipPavement 1}

3.11.2 Pavement Sensor Table

essPavementSensorTable OBJECT-TYPE
SYNTAX SEQUENCE OF EssPavementSensorEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION "Table containing the pavement sensor data fields."
::= {essNtcipPavement 2}

essPavementSensorEntry OBJECT-TYPE
SYNTAX EssPavementSensorEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION "Parameters for specific pavement sensor data fields."
INDEX {essPavementSensorIndex}
::= {essPavementSensorTable 1}

EssPavementSensorEntry ::= SEQUENCE {

```
    essPavementSensorIndex          INTEGER,
    essPavementSensorLocation       DisplayString,
    essPavementType                 INTEGER,
    essPavementElevation            INTEGER,
    essPavementExposure             INTEGER,
    essPavementSensorType           INTEGER,
    essSurfaceStatus                INTEGER,
    essSurfaceTemperature           INTEGER,
    essPavementTemperature          INTEGER,
    essSurfaceWaterDepth            INTEGER,
    essSurfaceSalinity              INTEGER,
    essSurfaceConductivity          INTEGER,
    essSurfaceFreezePoint           INTEGER,
    essSurfaceBlackIceSignal        INTEGER,
    essPavementSensorError          INTEGER}
```

3.11.2.1 Pavement Sensor Index

essPavementSensorIndex OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION "Enumerated list of row entries that will provide surface sensor data."
::= {essPavementSensorEntry 1}

3.11.2.2 Pavement Sensor Location

essPavementSensorLocation OBJECT-TYPE
SYNTAX DisplayString (SIZE (0..255))
ACCESS read-write
STATUS mandatory
DESCRIPTION "A textual string indicating the location of the pavement sensor."
::= { essPavementSensorEntry 2}

-- We have contacted the LRMS group to express a need for a better mechanism for
-- defining this location down to the lane level.

3.11.2.3 Pavement Type

essPavementType OBJECT-TYPE
SYNTAX INTEGER { other (1),
unknown (2),
asphalt (3),
openGradedAsphalt (4),
concrete (5),
steelBridge (6),
concreteBridge (7),
asphaltOverlayBridge (8),
timberBridge (9) }
ACCESS read-write
STATUS mandatory
DESCRIPTION "Indicates the type of pavement on the roadway.

other	a different type of bridge deck
unknown	the data was never recorded in the system
asphalt	asphalt pavement on ground
concrete	concrete pavement on ground
steelBridgeconcrete	a concrete driving surface on a steel girder bridge
steelBridgeAsphalt	an asphalt driving surface on a steel girder bridge
steelBridge	a steel lattice driving surface on the bridge
concreteBridge	a concrete driving surface on a concrete bridge
concreteBridgeAsphalt	an asphalt overlay driving surface on a concrete bridge
timberBridge	a wooden deck driving surface on the bridge"

::= { essPavementSensorEntry 3}

3.11.2.4 Pavement Elevation

essPavementElevation OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The elevation of the street surface in meters with respect to the essReferenceHeight. The value 1001 shall indicate a missing value."
::= { essPavementSensorEntry 4}

3.11.2.5 Pavement Exposure

essPavementExposure OBJECT-TYPE
SYNTAX INTEGER (0..101)
ACCESS read-write
STATUS mandatory
DESCRIPTION "Indicates a very rough percentage of the solar energy which will directly hit the sensor. A value of 100 indicates a fully visible sky. A value of 101 shall indicate a missing value."
::= { essPavementSensorEntry 5}

3.11.2.6 Pavement Sensor Type

essPavementSensorType OBJECT-TYPE
SYNTAX INTEGER {other (1),
contactPassive (2),
contactActive (3),
infrared (4),
radar (5),
vibrating (6),
microwave (7)}
ACCESS read-only

STATUS mandatory
DESCRIPTION "A value indicating the type of pavement sensor."
::= { essPavementSensorEntry 6}

3.11.2.7 Surface Status

essSurfaceStatus OBJECT-TYPE
SYNTAX INTEGER { other (1),
error (2),
dry (3),
traceMoisture (4),
wet (5),
chemicallyWet (6),
iceWarning (7),
iceWatch (8),
snowWarning (9),
snowWatch (10),
absorption (11),
dew (12),
frost (13),
absorptionAtDewpoint (14) }
ACCESS read-only
STATUS mandatory
DESCRIPTION "A value indicating the pavement surface status."
::= { essPavementSensorEntry 7}

3.11.2.8 Surface Temperature

essSurfaceTemperature OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The current pavement surface temperature in tenths of degrees Celsius. The value 1001 shall indicate an error condition or missing value."
::= { essPavementSensorEntry 8}

3.11.2.9 Pavement Temperature

essPavementTemperature OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS optional
DESCRIPTION "The current pavement temperature 2-10 cm below the pavement surface in tenths of degrees Celsius. The value 1001 shall indicate an error condition or missing value."
::= { essPavementSensorEntry 9}

3.11.2.10 Surface Water Depth

essSurfaceWaterDepth OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS optional
DESCRIPTION "The current depth of water on the surface of the roadway measured in millimeters. The value 255 shall indicate an error condition or missing value."
::= { essPavementSensorEntry 10}

3.11.2.11 Surface Salinity

essSurfaceSalinity OBJECT-TYPE

```
SYNTAX       INTEGER (0..65535)
ACCESS       read-only
STATUS       optional
DESCRIPTION "The pavement salinity in parts per one hundred thousand.  The value 65535 shall
indicate an error condition or missing value."
::= { essPavementSensorEntry 11}

-- A comment has been received to make both the surface salinity and surface conductivity optional
-- objects.  This issue will be discussed by the WG with any other comments received during balloting.
```

3.11.2.12 Surface Conductivity

```
essSurfaceConductivity OBJECT-TYPE
SYNTAX       INTEGER (0..65535)
ACCESS       read-only
STATUS       optional
DESCRIPTION "Indicates the conductance of the ice/liquid mixture on the pavement as detected by the
sensor, in mhos, which is the inverse of ohms. The value  65535 shall indicate an error condition or
missing value."
::= { essPavementSensorEntry 12}
```

3.11.2.13 Pavement Freezing Point

```
essSurfaceFreezePoint OBJECT-TYPE
SYNTAX       INTEGER (-1000..1001)
ACCESS       read-only
STATUS       optional
DESCRIPTION "The temperature in tenths of degrees Celsius at which the existing solution on the
roadway will freeze.  The value 1001 shall indicate an error condition or missing value."
::= { essPavementSensorEntry 13}
```

3.11.2.14 Surface Black Ice Signal

```
essSurfaceBlackIceSignal OBJECT-TYPE
SYNTAX       INTEGER {other (1),
                      noIce (2),
                      blackIce (3),
                      detectorError (4) }
ACCESS       read-only
STATUS       optional
DESCRIPTION "A value indicating if Black Ice is detected by the sensor."
::= { essPavementSensorEntry 14}
```

3.11.2.15 Surface Sensor Error

```
essPavementSensorError OBJECT-TYPE
SYNTAX       INTEGER {other (1),
                      none (2),
                      noResponse (3),
                      cutCable (4),
                      shortCircuit (5),
                      dirtyLens (6) }
ACCESS       read-only
STATUS       mandatory
DESCRIPTION "A value indicating the type of pavement sensor error."
::= { essPavementSensorEntry 15}
```

3.11.3 Number of Sub-Surface Sensors

numEssSubSurfaceSensors OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION “Indicates the number of entries in the Sub-Surface Sensor Table.”
::= {essNtcipPavement 3}

3.11.4 Sub-Surface Sensor Table

essSubSurfaceSensorTable OBJECT-TYPE
SYNTAX SEQUENCE OF EssSubSurfaceSensorEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION “Table containing the surface sensor data fields.”
::= {essNtcipPavement 4}

essSubSurfaceSensorEntry OBJECT-TYPE
SYNTAX EssSubSurfaceSensorEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION “Parameters for specific sub-surface sensor data fields.”
INDEX {essSubSurfaceSensorIndex}
::= {essSubSurfaceSensorTable 1}

EssSubSurfaceSensorEntry ::= SEQUENCE {
essSubSurfaceSensorIndex INTEGER,
essSubSurfaceSensorLocation DisplayString,
essSubSurfaceType INTEGER,
essSubSurfaceSensorDepth INTEGER,
essSubSurfaceTemperature INTEGER,
essSubSurfaceMoisture INTEGER,
essSubSurfaceSensorError INTEGER}

3.11.4.1 Sub-Surface Sensor Index

essSubSurfaceSensorIndex OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION “Enumerated list of row entries that will provide surface sensor data.”
::= { essSubSurfaceSensorEntry 1}

3.11.4.2 Sub-Surface Sensor Location

essSubSurfaceSensorLocation OBJECT-TYPE
SYNTAX DisplayString (SIZE (0..255))
ACCESS read-write
STATUS mandatory
DESCRIPTION “A textual string indicating the location of the subsurface sensor.”
::= { essSubSurfaceSensorEntry 2}

3.11.4.3 Sub-Surface Type

essSubSurfaceType OBJECT-TYPE
SYNTAX INTEGER {other (1),
unknown (2),
concrete (3),
asphalt (4),
openGradedAsphalt (5),

gravel (6),
clay (7),
loam (8),
sand (9),
permafrost (10),
variousAggregates (11),
air (12)}
ACCESS read-write
STATUS mandatory
DESCRIPTION "Indicates the type of sub-surface. A value of air would indicate a bridge."
::= { essSubSurfaceSensorEntry 3}

3.11.4.4 Sub-Surface Sensor Depth

essSubSurfaceSensorDepth OBJECT-TYPE
SYNTAX INTEGER (0..1001)
ACCESS read-write
STATUS mandatory
DESCRIPTION "Depth of sub-surface sensor in centimeters below the pavement surface. The value 1001 shall indicate an error condition or missing value."
::= { essSubSurfaceSensorEntry 4}

3.11.4.5 Sub-Surface Temperature

essSubSurfaceTemperature OBJECT-TYPE
SYNTAX INTEGER (-1000..1001)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The current sub-surface temperature in tenths of degrees Celsius. The value 1001 shall indicate an error condition or missing value."
::= { essSubSurfaceSensorEntry 5}

3.11.4.6 Sub-Surface Moisture

essSubSurfaceMoisture OBJECT-TYPE
SYNTAX INTEGER (0..101)
ACCESS read-only
STATUS optional
DESCRIPTION "The sub-surface moisture expressed as a percentage (eg. 0 indicates dry, 100 indicates saturated). The value 101 indicates an error condition or missing value"
::= { essSubSurfaceSensorEntry 7}

3.11.4.7 Sub-Surface Sensor Error

essSubSurfaceSensorError OBJECT-TYPE
SYNTAX INTEGER {other (1),
none (2),
noResponse (3),
cutCable (4),
shortCircuit (5)}
ACCESS read-only
STATUS mandatory
DESCRIPTION "A value indicating the type of sensor error."
::= { essSubSurfaceSensorEntry 8}

3.12 MOBILE PLATFORM OBJECTS

-- This node contains objects which have been developed to facilitate experiments with data that collected
-- by mobile platforms (e.g., specially equipped maintenance vehicles).

-- There has been limited use of mobile ESS platforms within the surface transportation industry and as
-- such these objects should be considered experimental.
-- It is expected that mobile platforms will use the objects defined above plus these objects.
essNtcipMobile OBJECT IDENTIFIER ::= {essNtcip 10}

3.12.1 Mobile Friction

essMobileFriction OBJECT-TYPE
SYNTAX INTEGER (0..101)
ACCESS read-only
STATUS mandatory
DESCRIPTION "Indicates measured coefficient of friction in percent. The value 101 shall indicate an error condition or missing value."
::= { essNtcipMobile 1}

3.12.2 Mobile Observation for the State of the Ground

essMobileObservationGroundState OBJECT-TYPE
SYNTAX INTEGER {other (1),
dry (2),
moist (3),
wet (4),
flooded (5),
frozen (6),
glaze (7),
dustySandy (8),
veryDry (9),
icy (10),
patchyWetSnow (11),
moderateWetSnowCover (12),
fullWetSnowCover (13),
patchyDrySnow (14),
moderateDrySnowCover (15),
fullDrySnowCover (16),
driftingSnow (17),
unknown (18)}
ACCESS read-only
STATUS mandatory
DESCRIPTION "The prevailing observed ground state of the surrounding environment as determined by the observer. This is an indicator of past weather conditions."
::= { essNtcipMobile 2}

3.12.3 Mobile State of the Pavement

essMobileObservationPavement OBJECT-TYPE
SYNTAX INTEGER {other (1),
dry (2),
wet (3),
puddles (4),
shallowStandingWater (5),
shallowFlowingWater (6),
deepStandingWater (7),
deepFlowingWater (8),
dustingFreshSnow (9),
moderateFreshSnow (10),
deepFreshSnow (11),
plowedSnow (12),
slush (13),

packedSnowPatches (14),
packedSnow (15),
lightSnowDrifts (16),
moderateSnowDrifts (17),
heavySnowDrifts (18),
frost (19),
icePatches (20),
moderatelyIcy (21),
heavyIcing (22),
blackIce (23),
sheetIce (24),
frozenSlush (25) }

ACCESS read-only
STATUS mandatory
DESCRIPTION “The prevailing observed conditions on the driving surface as determined by the observer.”
::= { essNtcipMobile 3}

3.13 PAVEMENT TREATMENT OBJECTS

-- This node contains objects which have been developed to monitor the various types and amounts of
-- treatments that are spread on the pavement surface.
essNtcipTreatment OBJECT IDENTIFIER ::= { essNtcip 11 }

3.13.1 Number of Treatments

numEssTreatments OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION “Indicates the number of entries in the Pavement Treatment Table.”
::= {essNtcipTreatment 1}

3.13.2 Pavement Treatment Table

essPavementTreatmentTable OBJECT-TYPE
SYNTAX SEQUENCE OF EssPavementTreatmentEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION “Table containing the pavement treatment data fields.”
::= {essNtcipTreatment 2}

essPavementTreatmentEntry OBJECT-TYPE
SYNTAX EssPavementTreatmentEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION “Parameters for specific pavement treatment data fields.”
INDEX {essPavementTreatmentIndex}
::= {essPavementTreatmentTable 1}

EssPavementTreatmentEntry ::= SEQUENCE {
essPavementTreatmentIndex INTEGER,
essPaveTreatProductType INTEGER,
essPaveTreatProductForm INTEGER,
essPercentProductMix INTEGER}

3.13.2.1 Pavement Treatment Index

essPavementTreatmentIndex OBJECT-TYPE

SYNTAX INTEGER (1..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION "Enumerated list of row entries that will provide pavement treatment data."
::= { essPavementTreatmentEntry 1}

3.13.2.2 Pavement Treatment Product Type

essPaveTreatProductType OBJECT-TYPE
SYNTAX INTEGER {other (1),
sand (2),
dirt (3),
gravel (4),
cinders (5),
water (6),
enhancedSalts (7),
naCl (8),
caCl (9),
mgCl (10),
cMA (11),
kAC (12),
naFormate (13),
naA (14) }
ACCESS read-only
STATUS mandatory
DESCRIPTION "Indicates the type of treatment being applied to the road. An enhanced definition of some of the values are as follows:
other - any other type of treatment
water - used as a diluting agent
cMA - Calcium-Magnesium Acetate
kAC - Potassium-Magnesium Acetate
naFormate - Sodium Formate
naA - Sodium Acetate"
::= { essPavementTreatmentEntry 2}

3.13.2.3 Treatment Product Form

essPaveTreatProductForm OBJECT-TYPE
SYNTAX INTEGER { other (1),
dry (2),
prewet (3),
liquid (4)}
ACCESS read-only
STATUS mandatory
DESCRIPTION "Indicates the condition of the treatment being applied to the road."
::= { essPavementTreatmentEntry 3}

3.13.2.4 Percentage of Treatment Type in Mix

essPercentProductMix OBJECT-TYPE
SYNTAX INTEGER (0..100)
ACCESS read-only
STATUS mandatory
DESCRIPTION "Indicates the percentage of the total application mix by weight that is of the type specified in *essPaveTreatProductType*. The sum of these percentages within the total mixture shall equal 100."
::= { essPavementTreatmentEntry 4}

3.13.3 Treatment Amount

essPaveTreatmentAmount OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION "Indicates quantity of the treatment being applied in kilograms per lane kilometer."
::= { essNtcipTreatment 3}

3.13.4 Treatment Width

essPaveTreatmentWidth OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION "Indicates the width of the spread of treatment in meters."
::= { essNtcipTreatment 4}

3.14 AIR QUALITY PARAMETERS

essNtcipAirQuality OBJECT IDENTIFIER ::= { essNtcip 12 }
-- This node contains objects used for monitoring air quality conditions.

-- A comment has been received to add error conditions to these objects as per previous objects. This
-- was the original intent and this modification will be discussed by the WG along with any other comments
-- received during balloting.

3.14.1 Carbon Monoxide Parameter

essCO OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The concentration of carbon monoxide in the air, measured in parts per million. The value 255 shall indicate an error condition or missing value."
::= {essNtcipAirQuality 1}

3.14.2 Carbon Dioxide Parameter

essCO2 OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The concentration of carbon dioxide in the air, measured in parts per billion. The value 65535 shall indicate an error condition or missing value."
::= {essNtcipAirQuality 2}

3.14.3 Nitrous Oxide Parameter

essNO OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The concentration of nitrous oxide in the air, measured in parts per million. The value 255 shall indicate an error condition or missing value."
::= {essNtcipAirQuality 3}

3.14.4 Nitrogen Dioxide Parameter

essNO2 OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The concentration of nitrogen dioxide in the air, measured in parts per billion. The value 255 shall indicate an error condition or missing value."
::= {essNtcipAirQuality 4}

3.14.5 Sulfur Dioxide Parameter

essSO2 OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The concentration of sulfur dioxide in the air, measured in parts per billion. The value 65535 shall indicate an error condition or missing value."
::= {essNtcipAirQuality 5}

3.14.6 Ozone Parameter

essO3 OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The concentration of ozone in the air, measured in parts per one hundred billion. The value 255 shall indicate an error condition or missing value."
::= {essNtcipAirQuality 6}

3.14.7 Particulate Matter Parameter

essPM10 OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION "The concentration of small particulate matter of 10 micrometers or less in diameter in the air, measured in micrograms per cubic meter. The value 65535 shall indicate an error condition or missing value."
::= {essNtcipAirQuality 7}

3.15 WATER QUALITY PARAMETERS

essNtcipWaterQuality OBJECT IDENTIFIER ::= { essNtcip 13 }
-- This node contains objects used for monitoring water quality conditions. Appropriate agencies have
-- been contacted to assist in the development of these objects for future versions.

END -- ESS-MIB

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Section 4
CONFORMANCE

The conformance groups have been developed to be used as minimum requirements to claim compliance to the standard. There may be varying levels of compliance to the standard as there are numerous devices that have varying levels of performance. Therefore, hierarchical levels of conformance for certain data have been developed. These levels of conformance have been defined as Basic, Standard, Enhanced, and Emerging. Basic Conformance identifies the object(s) that must be supported to claim the lowest level of compliance to the standard. Standard Conformance identifies the object(s) that are supported by current technology. These objects must be supported to claim compliance at the Standard Conformance level.

The Enhanced Conformance level identifies new technology that will become common in the near future but are currently used in some areas. To claim compliance at the Enhanced Conformance level, the object(s) listed at this level must be supported. The Emerging Conformance level identifies that object(s) that must be supported to claim the highest level of compliance to the standard. The Emerging Conformance level identifies the object(s) that are under development or are being tested, but not being used. These objects are considered to be enhancements that may not be available in the near future.

4.1 CONFORMANCE STATEMENT

ESS devices shall adhere to the conformance requirements specified in Table 4-1 as a minimum to claim compliance to this standard. Additional objects or groups may be supported without being non-compliant with ESS objects or NTCIP.

Minimum and maximum ranges of objects that differ from the values of the object's SYNTAX field may be enforced by an application running on a device.

A device may enforce range limits within the bounds specified by the values of the object's SYNTAX field without being categorized as non-compliant with ESS objects or NTCIP; however, it may be categorized as non-compliant for other reasons. For example, a temperature sensor which only supports a range of -40°C to 100°C is compliant if all other requirements are met.

A device may support a subset of defined values for an enumerated object without being categorized as non-compliant with ESS objects or NTCIP; however, it may be categorized as non-compliant for other reasons. For example, a visibility sensor which can only distinguish between fog and other visual anomalies is compliant if all other requirements are met.

Table 4-1: Conformance Table

CONFORMANCE GROUP	REFERENCE	CONFORMANCE REQUIREMENT
Configuration	NTCIP 1201	mandatory
Database Management	NTCIP 1201	optional
Time Management	NTCIP 1201	mandatory
Timebase Event Schedule	NTCIP 1201	optional
Report	NTCIP 1201	optional
STMF	NTCIP 1201	optional
PMPP	NTCIP 1201	optional
ESS Configuration	NTCIP 1204	mandatory
ESS Location	NTCIP 1204	mandatory
Pressure	NTCIP 1204	optional
Wind Data	NTCIP 1204	optional
Mobile Wind Data	NTCIP 1204	optional
Basic Temperature Data	NTCIP 1204	optional
Enhanced Temperature Data	NTCIP 1204	optional
Basic Precipitation Data	NTCIP 1204	optional
Standard Precipitation Data	NTCIP 1204	optional
Enhanced Precipitation Data	NTCIP 1204	optional
Emerging Precipitation Data	NTCIP 1204	optional
Solar Radiation	NTCIP 1204	optional
Visibility Data	NTCIP 1204	optional
Standard Pavement Sensor Data	NTCIP 1204	optional
Enhanced Pavement Sensor Data	NTCIP 1204	optional
Standard Sub-Surface Sensor Data	NTCIP 1204	optional
Enhanced Sub-Surface Sensor Data	NTCIP 1204	optional
Emerging Mobile Platform	NTCIP 1204	optional
Pavement Treatment	NTCIP 1204	optional
Air Quality	NTCIP 1204	optional
Staffed Station	NTCIP 1204	optional

For additional information in producing procurement specifications, visit the NTCIP Home Page at http://www.ntcip.org.

4.2 CONFORMANCE GROUPS

A Conformance Group is defined in NTCIP 1101 Simple Transportation Management Framework (STMF), clause 3.3.5, as a basic unit of conformance.

A Conformance Statement refers to Conformance Groups and defines them as being either mandatory or optional. For a device to claim compliance to a Conformance Statement, it must be compliant with each of the mandatory Conformance Groups as defined within that Conformance Statement.

For a device to claim compliance to a Conformance Group, it must be compliant with each of the mandatory tables and mandatory objects as defined within that Conformance Group.

For a device to claim compliance with a table, it must be compliant with each of the mandatory objects included in the table.

For a device to claim compliance to an object, it must support at least one value of the object and all indicated functionality for the values it supports.

A device may support any optional feature.

Table 4-2: Object Support Requirements

OBJECT STATUS	TABLE STATUS	CONFORMANCE GROUP STATUS (IF ANY)	OBJECT SUPPORT
mandatory	Mandatory	mandatory	mandatory
mandatory	Mandatory	optional	mandatory, if conformance group is supported
mandatory	Optional	mandatory	mandatory, if table is supported
mandatory	Optional	optional	mandatory, if both the conformance group and table are supported
optional	Mandatory	mandatory	optional
optional	Mandatory	optional	optional
optional	Optional	mandatory	optional
optional	Optional	optional	optional

The Conformance Group definitions for Environmental Sensor Station (ESS) are defined in the following Clauses. An ESS may have multiple capabilities; thus, Conformance Groups are defined for each capability.

4.2.1 ESS Configuration Conformance Group

The ESS Configuration Conformance Group consists of a variety of ESS objects related to general configuration information. The ESS Configuration Conformance Group shall consist of the following objects and tables:

Object or Table Name	Reference
essNtcipCategory	NTCIP 1204
essNtcipSiteDescription	NTCIP 1204
essTypeofStation	NTCIP 1204

4.2.2 ESS Location Conformance Group

The ESS Location Conformance Group consists of objects that specify the location of the ESS. The ESS Location Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essLatitude	NTCIP 1204
essLongitude	NTCIP 1204
essReferenceHeight	NTCIP 1204

4.2.3 Pressure Conformance Group

The Pressure Conformance Group consists of objects that specify the pressure sensor height and pressure measurement of the ESS. The Pressure Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essPressureHeight	NTCIP 1204

essAtmosphericPressure	NTCIP 1204

4.2.4 Wind Data Conformance Group

The Wind Data Conformance Group consists of objects that describe the wind sensor elevation and wind data collected by the ESS. The Wind Data Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essWindSensorHeight	NTCIP 1204
essAvgWindDirection	NTCIP 1204
essAvgWindSpeed	NTCIP 1204
essMaxWindGustSpeed	NTCIP 1204
essMaxWindGustDir	NTCIP 1204

4.2.5 Mobile Wind Data Conformance Group

The Mobile Wind Data Conformance Group consists of objects that describe the wind sensor elevation and wind data collected by a mobile ESS. The Mobile Wind Data Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essWindSituation	NTCIP 1204
essSpotWindDirection	NTCIP 1204
essSpotWindSpeed	NTCIP 1204

4.2.6 Basic Temperature Data Conformance Group

The Basic Temperature Data Conformance Group consists of objects that describe the basic temperature data collected by the ESS. The Basic Temperature Data Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essNumTemperatureSensors	NTCIP 1204
essTemperatureSensorTable	NTCIP 1204
essTemperatureSensorIndex	NTCIP 1204
essTemperatureSensorHeight	NTCIP 1204
essAirTemperature	NTCIP 1204
essMaxTemp	NTCIP 1204
essMinTemp	NTCIP 1204

4.2.7 Enhanced Temperature Data Conformance Group

The Enhanced Temperature Data Conformance Group consists of objects that describe the enhanced temperature data collected by the ESS. The Enhanced Temperature Data Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essNumTemperatureSensors	NTCIP 1204
essTemperatureSensorTable	NTCIP 1204
essTemperatureSensorIndex	NTCIP 1204
essTemperatureSensorHeight	NTCIP 1204
essAirTemperature	NTCIP 1204

essMaxTemp	NTCIP 1204
essMinTemp	NTCIP 1204
essRelativeHumidity	NTCIP 1204
essWetBulbTemp	NTCIP 1204
essDewpointTemp	NTCIP 1204

4.2.8 Basic Precipitation Data Conformance Group

The Basic Precipitation Data Conformance Group consists of objects that describe the precipitation data collected by the ESS. The Basic Precipitation Data Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essPrecipYesNo	NTCIP 1204

4.2.9 Standard Precipitation Data Conformance Group

The Standard Precipitation Data Conformance Group consists of objects that describe the precipitation data collected by the ESS. The Standard Precipitation Data Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essPrecipRate	NTCIP 1204
essPrecipitationStartTime	NTCIP 1204
essPrecipitationEndTime	NTCIP 1204

4.2.10 Enhanced Precipitation Data Conformance Group

The Enhanced Precipitation Data Conformance Group consists of objects that describe the precipitation data collected by the ESS. The Enhanced Precipitation Data Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essPrecipRate	NTCIP 1204
essPrecipitationStartTime	NTCIP 1204
essPrecipitationEndTime	NTCIP 1204
essPrecipitationOneHour	NTCIP 1204
essPrecipitationThreeHour	NTCIP 1204
essPrecipitationSixHour	NTCIP 1204
essPrecipitationTwelveHour	NTCIP 1204
essPrecipitation24Hours	NTCIP 1204
essPrecipSituation	NTCIP 1204

4.2.11 Emerging Precipitation Data Conformance Group

The Emerging Precipitation Data Conformance Group consists of objects that describe the precipitation data collected by the ESS. The Emerging Precipitation Data Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essPrecipRate	NTCIP 1204
essPrecipitationStartTime	NTCIP 1204
essPrecipitationEndTime	NTCIP 1204

essPrecipitationOneHours	NTCIP 1204
essPrecipitationThreeHours	NTCIP 1204
essPrecipitationSixHours	NTCIP 1204
essPrecipitationTwelveHours	NTCIP 1204
essPrecipitation24Hours	NTCIP 1204
essWaterDepth	NTCIP 1204
essRoadwaySnowDepth	NTCIP 1204
essRoadwaySnowPackDepth	NTCIP 1204
essIceThickness	NTCIP 1204
essAdjacentSnowDepth	NTCIP 1204
essSnowfallRate	NTCIP 1204
essPrecipSituation	NTCIP 1204

4.2.12 Solar Radiation Conformance Group

The Solar Radiation Conformance Group consists of objects that describe the solar radiation data collected by the ESS. The Solar Radiation Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essSolarRadiation	NTCIP 1204
essSurfaceTotalSun	NTCIP 1204

4.2.13 Visibility Data Conformance Group

The Visibility Data Conformance Group consists of objects that describe the wind data collected by the ESS. The Visibility Data Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essVisibility	NTCIP 1204
essVisibilitySituation	NTCIP 1204

4.2.14 Standard Pavement Sensor Data Conformance Group

The Standard Pavement Sensor Data Conformance Group consists of objects that describe the standard pavement surface data collected by the ESS. The Standard Pavement Sensor Data Conformance Group shall consist of the following objects:

Object or Table Name	Reference
numEssPavementSensors	NTCIP 1204
essPavementSensorTable	NTCIP 1204
essPavementSensorIndex	NTCIP 1204
essPavementSensorLocation	NTCIP 1204
essPavementType	NTCIP 1204
essPavementElevation	NTCIP 1204
essPavementExposure	NTCIP 1204
essPavementSensorType	NTCIP 1204
essSurfaceStatus	NTCIP 1204
essSurfaceTemperature	NTCIP 1204
essPavementSensorError	NTCIP 1204

4.2.15 Enhanced Pavement Sensor Data Conformance Group

The Enhanced Pavement Sensor Data Conformance Group consists of objects that describe the standard and enhanced pavement surface data collected by the ESS. A device claiming conformance to the Enhanced Pavement Sensor Data Conformance Group shall support all of the following objects:

Object or Table Name	Reference
numEssPavementSensors	NTCIP 1204
essPavementSensorTable	NTCIP 1204
essPavementSensorIndex	NTCIP 1204
essPavementSensorLocation	NTCIP 1204
essPavementType	NTCIP 1204
essPavementElevation	NTCIP 1204
essPavementExposure	NTCIP 1204
essPavementSensorType	NTCIP 1204
essSurfaceStatus	NTCIP 1204
essSurfaceTemperature	NTCIP 1204
essPavementSensorError	NTCIP 1204
essPavementTemperature	NTCIP 1204
essSurfaceWaterDepth	NTCIP 1204
essSurfaceFreezePoint	NTCIP 1204
essSurfaceBlackIceSignal	NTCIP 1204

4.2.16 Standard Sub-Surface Sensor Data Conformance Group

The Sub-Surface Sensor Data Conformance Group consists of objects that describe the pavement surface data collected by the ESS. The Sub-Surface Sensor Data Conformance Group shall consist of the following objects:

Object or Table Name	Reference
numEssSubSurfaceSensors	NTCIP 1204
essSubSurfaceSensorTable	NTCIP 1204

4.2.17 Enhanced Sub-Surface Sensor Data Conformance Group

The Enhanced Sub-Surface Sensor Data Conformance Group consists of objects that describe the standard and enhanced sub-surface data collected by the ESS. A device claiming conformance to the Enhanced Sub-Surface Sensor Data Conformance Group shall support all of the Standard Sub-Surface Sensor Data Conformance Group and the following object:

Object or Table Name	Reference
essSubSurfaceMoisture	NTCIP 1204

4.2.18 Emerging Mobile Platform Conformance Group

The Emerging Mobile Platform Conformance Group consists of objects that describe the data collected by a mobile ESS. The Mobile Platform Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essVehicleSpeed	NTCIP 1204
essVehicleBearing	NTCIP 1204
essVehicleOdometer	NTCIP 1204
essMobileFriction	NTCIP 1204
essSpotWindSpeed	NTCIP 1204
essSpotWindDirection	NTCIP 1204

4.2.19 Pavement Treatment Conformance Group

The Pavement Treatment Conformance Group consists of objects that describe the pavement treatment which is being applied by the maintenance vehicle. The Pavement Treatment Conformance Group shall consist of the following objects:

Object or Table Name	Reference
numEssTreatments	NTCIP 1204
essPavementTreatmentTable	NTCIP 1204
essPavementTreatmentIndex	NTCIP 1204
essPaveTreatProductType	NTCIP 1204
essPaveTreatProductForm	NTCIP 1204
essPercentProductMix	NTCIP 1204
essPaveTreatmentAmount	NTCIP 1204
essPaveTreatmentWidth	NTCIP 1204

4.2.20 Air Quality Conformance Group

The Air Quality Conformance Group consists of objects that describe the air quality data collected by the ESS. The Air Quality Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essCO	NTCIP 1204
essCO2	NTCIP 1204
essNO	NTCIP 1204
essNO2	NTCIP 1204
essSO2	NTCIP 1204
essO3	NTCIP 1204
essPM10	NTCIP 1204

4.2.21 Staffed Station Conformance Group

The Staffed Station Conformance Group consists of objects that describe those data which can be provided from staffed ESS. The Staffed Station Conformance Group shall consist of the following objects:

Object or Table Name	Reference
essWindSituation	NTCIP 1204
essWaterDepth	NTCIP 1204
essRoadwaySnowDepth	NTCIP 1204
essRoadwaySnowPackDepth	NTCIP 1204
essIceThickness	NTCIP 1204
essAdjacentSnowDepth	NTCIP 1204
essPrecipSituation	NTCIP 1204
essCloudSituation	NTCIP 1204
essVisibilitySituation	NTCIP 1204
essMobileObservationGroundState	NTCIP 1204
essMobileObservationPavement	NTCIP 1204

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A Recommended Standard of the Joint Committee on the NTCIP

NTCIP 1209 v01.18 d

National Transportation Communications for ITS Protocol

Data Element Definitions for Transportation Sensor Systems

v01.18 January 2003
v01.18d April 2004

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American Association of State Highway and Transportation Officials (AASHTO)
444 North Capitol St., N.W., Suite 249
Washington, DC, 20001

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1099 14th Street, N.W., Suite 300 West
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ACKNOWLEDGEMENTS

This publication was prepared by the NTCIP TSS Working Group, which is a subdivision of the NTCIP Joint Committee. The Joint Committee is organized under a Memorandum of Understanding among the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the National Electrical Manufacturers Association (NEMA). The Joint Committee on the NTCIP consists of six representatives from each of the standards organizations, and provides guidance for NTCIP development.

At the time that this document was prepared, the following individuals were members of the NTCIP TSS Working Group:

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- Earl Hoekman
- Allen Jacobs
- Dan Manor
- Andrew Mao
- Greg McKhann
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- Mike Juha
- Wim Maes
- Alastair Wiggens

In addition to the many volunteer efforts, recognition is also given to those organizations that supported the efforts of the NTCIP TSS Working Group by providing comments and resources for the development of the standard, including:

- 3M Intelligent Transportation Systems
- California Department of Transportation
- Federal Highway Administration
- Denver Regional Council of Governments
- Electronic Integrated Systems, Inc.
- G. C. Herrick & Associates, Inc.
- Golden River Traffic, Ltd.
- Harris County Traffic & Transportation Department
- Image Sensing Systems, Inc.
- Los Angeles Department of Transportation
- Ontario Ministry of Transportation
- Peek Traffic Systems, Inc.
- Reno A&E, Inc.
- Traficon, Inc.

FOREWORD

The purpose of this document is to define the Transportation Sensor System (TSS) data elements that are supported by the National Transportation Communications for ITS Protocol (NTCIP). A TSS is defined as any system capable of detecting and communicating certain traffic parameters using NTCIP.

This document is an NTCIP Data Dictionary Standard. Data Dictionary Standards provide definitions of data elements for use within NTCIP systems.

A Joint NTCIP [type of document] standards publication is equivalent to these document types at the standards organizations:

AASHTO – [Recommended Practice]
ITE – [Informational Report]
NEMA – [Authorized Engineering Information]

For more information about NTCIP standards, visit the NTCIP Web site at http://www.ntcip.org.

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A User Comment should be submitted to this address:

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e-mail: ntcip@nema.org

A User Comment should be submitted in the following form:

Standard Publication number and version:
Page:
Paragraph or Clause:
Comment:

Please include your name, organization, and address in your correspondence.

Approvals

TBD This document was separately balloted and approved by AASHTO, ITE, and NEMA after recommendation by the Joint Committee on the NTCIP. Each organization has approved this standard as the following standard type, as of the date:

AASHTO – Standard Specification; ***TBD*** 2004
ITE – Software Standard; ***TBD*** 2004
NEMA – Standard; ***TBD*** 2004

History

From 1996 to 1999, this document was referenced as NEMA TS 3.TSS. However, to provide an organized numbering scheme for the NTCIP documents, this document is now referenced as NTCIP 1209. The technical specifications of NTCIP 1209 are identical to the former reference, except as noted in the development history below:

NEMA TS 3.TSS. ***TBD***

NTCIP 1209 v01. ***TBD***

INTRODUCTION

The purpose of this document is to define the Transportation Sensor System (TSS) data elements that are supported by the NTCIP. A TSS is defined as any system capable of sensing and communicating traffic parameters using the NTCIP.

The *NTCIP Data Element Definitions for Transportation Sensor Systems* defines data elements in ASN.1 using the SNMP Object Type Macro for devices that sense the presence or similar characteristics of vehicles. These definitions are intended for detection devices that range from smart inductive loop amplifiers to state-of-the-art technologies such as machine vision and microwave.

This standard defines requirements that are applicable to all NTCIP environments and it also contains optional and conditional clauses that are applicable to specific environments for which they are intended.

The following keywords apply to this document: AASHTO, ITE, NEMA, NTCIP, TSS, sensor, data elements, vehicle detection.

In 1992, the NEMA 3-TS Transportation Management Systems and Associated Control Devices Section began the effort to develop the NTCIP. Under the guidance of the Federal Highway Administration's NTCIP Steering Group, the NEMA effort was expanded to include the development of communications standards for all transportation field devices that could be used in an ITS network.

In September 1996, an agreement was executed among AASHTO, ITE, and NEMA to jointly develop, approve, and maintain the NTCIP standards. In August 1997, the Working Group was first organized to develop data element definitions for Advanced Systems Sensors. Subsequently the WG was renamed the Transportation Sensor Systems Working Group.

CONTENTS

Section 1
GENERAL

1.1 SCOPE

The communications between an ITS Management Center or portable computer and a Transportation Sensor System (TSS) is accomplished by using the NTCIP Application Layer services to convey requests to access or modify values of TSS data elements resident in the device via an NTCIP network. An NTCIP message consists of a specific Application Layer service and a set of data elements. An NTCIP message may be conveyed using any NTCIP defined class of service that has been specified to be compatible with the Simple Transportation Management Framework (STMF).

The scope of this document is limited to the functionality related to TSS within a transportation environment. This publication defines data elements that are specific to TSS and also defines standardized data element Groups that can be used for conformance statements. The limits and descriptions of the parameters are established to give the user maximum flexibility to operate devices that either exist at the time this document was authored or may exist in the future

1.2 REFERENCES

For approved revisions, contact:

NTCIP Coordinator
National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209-3801

Proposed revisions, which are under discussion by the relevant NTCIP Working Group, and revisions recommended by the NTCIP Joint Committee are available on the World Wide Web at http://www.ntcip.org.

The following standards (normative references) contain provisions that, through reference in this text, constitute provisions of this Standard. Other documents and standards (other references) are referenced in these documents, which might provide a complete understanding of the entire protocol and the relations between all parts of the protocol. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of each standard listed below.

1.2.1 Normative References

NEMA	NTCIP 1201 v02 (formerly TS 3.4)	*National Transportation Communications for ITS Protocol – Global Object Definitions*
NEMA	NTCIP 1103 v02	*National Transportation Communications for ITS Protocol – Transportation Management Protocols*
NEMA	NTCIP 2301 v02	*National Transportation Communications for ITS Protocol – Simple Transportation Management Framework Application Profile*
ISO/IEC	8824-1:1998	*Information Technology—Abstract Syntax Notation One (ASN.1): Specification of Basic Notation*

IAB STD 16	RFC1155 - 05/10/1990	*Structure and Identification of Management Information for TCP/IP-based Internets*
IAB STD 16	RFC1212 - 03/26/1991	*Concise MIB Definitions*

1.2.2 Other References

1.2.2.1 Standards Related

NEMA	NTCIP 1201:1997	*National Transportation Communications and ITS Protocol – Simple Transportation Management Framework*
NEMA	NTCIP 8003	*National Transportation Communications for ITS Protocol – Framework and Classifications of Profiles*
NEMA	NTCIP 9001	*National Transportation Communications For ITS Protocol (NTCIP) The NTCIP Guide*
ISO/IEC	8825-1:1998	*Information Technology—ASN.1 Encoding Rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER).*
IAB STD 15	RFC1157 - 05/10/1990	*A Simple Network Management Protocol (SNMP).*
IAB STD 17	RFC1213 - 03/1991	*Management Information Base for Network Management of TCP/IP-based Internets: MIB-II.*

1.2.2.2 Texts

David Perkins and Evan McGinnis, *Understanding SNMP MIBs*, New Jersey, Prentice Hall PTR, 1997, ISBN 0-13-437708-7.

1.2.3 Contact Information

1.2.3.1 ISO/IEC Standards

Members of the ISO maintain registers of currently valid ISO/IEC International Standards. For the USA, the member of ISO is the American National Standards Institute (ANSI), which may be contacted as follows:

ANSI
11 West 42nd Street, 13th Floor
New York, New York 10036
(212) 642-4900

1.2.3.2 RFC Documents

Electronic copies of RFC documents may be obtained using “anonymous” FTP to the host <www.nic.mil/dodnic/> or <www.alternic.org/rfcs/>. Printed copies are available from:

DDN Network Information Center
14200 Park Meadow Drive, Suite 200
Chantilly, VA 22021
(800) 365-3642
(703) 802-4535

1.3 TERMS

For the purposes of this standard, the following terms and definitions apply. For terms not defined in this clause, English words are used in accordance with their definitions in the latest edition of *Webster's New Collegiate Dictionary*. Electrical and electronic terms not defined in this clause or in *Webster's New Collegiate Dictionary* are used in accordance with their definitions in IEEE Standard 100-1992.

Transportation Sensor System	A TSS is defined as any system capable of sensing and communicating near real-time traffic parameters using the National Transportation Communications for ITS Protocol (NTCIP).
CTime	CTime is a function that converts a long integer, pointed to by a clock function, representing the time in seconds since the Epoch (00:000:00 UTC, January 1, 1970), and returns a pointer to a 26-character string of the form Www Mmm dd hh:mm:ss yyyy \n\0 (e.g. Thu Nov 24 18:22:48 2001\n\0) with Www being weekday, Mmm being month, dd being day, hh being hour, mm being minute, ss being second, yyyy being year, \n being a new line control code, and \0 being a null-character control code. All fields have a consistent width. Time zone and daylight savings corrections are made before string generation.
sensor	A sensor is the physical device used for sensing traffic.
zone	An area in which traffic parameters can be measured and/or traffic data can be generated.

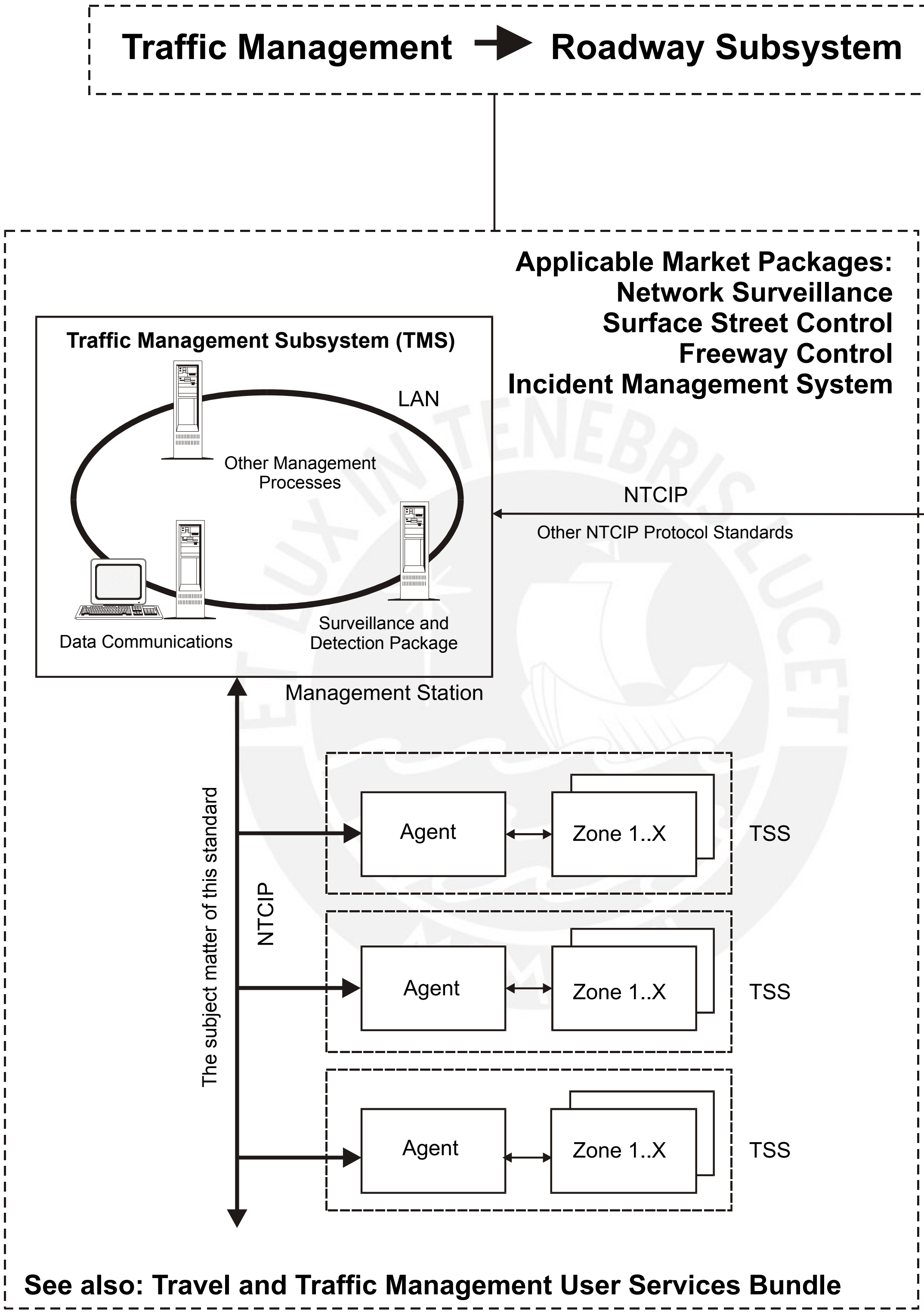
1.4 ACRONYMS

The following acronyms are used in this standards publication.

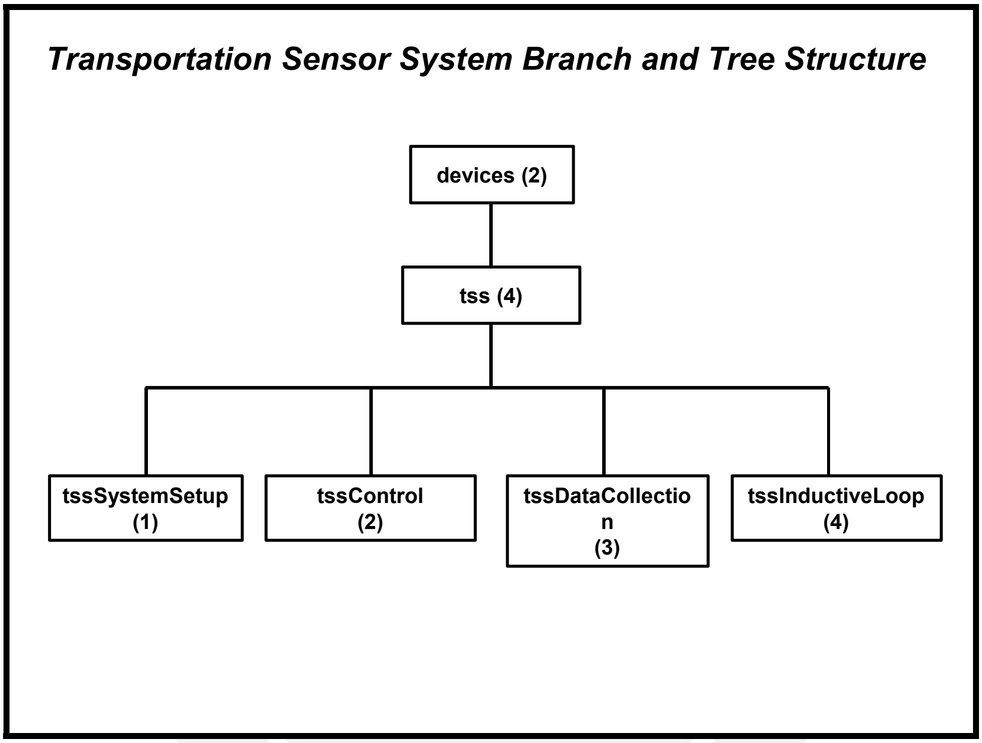
AASHTO	American Association of State Highway and Transportation Officials
IAB	Internet Architecture Board
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
MIB	Management Information Base
NEMA	National Electrical Manufacturers Association
NTCIP	National Transportation Communications for ITS Protocol
RFC	Request for Comment
STD	Standard
TSS	Transportation Sensor System

1.5 SUPPLEMENTAL FIGURES

The following two figures provide a pictorial representation of the TSS architecture and the Transportation Sensor System Branch and Tree Structure. This is an architecture that is a proposed component for the National ITS Architecture. The architecture diagram identifies some of the terms and acronyms described above, in addition to identifying the focus of this standard. The tree structure identifies how the data element definitions are combined under specific nodes.



Architectural Terminology Diagram


Transportation Sensor System Branch and Tree Structure
devices (2)
tss (4)
tssSystemSetup (1)
tssControl (2)
tssDataCollection (3)
tssInductiveLoop (4)

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Section 2
TSS OVERVIEW

2.1 INTRODUCTION TO TSS

The context of the NTCIP is one part of the Intelligent Transportation Systems (ITS) standardization activities covering base standards, profiles, and registration mechanisms.

- Base Standards define procedures and rules for providing the fundamental operations associated with communications and information that is exchanged over fixed-point communications links.

- Profiles define subsets or combinations of base standards used to provide specific functions or services. Profiles prescribe particular subsets or options available in base standards necessary for accomplishing a particular function or service. This provides a basis for the development of uniform, nationally recognized conformance.

- Registration Mechanisms provide a means to specify and uniquely identify detailed parameters within the framework of base standards and/or profiles.

Within the Joint AASHTO/ITE/NEMA NTCIP Committee, other working groups are concerned with the methodology of defining profiles, and their documentation in Standards Publications. The objective is to facilitate the specification of ITS systems characterized by a high degree of interoperability and interchangeability of its components.

This document covers the control and status requirements of transportation sensor system devices. Such devices include smart inductive loop sensors, microwave sensors, and machine vision sensing devices.

Unfortunately, there are no existing standards that define how these devices communicate with other related equipment. As a result, each manufacturer has developed its own protocol to meet their particular needs. To integrate systems manufactured by different companies, considerable extra work must be performed resulting in increased costs. This shortcoming limits interchangeability of components between different vendors and restricts the sharing of information and control within and between user organizations.

These problems have not been limited to TSS surveillance systems. Many other devices also need to share network infrastructure and exchange information. In surface transportation, examples include traffic signal controllers, dynamic message signs, bus priority sensors, etc. To address these problems, the NTCIP is developing a family of open standards for communications among field devices and between field devices and central management stations, known as Traffic Management Subsystems (TMS).

The NTCIP TSS standard describes data elements for controlling and monitoring transportation sensor system devices.

2.2 BENEFITS OF STANDARDIZATION

As transportation systems become more sophisticated, planners, users, and equipment manufacturers recognize the need for system interoperability and integration. Currently, there is no common protocol with which different types of equipment can communicate. If TSS is to be integrated with ITS, common communications standards must be established.

Before the NTCIP development started, each vendor of electronic devices used in transportation adopted a different protocol for data communications. This made it very difficult to mix equipment from different vendors in the same system, and to communicate between systems operated by adjacent agencies. The NTCIP is now providing a common standard that can be used by all vendors.

The NTCIP offers increased flexibility and choice for agencies operating traffic management systems. It removes barriers to inter-jurisdictional coordination and allows equipment of different types and manufacturers to be mixed on the same communications line. For these reasons, operating agencies will benefit from specifying that the NTCIP is included in all future purchases and upgrades.

Benefits of adopting open standards based on the NTCIP include:

- *Avoiding Early Obsolescence*: Though it may not be practical to retrofit NTCIP support in some old equipment, most TSS vendors will offer NTCIP support in current and future products. An operating agency can ensure that its equipment remains useful and compatible long into the future by requiring NTCIP support for all future purchases and upgrades. This will include central computers and TSS field devices, such as sensing devices.
- *Providing Choice of Vendor*: Once an agency has a TSS that includes support for NTCIP it can buy field devices from any manufacturer offering NTCIP-compatible products, and they will communicate with the agency's "Traffic Management Subsystem" ('TMS', typically termed CPU).
- *Allowing Interjurisdictional Coordination*: In the future, an agency may want to communicate with TSS devices owned by other users and/or procured from different vendors. Under NTCIP, these various devices can be added onto an existing communications channel and mixed with different types of devices on the same line.
- *Using one Communications Network for All Devices*: NTCIP also allows a central computer to communicate with a range of field devices on the same communications channel. For example, if a dynamic message sign is installed near a TSS device, the central computer could communicate with the sign controller using the communications channel already in place for the TSS device. The communications network is usually the most expensive component of a transportation management system and use of the NTCIP maximizes that investment.

Several state and local transportation agencies already have a number of TSS devices deployed for traffic and transportation management. At present, however, these systems often include proprietary elements that limit expansion and upgrade opportunities.

The development of the NTCIP will allow a more open-systems approach, not only among TSS equipment, but also with a wide variety of other field devices. It is expected that this open-systems approach will result in lower deployment and equipment costs similar to the PC industry. This in turn will allow for more devices to be deployed resulting in better decision-support to decrease maintenance costs.

To make best use of these advancements, TSS should be viewed in the much broader context of Intelligent Transportation Systems (ITS). The key to these benefits is open standards, allowing agencies to share data and avoid becoming locked into proprietary systems.

2.3 EXISTING STANDARDS

There are great benefits of adopting existing standards where possible. These include:

- reuse of software modules during development
- faster implementations
- reducing risks
- ability to integrate components from different manufacturers
- unambiguous meanings of terminology
- building on proven technologies

2.3.1 Internet Standards

The Internet Engineering Task Force (IETF) is responsible for developing and maintaining the standards, guidelines and procedures for communications over the Internet. This group has become increasingly important over the last few years as the Internet has gained popularity. A wide range of Internet standards exist, including:

- Point-to-Point Protocol (PPP) - which may be used for NTCIP dial-up links
- Internet Protocol (IP) - which may be used for NTCIP communications over networks
- Transport Control Protocol (TCP) - which may be used to provide connection-oriented transport services over NTCIP networks
- User Datagram Protocol (UDP) - which may be used to provide connectionless transport services over NTCIP networks
- Simple Network Management Protocol (SNMP) - which may be used to exchange NTCIP data elements such as those defined within this document.

2.3.2 International Organization of Standardization Standards

The International Organization of Standardization (ISO) also develops various communication standards among a wide variety of other standards. The Open Systems Interconnect Reference Model (OSI) is a widely-referenced ISO standard which defines the standard seven-layered communications model. While most implementations do not strictly conform to this standard, virtually all modern communications schemes, including the NTCIP, use many of the concepts defined within the standard. In addition, NTCIP communications may use the High Level Data Link Control Protocol (HDLC), another ISO standard, in specifying how to send a message over a single communications link.

2.3.3 NTCIP

To support ITS developments, US DOT funded the design of a National ITS Architecture. This architecture defines major ITS subsystems and the needs for information exchange among them. The National Transportation Communications for ITS Protocol (NTCIP) group is now developing standards for these information exchanges. NTCIP – a joint initiative of AASHTO, ITE, and NEMA – recognizes that transportation sensor systems are vital components of traffic and transportation management systems. The family of NTCIP standards will enhance TSS implementation and provide a mechanism for the manipulation of the basic detection functions within TSS systems.

2.3.4 NTCIP System Design

NTCIP was initially designed to support traffic signal controllers because that was seen as an area of most pressing need for a common communications protocol. However, the development process has recognized the need to extended NTCIP to other transportation environments (e.g., ITS) and, where appropriate, to other environments.

The NTCIP family of protocols is continually expanding to address additional needs. Work is in progress on additional protocols for computer-to-computer or center-to-center data exchange, transit communications, and communications with or between moving vehicles. The NTCIP, along with other US DOT standards efforts, will eventually provide a comprehensive family of communications protocols covering all appropriate ITS applications.

There may also be a future demand to use the system for communications to field devices that are not transportation related. The ultimate scope of NTCIP cannot be rigidly determined. The key is to determine how those changes might affect the system design and to provide flexible standards that accommodate these changes. NTCIP will seek to utilize existing telecommunications and computer industry standards to the extent possible.

2.4 TRANSPORTATION SENSOR SYSTEMS

The selection of Transportation Sensor System as a name for what was originally regarded as "advanced sensors" stemmed from the realization that modern sensing devices extend well beyond the simple detection of automobiles and now include light-rail vehicles, pedestrians, and many other modes of transportation. In addition, modern detection devices are now viewed as sensing systems, rather than simple sensors or detectors. As a result, the name Transportation Sensor System has evolved to identify a class of technology that is used for detection within the transportation community.

A Transportation Sensor System (TSS) is defined as any system capable of sensing and communicating near real-time traffic parameters using the National Transportation Communications for ITS Protocol (NTCIP).

In its simplest form, a TSS could be a single loop detector that is capable of communicating using NTCIP. Other more elaborate systems can include visual image processing systems that are used for sensing and communicating a variety of traffic parameters. The key factor that sets a TSS apart from a simple detector is the ability to communicate. Ultimately, one can envision a scenario where a combination of devices, including a simple detector and some sort of remote processing unit with communications capabilities, could be configured as a TSS (examples include a traffic signal controller, ramp metering controller, etc). However, it should be noted that devices like traffic signal controllers and ramp metering controllers might use their own detection related data elements that are designed specifically to address their primary function.

2.4.1 Description of Zone

A zone is an area within which traffic parameters can be measured. Zone is an abstract representation of area that is independent of technology. The TSS data elements will allow up to 255 zones per Transportation Sensor System.

Traditionally, the terminology sensor and detector were used in a variety of ways that often referred to the physical device used for detection or the area where the detection was occurring. Sometimes these terms were used to mean an inductive loop amplifier or some other device used for measuring traffic parameters and other times they were used to define the area where the traffic measurements were being taken as in the case with some visual image processing systems. The use of zone as a descriptor for any entity capable of sensing or measuring traffic parameters and/or gathering traffic data is an effort to move away from technology dependencies and ambiguous terminology.

2.4.1.1 Combination of Zones

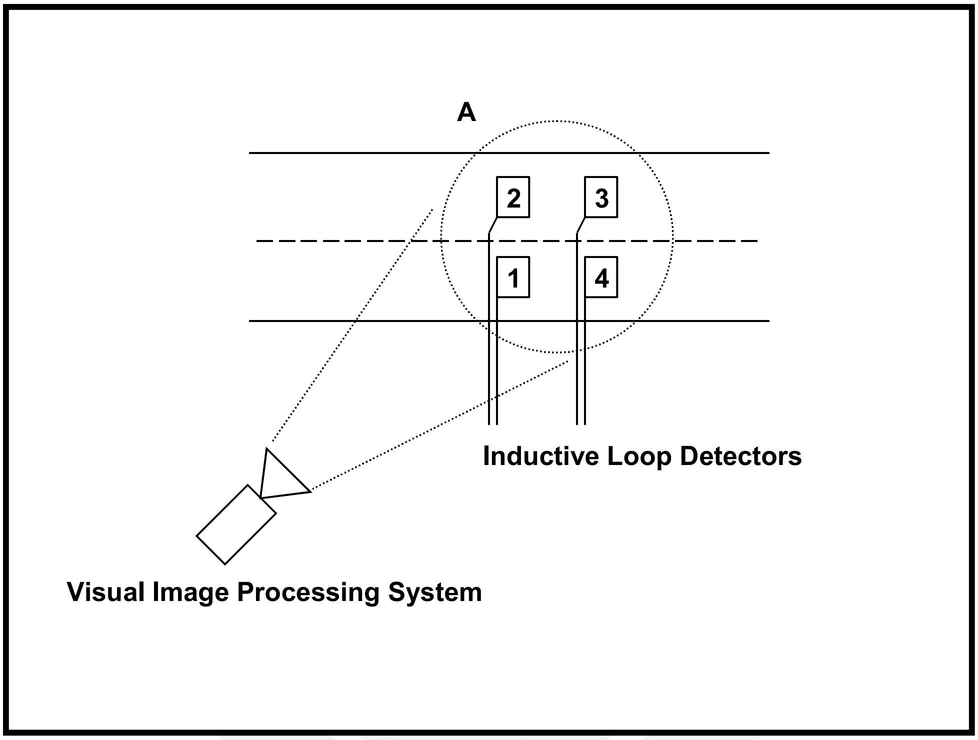
Zones can exist individually, or they can be logically grouped with other zones. Boolean operators are provided for "AND" and "OR" combinations. Up to eight (8) zones can be logically grouped with each Boolean operator.

2.4.1.2 Description of Virtual Zone

A virtual zone is terminology used to identify a zone that is created as the result of logical combination of physical zones. For example, let us take the case of an "OR" combination of three detector zones mapped to one output. In this case, the three physical zones are logically grouped to a fourth zone that exists only to provide the resulting output. This fourth zone might be referred to as a virtual zone since it has no direct sensing capability. This virtual zone is the result of the logical combination of other zones and would otherwise have all the characteristics associated with a physical zone. There is no differentiation in this standard between regular zones and virtual zones in this standard, since all zones have identical characteristics and can be used in either fashion. The concept of virtual zones is presented here only as a means of describing the concept of operations for logically combining zones.

2.4.2 Description of Sensor

A sensor is the physical device used for sensing traffic. A sensor may be able to provide for one or more detection zones. An inductive loop detector and a visual image processing system will be used to illustrate the difference between sensors and zones, as shown in the figure. In the case of an inductive loop detector, one sensor may equal one zone (examples include “1”, “2”, “3”, and “4”). In the case of the visual image processing system, one sensor may equal many zones (as seen with the area identified by “A”).



2.4.3 Outputs and Output Groups

Physical device outputs are provided to identify discrete activity states that are sensed within a zone. A zone can be mapped to any available output.

The state of “ON” or “OFF” for each output can be retrieved in groups of eight (8) sequentially numbered outputs. For instance, Output Group 1 consists of Outputs 1 to 8, Output Group 2 consists of Outputs 9 to16, etc., up to the maximum number of outputs.

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Section 3
TSS MIB

This section defines those data elements that are expected to be used by transportation sensor system devices. The data elements (objects) are described in terms of the ASN.1 (defined in ISO/IEC 8824-1, ISO/IEC 8824-2, ISO/IEC 8824-3, and ISO/IEC 8824-4) macro OBJECT-TYPE. The OBJECT-TYPE macro is defined in RFC 1212. The text provided from Clause 3.1 through the end of the section (except the clause headings) constitutes the NTCIP Standard TSS MIB.

The clauses below present the data elements in lexigraphical order of their OBJECT IDENTIFIERS that correspond to their physical location within the global naming tree. The data elements defined in this document reside under the "tss" node of the global naming tree. To aid in data element management, the "tss" node has been subdivided into logical categories, each defined by a node under the "tss" node. The individual data elements are then located under the appropriate node.

Nodes should not be confused with conformance groups, which are defined in Annex A. A conformance group is a logical grouping of data elements that is used for conformance statements. While conformance groups will frequently correspond to the nodal structure, a conformance group may contain data elements that are not lexigraphically ordered. For example, a schedule conformance group may contain both "global" and "tss" specific data elements.

A data element status of Optional should not be confused with a conformance status of optional or mandatory as defined in Annex A. The data element Status of Optional in the MIB means that the data element and data element definition is current. The status of optional or mandatory in Annex A dictates whether the data element is required or not.

Text preceded by a double hyphen in the MIB definitions represent normative text for this standard.

All management applications shall reference the specific device MIB as provided by the device manufacturer for support and constraints (sub-ranges).

3.1 TRANSPORTATION SENSOR SYSTEM (TSS) DATA ELEMENTS

```
TSS-MIB1 DEFINITIONS ::= BEGIN

-- the following OBJECT IDENTIFIERS are used in the TSS MIB:

IMPORTS
    OBJECT-TYPE
        FROM RFC-1212
    Counter
        FROM RFC1155-SMI
    devices
        FROM TMIB-II;

-- For the purposes of this section, the following OBJECT IDENTIFIERS are used:
tss     OBJECT IDENTIFIER ::= {devices 4}
```

3.2 TSS SYSTEM SETUP DATA ELEMENTS

tssSystemSetup OBJECT IDENTIFIER ::= { tss 1 }

-- This node contains the configuration data elements for traffic sensor systems

3.2.1 Sensor System Reset Parameter

```
sensorSystemReset  OBJECT-TYPE
SYNTAX          INTEGER {       restart (1),
                                reinitializeUserSettings (2),
                                restoreFactoryDefaults (3),
                                retune (4),
                                resyncSamplingPeriods (5),
                                shortDiagnostics (6),
                                fullDiagnostics (7) }
ACCESS          read-write
STATUS          mandatory
DESCRIPTION
"<Definition> This data element commands the entire sensor system to reset. The reset commands are
described as follows:
        restart:   Restart command shall cause the unit to enter restart state and go through a complete
                shut-down and start-up process, causing a reset and initialization of the number of
                seconds since most recent device initialization to a value of zero;
        reinitalizeUserSettings:   Reinitialize User Settings command shall cause the unit to flush all
                volatile memory and reinitialize all settings to their user defined default values, and reset
                and initialize the number of seconds since most recent device initialization to a value of
                zero;
        restoreFactoryDefaults:   Restore Factory Defaults command shall cause the unit to flush all
                volatile memory, restore all settings to their factory default values, and reset and initialize
                the number of seconds since most recent device initialization to a value of zero;
        retune:   Retune command recalibrates unit background settings for all zones without resetting or
                flushing of any collected data;
        resyncSamplingPeriods:   Re-synchronize Sampling Periods command shall cause the unit to
                synchronize all startup sampling period clocks within 1 second of command issuance and
                a reset and initialize of the number of seconds since most recent device initialization to a
                value of zero;
        shortDiagnostics:   Short diagnostics command shall cause the unit to go through an
                abbreviated vendor specific diagnostic routine which may be the same as full diagnostics
                for some vendors;
        fullDiagnostics:   Full diagnostics shall cause the unit to go through a complete vendor specific
                diagnostic routine which may be the same as short diagnostics for some vendors,
                causing a reset and initialization of the number of seconds since most recent device
                initialization to a value of zero.
<DescriptiveName> Tss.sensorSystemReset:code
<DataConceptType> Data Element”
::= {tssSystemSetup 1 }
```

3.2.2 Sensor System Status Parameter

```
sensorSystemStatus OBJECT-TYPE
SYNTAX          INTEGER {       other (1),
                                oK (2),
                                initializing (3) }
```

ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> This data element provides an indication of the overall sensor system status, as follows:
other: Other indicates the presence of a hardware or software status that is not designated as either OK or initializing;
oK: OK indicates that the unit is operating normally with no known hardware or software faults, with no implications about data;
initalizing: Initializing indicates that the unit has encountered no fault, but is not ready for detection.
<DescriptiveName> Tss.sensorSystemStatus:code
<DataConceptType> Data Element"
::= { tssSystemSetup 2 }

3.2.3 Sensor System Occupancy Type Parameter

sensorSystemOccupancyType OBJECT-TYPE
SYNTAX INTEGER { normalizedOtherOccupancy (1),
nonNormalizedOccupancy (2),
zoneOccupancy (3),
normalizedSixFootLoopOccupancy (4),
normalizedTwoMeterLoopOccupancy (5) }
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> A set of flags on a per unit basis that indicate how to interpret the occupancy data parameter, as follows:
normalizedOtherOccupancy: Occupancy is normalized to other specific criteria that is not defined within this data element;
nonNormalizedOccupancy: Occupancy is presented as non-normalized or raw occupancy data,
zoneOccupancy: Occupancy is presented for a given zone,
normalizedSixFootLoopOccupancy: Occupancy is normalized to a 6 foot by 6 foot loop,
normalizedTwoMeterLoopOccupancy: Occupancy is normalized to a 2 meter by 2 meter loop.
<DescriptiveName> Tss. SensorSystemOccupancyType:code
<DataConceptType> Data Element "
::= { tssSystemSetup 3 }

3.2.4 Maximum Number of Sensor Zones Parameter

maxSensorZones OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> The maximum number of sensor zones this transportation sensor system supports. This data element indicates the maximum rows that shall appear in the sensorZoneTable data element.
<DescriptiveName> Tss.maxSensorZones:quantity
<DataConceptType> Data Element
<Unit> zone"
::= { tssSystemSetup 4 }

3.2.5 Sensor Zone Table

sensorZoneTable OBJECT-TYPE
SYNTAX SEQUENCE OF SensorZoneEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
"<Definition> A table containing sensor zone unit parameters. The number of rows in this table is equal to the maxSensorZones data element. Table rows are set by the manufacturer, and row creation/deletion is not supported.
<DescriptiveName> Tss.sensorZoneTable
DataConceptType> Entity Type
<TableType> static "
::= { tssSystemSetup 5}

sensorZoneEntry OBJECT-TYPE
SYNTAX SensorZoneEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
"<Definition> Table for sensor zone parameters.
<DescriptiveName> sensorZoneEntry
<DataConceptType> Entity Type"
INDEX { sensorZoneNumber }
::= { sensorZoneTable 1 }

SensorZoneEntry ::= SEQUENCE {
sensorZoneNumber INTEGER,
sensorZoneOptions OCTET STRING,
sensorZoneOptionsStatus OCTET STRING,
sensorZoneSamplePeriod INTEGER,
sensorZoneLabel OCTET STRING,
sensorZoneAndOperator OCTET STRING,
sensorZoneOrOperator OCTET STRING
}

3.2.5.1 Sensor Zone Number Parameter

sensorZoneNumber OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> The numerical label or number of the sensor zone. This value shall not exceed the maxSensorZones data element value.
<DescriptiveName> Tss.sensorZoneNumber:identifier
<DataConceptType> Data Element"
::= { sensorZoneEntry 1 }

3.2.5.2 Sensor Zone Options Parameter

sensorZoneOptions OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(1))

ACCESS read-write
STATUS mandatory
DESCRIPTION
"<Definition> A bit-mapped value as defined below for commanding this sensor zone to be ENABLED or DISABLED. A non-configured system shall default to DISABLED.

bit 7	0 = DISABLED, 1 = ENABLED	To command this sensor zone to be enabled or disabled;
bits 6..0		Reserved (bit 0 = LSB).

<DescriptiveName> Tss.sensorZoneOptions:text
<DataConceptType> Data Element"
::= { sensorZoneEntry 2 }

3.2.5.3 Sensor Zone Options Status Parameter

sensorZoneOptionsStatus OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(1))
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> A bit-mapped value as defined below for indicating the status of whether this sensor zone is ENABLED or DISABLED.

bit 7	0 = DISABLED, 1 = ENABLED	To indicate the status of this sensor zone;
bits 6..0		Reserved (bit 0 = LSB).

<DescriptiveName> Tss.sensorZoneOptionsStatus:text
<DataConceptType> Data Element"
::= { sensorZoneEntry 3 }

3.2.5.4 Sensor Zone Sample Period Parameter

sensorZoneSamplePeriod OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"<Definition> Duration of the sample period in seconds for the sensor zone over which time data is collected. Sample period durations from 0 to 3600 are available for use. Values 3601..65535 are reserved for future use. A sampling period of zero (0) means that data is not being collected, while the sensor zone may continue to be enabled.
<DescriptiveName> Tss.sensorZoneSamplePeriod:quantity
<DataConceptType> Data Element
<Unit> second"
DEFVAL { 0 }
::= { sensorZoneEntry 4 }

3.2.5.5 Sensor Zone Label Parameter

sensorZoneLabel OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(0..255))
ACCESS read-write
STATUS optional
DESCRIPTION
“<Definition> A text string used to describe the TSS sensor zone. A maximum string length of less than 255 may be supported.

<DescriptiveName> Tss.sensorZoneLabel:text
<DataConceptType> Data Element"
::={ sensorZoneEntry 5 }

3.2.5.6 Sensor Zone Boolean AND Operator Parameter

sensorZoneAndOperator OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(8))
ACCESS read-write
STATUS optional
DESCRIPTION
"<Definition> This data element identifies up to eight (8) unique zones that can be sequentially combined with a Boolean AND command to provide an input to this zone, as follows:
Byte 1 Sensor zone number for the first Boolean AND combined with this zone,
Byte 2 Sensor zone number for the second Boolean AND combined with this zone,
Byte 3 Sensor zone number for the third Boolean AND combined with this zone,
Byte 4 Sensor zone number for the fourth Boolean AND combined with this zone,
Byte 5 Sensor zone number for the fifth Boolean AND combined with this zone,
Byte 6 Sensor zone number for the sixth Boolean AND combined with this zone,
Byte 7 Sensor zone number for the seventh Boolean AND combined with this zone,
Byte 8 Sensor zone number for the eighth Boolean AND combined with this zone.
Boolean AND combinations are processed before Boolean OR combinations. When read, this object returns last value written.
<DescriptiveName> TSS.orOperator:text
<DataConceptType> Data Element"
::= { sensorZoneEntry 6 }

3.2.5.7 Sensor Zone Boolean OR Operator Parameter

sensorZoneOrOperator OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(8))
ACCESS read-write
STATUS optional
DESCRIPTION
"<Definition> This data element identifies up to eight (8) unique zones that can be sequentially combined with a Boolean OR command to provide an input to this zone, as follows:
Byte 1 Sensor zone number for the first Boolean OR combined with this zone,
Byte 2 Sensor zone number for the second Boolean OR combined with this zone,
Byte 3 Sensor zone number for the third Boolean OR combined with this zone,
Byte 4 Sensor zone number for the fourth Boolean OR combined with this zone,
Byte 5 Sensor zone number for the fifth Boolean OR combined with this zone,
Byte 6 Sensor zone number for the sixth Boolean OR combined with this zone,
Byte 7 Sensor zone number for the seventh Boolean OR combined with this zone,
Byte 8 Sensor zone number for the eighth Boolean OR combined with this zone.
Boolean AND combinations are processed before Boolean OR combinations. When read, this object returns last value written.
<DescriptiveName> TSS.orOperator:text
<DataConceptType> Data Element"
::= { sensorZoneEntry 7 }

3.2.6 Clock Available Parameter

clockAvailable OBJECT-TYPE

SYNTAX INTEGER { clockYes (1),
clockNo (2) }
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> This data element identifies the availability of a real time clock within the TSS device so that time can be referenced to CTime.

clockYes: A real-time clock is provided within the TSS device, conformant with NTCIP 1201, and time is referenced to actual local time within the device.

clockNo: A real-time clock is not provided within the TSS device and time is expressed in the number of seconds since most recent device initialization.

<DescriptiveName> Tss.clockAvailable:code
<DataConceptType> Data Element"
::= { tssSystemSetup 6 }

3.3 TSS CONTROL DATA ELEMENTS

tssControl OBJECT IDENTIFIER ::= { tss 2 }
-- node for output control data elements
-- a sensor zone can be mapped to any available output
-- outputs identify discrete activity states sensed within a zone
-- output status should be refreshed upon change of state for each output

3.3.1 Maximum Number of Outputs Parameter

maxOutputNumber OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> The maximum number of outputs supported by the TSS device.
<DescriptiveName> Tss.maxOutputNumber:quantity
<DataConceptType> Data Element
<Unit> output"
::= { tssControl 1 }

3.3.2 Output Configuration Table

outputConfigurationTable OBJECT-TYPE
SYNTAX SEQUENCE OF OutputConfigurationEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
"<Description> Table containing configuration data elements for each TSS physical device output. The number of rows in this table is equal to the maxOutputNumber data element. Table rows are set by the manufacturer, and row creation/deletion is not supported.
DescriptiveName> Tss.outputConfigurationTable
DataConceptType> Entity Type
<TableType> static"
::={ tssControl 2 }

outputConfigurationEntry OBJECT-TYPE

SYNTAX OutputConfigurationEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
"<Definition> Row containing output configuration data elements.
<DescriptiveName> Tss.outputConfigurationEntry
<DataConceptType> Entity Type"
INDEX { outputNumber }
::={ outputConfigurationTable 1}

```
OutputConfigurationEntry ::= SEQUENCE {
        outputNumber                INTEGER,
        outputSensorZoneNumber      INTEGER,
        outputFailsafeMode          INTEGER,
        outputModeStatus            OCTET STRING,
        outputLabel                 OCTET STRING
        }
```

3.3.2.1 Output Number Parameter

outputNumber OBJECT-TYPE
SYNTAX INTEGER (1..255)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition>The numerical label or number assigned to a physical device output. Output number is also the row to which the outputConfigurationTable is referenced.
<DescriptiveName> Tss.outputNumber:identifier
<DataConceptType> Data Element"
::={ outputConfigurationEntry 1}

3.3.2.2 Output Sensor Zone Number Parameter

outputSensorZoneNumber OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-write
STATUS mandatory
DESCRIPTION
"<Definition>The numerical label or number representing the sensor zone number that is associated with this output. A value of zero (0) indicated that no sensor zone number is associated with this output. When read, this data element returns the last value written.
<DescriptiveName> Tss.outputNumber:identifier
<DataConceptType> Data Element"
::={ outputConfigurationEntry 2}

3.3.2.3 Output Failsafe Mode Parameter

```
outputFailsafeMode  OBJECT-TYPE
SYNTAX        INTEGER {    failsafeModeOn (1),
                           failsafeModeOff (2),
                           overrideCommandOn (3),
                           overrideCommandOff (4),
                           normal (5) }
```

ACCESS read-write
STATUS mandatory
DESCRIPTION
"<Definition> Data element that allows configuration of outputs for failure override modes, as follows:
failsafeModeOn: Failsafe Mode ON, the output assumes an ON state whenever there is a failure that affects the proper performance of this output;
failsafeModeOff: Failsafe Mode OFF, the output assumes an OFF state whenever there is a failure that affects the proper performance of this output;
overrideCommandOn: Override Command ON, overrides the normal operational state of the output by setting the output to ON;
overrideCommandOff: Override Command OFF, overrides the normal operational state of the output by setting the output to OFF;
normal: Normal, ends the override of the output and returns that output to normal operations.
When read, this data element returns the last value written except for the value of 5. After a value of 5 is written, the value prior to the normal command is returned.
<DescriptiveName> Tss.outputFailsafeMode:code
<DataConceptType> Data Element"
::= { outputConfigurationEntry 3 }

3.3.2.4 Output Mode Status Parameter

outputModeStatus OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(1))
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> A bit-mapped value as defined below for reading the status of failure override modes, as follows:

bit 7	0 = OFF, 1 = ON	For Failsafe Mode Status ON indicates the status of the Failsafe Mode is ON, meaning that the output assumes an ON state whenever there is a failure that in any way affects the proper performance of this output and Failsafe Mode Status OFF indicates the status of the Failsafe Mode is OFF, meaning that the output assumes an OFF state whenever there is a failure that in any way affects the proper performance of this output (MSB);
bit 6	0 = OFF, 1 = ON	For Override Command Status ON indicates the presence of an Override to the normal operational state of the output to ON and Override Command Status Off indicates the presence of an Override to the normal operational state of the output to OFF;
bits 5..0		Reserved (bit 0 = LSB).

<DescriptiveName> Tss.outputModeStatus:text
<DataConceptType> Data Element"
::= { outputConfigurationEntry 4 }

3.3.2.5 Output Label Parameter

outputLabel OBJECT-TYPE
SYNTAX OCTET STRING (SIZE (0..255))
ACCESS read-write
STATUS optional
DESCRIPTION
"<Definition> Text string to describe the TSS output. A maximum string length of less than 255 may be

supported.
<DescriptiveName> Tss.outputLabel:text
<DataConceptType> Data Element"
::={ outputConfigurationEntry 5 }

3.3.3 Maximum Number of Output Groups Parameter

maxOutputGroups OBJECT-TYPE
SYNTAX INTEGER (1..32)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> The number of output groups each consisting of eight (8) outputs. Each output group represents a multiple of eight (8) sequentially numbered outputs. Example: Output Group 1 consists of Outputs 1 to 8, Output Group 2 consists of Outputs 9 to16, etc. A value of zero (0) means that no output groups are supported.
<DescriptiveName> Tss.maxOutputGroups:quantity
<DataConceptType> Data Element"
::= { tssControl 3 }

3.3.4 Output Group Table

outputGroupTable OBJECT-TYPE
SYNTAX SEQUENCE OF OutputGroupEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
"<Definition> A table containing input and output states for groups of eight outputs. Each output group represents a multiple of eight (8) sequentially numbered outputs. Output Group 1 consists of Outputs 1 to 8, Output Group 2 consists of Outputs 9 to16, etc. The number of rows in this table is equal to the maxOutputGroups data element. Table rows are set by the manufacturer, and row creation/deletion is not supported.
<DescriptiveName> Tss.outputGroupTable
<DataConceptType> Entity Type
<TableType> static"
::= { tssControl 4 }

outputGroupEntry OBJECT-TYPE
SYNTAX OutputGroupEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
"<Definition> Table for output states, in groups of eight outputs. Each output group represents a multiple of eight (8) sequentially numbered outputs. Example: Output Group 1 consists of Outputs 1 to 8, Output Group 2 consists of Outputs 9 to16, etc.
<DescriptiveName> Tss.outputGroupEntry
<DataConceptType> Entity Type"
INDEX { outputGroupNumber }
::= { outputGroupTable 1 }

```
OutputGroupEntry ::= SEQUENCE {
        outputGroupNumber               INTEGER,
        outputGroupOutputState          OCTET STRING
        }
```

3.3.4.1 Output Group Number Parameter

outputGroupNumber OBJECT-TYPE
SYNTAX INTEGER (1..32)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> Number of the output group, in groups of eight outputs. Each output group represents a multiple of eight (8) sequentially numbered outputs. Output Group 1 consists of Outputs 1 to 8, Output Group 2 consists of Outputs 9 to16, etc. A value of zero (0) means that no output groups are supported.
<DescriptiveName> Tss.outputGroupNumber:identifier
<DataConceptType> Data Element"
::= { outputGroupEntry 1 }

3.3.4.2 Output Group Output State Parameter

outputGroupOutputState OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(1))
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> Each bit represents the output state for each output within each output group. Each output group represents a multiple of eight (8) sequentially numbered outputs. Example: Output Group 1 consists of Outputs 1 to 8, Output Group 2 consists of Outputs 9 to16, etc. An Octet String with size zero (0) means that no output groups are supported. For Octet Strings 1..32, a value of 0 means OFF (activity not sensed) and a value of 1 means ON (activity sensed). Bit 0 represents output 1, bit 1 represents output 2, etc., as follows:

bit 7	0 = OFF, 1 = ON	For output 8 within the group (MSB),
bit 6	0 = OFF, 1 = ON	For output 7 within the group,
bit 5	0 = OFF, 1 = ON	For output 6 within the group,
bit 4	0 = OFF, 1 = ON	For output 5 within the group,
bit 3	0 = OFF, 1 = ON	For output 4 within the group,
bit 2	0 = OFF, 1 = ON	For output 3 within the group,
bit 1	0 = OFF, 1 = ON	For output 2 within the group,
bit 0	0 = OFF, 1 = ON	For output 1 within the group (LSB).

<DescriptiveName> Tss.outputGroupOutputState:text
<DataConceptType> Data Element"
::= { outputGroupEntry 2 }

3.4 TSS DATA COLLECTION DATA ELEMENTS

tssDataCollection OBJECT IDENTIFIER ::= { tss 3 }
-- node for data collection elements

3.4.1 Data Collection Table

dataCollectionTable OBJECT-TYPE
SYNTAX SEQUENCE OF DataCollectionEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION

“<Definition> Table containing the most recently completed sample period data. The number of rows in this table is equal to the maxSensorZones data element. Table rows are set by the manufacturer, and row creation/deletion is not supported.
<DescriptiveName> Tss.dataCollectionTable
<DataConceptType> Entity Type
<TableType> static”
::= { tssDataCollection 1 }

```
dataCollectionEntry OBJECT-TYPE
SYNTAX          DataCollectionEntry
ACCESS          not-accessible
STATUS          mandatory
DESCRIPTION
"<Definition> Table for data collection parameters.
<DescriptiveName> Tss.dataCollectionEntry
<DataConceptType> Entity Type"
INDEX   { sensorZoneNumber }
::= { dataCollectionTable 1 }

DataCollectionEntry ::= SEQUENCE {
--      sensorZoneNumber        INTEGER,
        endTime                 Counter,
        volumeData              INTEGER,
        percentOccupancy        INTEGER,
        speedData               INTEGER,
        zoneStatus              INTEGER
        }
```

3.4.1.1 End Time Parameter

```
endTime OBJECT-TYPE
SYNTAX          Counter
ACCESS          read-write
STATUS          mandatory
DESCRIPTION
```

"<Definition> Indicates the time at which the data collection period ended for the data contained in this row, the most recently completed sample period. If the clockAvailable data element indicates the presence of a clock, this time shall be expressed in local time as expressed in the controller-localTime data element (see NTCIP 1201); otherwise, this time shall be expressed in the number of seconds since the most recent device initialization.
<DescriptiveName> Tss.endTime:quantity
<DataConceptType> Data Element
<Unit> second"
::= { dataCollectionEntry 1 }

3.4.1.2 Volume Data Parameter

```
volumeData OBJECT-TYPE
SYNTAX          INTEGER (0..65535)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
```

“<Definition> Counts per sample period, for the most recently completed sample period. Counts are expressed as an integer value in the volumeData data element. The value of 65535 shall be returned to

represent a missing value. A missing value is reported when the zoneStatus is anything other than OK for the entire sampling period.
<DescriptiveName> Tss.volumeData:quantity
<DataConceptType> Data Element
<Unit> count"
::= { dataCollectionEntry 2 }

3.4.1.3 Percent Occupancy Parameter

percentOccupancy OBJECT-TYPE
SYNTAX INTEGER (0..1000 | 65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> Percent occupancy over the sample period for the most recently completed sample period. Occupancy is expressed in tenths of a percent, from 0 to 100.0 percent, in the percentOccupancy data element. The value of 65535 shall be return to represent an invalid or missing value. A missing value is reported when the zoneStatus is anything other than OK for the entire sampling period. Values 1001 through 65534 are reserved for future use.
<DescriptiveName> Tss.percentOccupancy:percent
<DataConceptType> Data Element
<Unit> percent"
::= { dataCollectionEntry 3 }

3.4.1.4 Speed Data Parameter

speedData OBJECT-TYPE
SYNTAX INTEGER (0..2550 | 65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> Arithmetic mean of speeds collected over the sample period with units of 1/10ths of km/h, for the most recently completed sample period. For a volume of zero during the sample period, the value of 65535 shall be returned to represent an invalid or missing value. A missing value is reported when the zoneStatus is anything other than OK for the entire sampling period. Values 2551 through 65534 are reserved for future use.
<DescriptiveName> Tss.speedData:rate
<DataConceptType> Data Element
<Unit> tenths of km/h"
::= { dataCollectionEntry 4 }

3.4.1.5 Zone Status Parameter

zoneStatus OBJECT-TYPE
SYNTAX INTEGER { other (1),
oK (2),
initializing (3),
noActivity (4),
maxPresence (5),
configurationError (6),
erraticCounts (7),
disabled (8),
overrideActive (9),

sensorFailure (10) }
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> Detailed status returned as result of diagnostics, as follows:
Value Meaning
other: Status returned indicating an error has occurred within the device for which there is no defined definition within this data element,
oK: Status returned indicating OK,
initializing: Status returned indicating an initialization or diagnostics procedure is in progress,
noActivity: Status returned indicating no activity error condition,
maxPresence: Status returned indicating max presence error condition,
configurationError: Status returned indicating an error within the device configuration setup,
erraticCounts: Status returned indicating erratic counts,
disabled: Status returned indicating that the zone is disabled.
overrideActive: Status returned indicating an override is active.
sensorFailure: Status returned indicating a sensing element failure,
If a condition occurs during the sample period, then that state remains for the duration of that sample period. If multiple conditions occur during a sample period, the last reported condition, other than OK, is retained.
<DescriptiveName> Tss.zoneStatus:code
<DataConceptType> Data Element"
::= { dataCollectionEntry 5 }

3.4.2 Data Buffer Table

dataBufferTable OBJECT-TYPE
SYNTAX SEQUENCE OF DataBufferEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
“<Definition> Table containing the second most recently completed previous sample period data, which value is specified by the value of the sensorZoneSamplePeriod data element. The previous period data overwrites the data for the sample period data immediately preceding the previous sample period. The number of rows in this table is equal to the maxSensorZones data element. Table rows are set by the manufacturer, and row creation/deletion is not supported.
<DescriptiveName> Tss.dataBufferTable
<DataConceptType> Entity Type
<TableType> static”
::= { tssDataCollection 2 }

dataBufferEntry OBJECT-TYPE
SYNTAX DataBufferEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
“<Definition> Table containing the data collection parameters for the second most recently completed previous sample period.
<DescriptiveName> Tss.dataBufferEntry
<DataConceptType> Entity Type”
INDEX { sensorZoneNumber }
::= { dataBufferTable 1 }

DataBufferEntry ::= SEQUENCE {

```
sensorZoneNumber            INTEGER,
endTimeBuffer               Counter,
volumeDataBuffer            INTEGER,
percentOccupancyBuffer      INTEGER,
speedDataBuffer             INTEGER,
zoneStatusBuffer            INTEGER
}
```

3.4.2.1 End Time Buffer Parameter

endTimeBuffer OBJECT-TYPE
SYNTAX Counter
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> Indicates the time at which the data collection period ended for the data contained in this row, the second most recently completed previous sample period. If the clockAvailable data element indicates the presence of a clock, this time shall be expressed in local time as expressed in the controller-localTime data element (see NTCIP 1201); otherwise, this time shall be expressed in the number of seconds since the most recent device initialization.
<DescriptiveName> Tss.endTimeBuffer:quantity
<DataConceptType> Data Element
<Unit> second"
::= { dataBufferEntry 1 }

3.4.2.2 Volume Data Buffer Parameter

volumeDataBuffer OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> Counts per sample period, for the second most recently completed previous sample period. Counts are expressed as an integer value in the volumeData data element. The value of 65535 shall be returned to represent a missing value. A missing value is reported when the zoneStatusBuffer is anything other than OK for the entire sampling period.
<DescriptiveName> Tss.volumeDataBuffer:quantity
<DataConceptType> Data Element
<Unit> count"
::= { dataBufferEntry 2 }

3.4.2.3 Percent Occupancy Buffer Parameter

percentOccupancyBuffer OBJECT-TYPE
SYNTAX INTEGER (0..1000 | 65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> Percent occupancy over the sample period for the second most recently completed previous sample period. Occupancy is expressed in tenths of a percent, from 0 to 100.0 percent, in the percentOccupancy data element. The value of 65535 shall be returned to represent an invalid or missing value. A missing value is reported when the zoneStatusBuffer is anything other than OK for the entire sampling period. Values 1001 through 65534 are reserved for future use.

<DescriptiveName> Tss.percentOccupancyBuffer
<DataConceptType> Data Element
<Unit> percent"
::= { dataBufferEntry 3 }

3.4.2.4 Speed Data Buffer Parameter

speedDataBuffer OBJECT-TYPE
SYNTAX INTEGER (0..2550 | 65535)
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Description> Arithmetic mean of speeds collected over the sample period, with units of 1/10ths of km/hr, for the second most recently completed previous sample period. For a volume of zero during the sample period, the value of 65535 shall be returned to represent an invalid or missing value. A missing value is reported when the zoneStatusBuffer is anything other than OK for the entire sampling period. Values 2551 through 65534 are reserved for future use.
<DescriptiveName> Tss.speedDataBuffer:rate
<DataConceptType> Data Element
<Unit> tenths of km/hr"
::= { dataBufferEntry 4 }

3.4.2.5 Zone Status Buffer Parameter

zoneStatusBuffer OBJECT-TYPE
SYNTAX INTEGER { other (1),
oK (2),
initializing (3),
noActivity (4),
maxPresence (5),
configurationError (6),
erraticCounts (7),
disabled (8),
overrideActive (9),
sensorFailure (10) }
ACCESS read-only
STATUS mandatory
DESCRIPTION "Detailed status returned as result of diagnostics, for the previous sample period, as follows:

Value Meaning

other: Status returned indicating an error has occurred within the device for which there is no defined definition within this data element,
oK: Status returned indicating OK,
initializing: Status returned indicating an initialization or diagnostics procedure is in progress,
noActivity: Status returned indicating no activity error condition,
maxPresence: Status returned indicating max presence error condition,
configurationError: Status returned indicating an error within the device configuration setup,
erraticCounts: Status returned indicating erratic counts,
disabled: Status returned indicating that the zone is disabled,
overrideActive: Status returned indicating an override is active,
sensorFailure: Status returned indicating a sensing element failure.

If a condition occurs during the sample period, then that state remains for the duration of that sample period.
<DescriptiveName> Tss.zoneStatusBuffer:code

<DataConceptType> Data Element"
::= { dataBufferEntry 5 }

3.5 TSS INDUCTIVE LOOP DETECTOR DATA ELEMENTS

tssInductiveLoop OBJECT IDENTIFIER ::= { tss 4 }

-- This node contains the configuration objects specific to inductive loop detectors
-- These objects setup physical parameters on the detector that are controlled on a per output basis.
-- These objects are only valid for the zones that map directly to an output on the detector.
-- Zone 1 maps to output 1 and Zone 2 maps to output 2 on a two output detector and Zone 3 maps
-- to output 3, and Zone 4 maps to output 4 on a four output detector.
-- For inductive loop detectors, the term “channel” is often used to refer to an “output”.

3.5.1 Loop System Setup Table

loopSensorSetupTable OBJECT-TYPE
SYNTAX SEQUENCE OF LoopSensorSetupEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
“<Definition> This table contains inductive loop detector sensor zone parameters. The number of rows in this table does not exceed maxSensorZones. This table contains the configuration objects specific to inductive loop detectors. These objects set up physical parameters on the detector that are controlled on a per output basis. A zone maps directly to an output on an inductive loop detector - Zone 1 maps to output 1, Zone 2 maps to output 2, and, on a four output inductive loop detector, Zone 3 maps to output 3 and Zone 4 maps to output 4. Table rows are set by the manufacturer, and row creation/deletion is not supported.
<DescriptiveName> Tss.loopSensorSetupTable
<DataConceptType> Entity Type
<TableType> static”
::= { tssInductiveLoop 1 }

loopSensorSetupEntry OBJECT-TYPE
SYNTAX LoopSensorSetupEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
“<Definition> Row in table that contains inductive loop detector sensor zone parameters. The number of rows in this table does not exceed maxSensorZones or maxOutputNumber, whichever is greater. Table rows are set by the manufacturer, and row creation/deletion is not supported.
<DescriptiveName> Tss.loopSensorSetupEntry
<DataConceptType> Entity Type”
INDEX { sensorZoneNumber }
::= { loopSensorSetupTable 1 }

```
LoopSensorSetupEntry ::= SEQUENCE {
--      sensorZoneNumber          INTEGER,
        zoneSensitivityMode       INTEGER,
        zoneSensitivity           OCTET STRING,
        zoneFrequencyRange        OCTET STRING
        }
```

3.5.1.1 Zone Sensitivity Mode

zoneSensitivityMode OBJECT-TYPE
SYNTAX INTEGER { deltaL (1),
deltaLOverSqrtL (2),
deltaLOverL (3) }
ACCESS read-only
STATUS mandatory
DESCRIPTION
"<Definition> Sensitivity mode in use (3=ΔL/L, 2=ΔL/√L, 1=ΔL). This is a characteristic of the loop detector being used.
<DescriptiveName> Tss.zoneSensitivityMode:code
<DataConceptType> Data Element"
::= { loopSensorSetupEntry 1 }

3.5.1.2 Zone Sensitivity

zoneSensitivity OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(2))
ACCESS read-write
STATUS mandatory
DESCRIPTION
"<Definition> This bit-mapped object allows the setting and reading of the sensitivity for the zone as follows:

bit 3,bit 2,bit1,bit 0	Meaning
0000	Zone OFF (Disabled) (LSB)
0001	Detect ΔL = 512 nanohenries or ΔL/L = 0.64%
0010	Detect ΔL = 256 nanohenries or ΔL/L = 0.32%
0011	Detect ΔL = 128 nanohenries or ΔL/L = 0.16%
0100	Detect ΔL = 64 nanohenries or ΔL/L = 0.08%
0101	Detect ΔL = 32 nanohenries or ΔL/L = 0.04%
0110	Detect ΔL = 16 nanohenries or ΔL/L = 0.02%
0111	Detect ΔL = 8 nanohenries or ΔL/L = 0.01%
or, if bit 15=1	Detect ΔL = 0 to 32,767 nanohenries or ΔL/L = 0 to 32.767% (MSB)

These sensitivity definitions are equal with a loop inductance of 80 microhenries. A detector need not support all of these settings. However, the sensitivities it does support must conform with these definitions, e.g. a sensitivity setting of 3 is always 128 nanohenries or 0.16% with an 80 microhenry loop. If bit 15=1, bit 0 – bit 14 contain the sensitivity in nanohenries or one-thousands of a percent, e.g. 3650 is 3.650%. A value of 65535 shall be returned to represent invalid data or not a physical zone. Values of 8 through 32767 are reserved.
<DescriptiveName> Tss.zoneSensitivity:text
<DataConceptType> Data Element"
::={ loopSensorSetupEntry 2 }

3.5.1.3 Zone Frequency Mode

zoneFrequencyRange OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(1))
ACCESS read-write
STATUS mandatory
DESCRIPTION
"<Definition> Allows the setting and reading of the frequency range as follows:
bit 2, bit 1, bit 0 Meaning

000 Frequency Range 0 (lowest frequency) (LSB)
001 Frequency Range 1
010 Frequency Range 2
011 Frequency Range 3 (highest frequency for 4 freq. unit) (MSB)

As the frequency number increases the operation frequency shall increase. The loop frequency at the lowest frequency setting shall be less than 88% of the loop frequency at the highest frequency setting. A value of 255 shall be returned to represent invalid data or not a physical zone. Values of 8 through 254 are reserved.
<DescriptiveName>Tss.zoneFrequencyRange:text
<DataConceptType> Data Element"
::= { loopSensorSetupEntry 3 }

3.5.2 Loop Output Conditioning Table

```
loopOutputConditioningTable OBJECT-TYPE
SYNTAX        SEQUENCE OF LoopOutputConditioningEntry
ACCESS        not-accessible
STATUS        mandatory
DESCRIPTION
"<Definition> Each table row contains objects for configuring inductive loop detector sensor zone outputs.
The number of rows in this table does not exceed maxSensorZones. Table rows are set by the
manufacturer, and row creation/deletion is not supported.
<DescriptiveName> Tss.loopOutputConditioningTable
<DataConceptType> Entity Type
<TableType> static"
::= { tssInductiveLoop 2 }

loopOutputConditioningEntry OBJECT-TYPE
SYNTAX        LoopOutputConditioningEntry
ACCESS        not-accessible
STATUS        mandatory
DESCRIPTION
"<Definition> Each table row contains inductive loop detector sensor zone output conditioning
parameters.
<DescriptiveName> Tss.loopOutputConditioningEntry
<DataConceptType> Entity Type"
INDEX { sensorZoneNumber }
::= { loopOutputConditioningTable 1 }

LoopOutputConditioningEntry ::= SEQUENCE {
        sensorZoneNumber          INTEGER,
        zoneOutputMode            INTEGER,
        zoneMaxPresenceTime       INTEGER,
        zoneOutputDelayTime       INTEGER,
        zoneOutputExtendTime      INTEGER,
        zoneOutputExtendEnable    OCTET STRING,
        zoneOutputDelayEnable     OCTET STRING
        }
```

3.5.2.1 Zone Output Mode

```
zoneOutputMode        OBJECT-TYPE
SYNTAX        INTEGER {     other (1),
                            pulse (2),
```

presence (3) }
ACCESS read-write
STATUS mandatory
DESCRIPTION
“<Definition> This object sets the length of the output during a detect condition. These detect outputs are described as follows:

other: Other – an output mode other than that defined in this standard
pulse: Pulse - a pulse of 125ms (±25ms) is output when a vehicle is detected.
presence: Presence - the output lasts the duration of a detect condition or until the detector tunes out the detect signal.

A value of 255 shall be returned to represent invalid data.
<DescriptiveName> Tss.zoneOutputMode:code
<DataConceptType> Data Element”
::= { loopOutputConditioningEntry 1 }

3.5.2.2 Zone Max Presence Feature Time

zoneMaxPresenceTime OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-write
STATUS optional
DESCRIPTION
“<Definition> This object sets the maximum time that the zone will hold presence before retuning. Values of 1 to 65534 seconds are available. A value of 0 disables this timer and prevents a sensor zone occupancy from being tuned out at the end of a specific time. A value of 65,535 represents invalid data.
<DescriptiveName> Tss.zoneMaxPresenceTime:quantity
<DataConceptType> Data Element
<Unit> second”
::= { loopOutputConditioningEntry 2 }

3.5.2.3 Zone Output Delay Time

zoneOutputDelayTime OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-write
STATUS optional
DESCRIPTION
“<Definition> The output for the zone is delayed from start of sensor zone occupancy by the time specified (tenths of a second: 00.0 to 6553.5 sec). For the output to actually switch, the sensor zone occupancy must be continuous and still be present at the end of the delay time.
<DescriptiveName> Tss.zoneOutputDelayTime:quantity
<DataConceptType> Data Element
<Unit> tenths of a second
REFERENCE
NEMA TS2 Clause 3.5.5.5.4.c and 6.5.2.24.1”
::= { loopOutputConditioningEntry 3 }

3.5.2.4 Zone Output Extend Time

zoneOutputExtendTime OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-write
STATUS optional
DESCRIPTION
"<Definition> The output for the zone is extended, after the end of the period in which the sensor zone is occupied, by the amount of time specified (tenths of a second: 00.0 to 6553.5 sec).
<DescriptiveName> Tss.zoneOutputExtendTime:quantity
<DataConceptTime> Data Element
<Unit> tenths of a second
REFERENCE
NEMA TS2 Clause 3.5.5.5.4.d and 6.5.2.24.2"
::= { loopOutputConditioningEntry 4 }

3.5.2.5 Zone Output Extend Enable

zoneOutputExtendEnable OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(1))
ACCESS read-write
STATUS optional
DESCRIPTION
"<Definition> A bit-mapped value as defined below to enable and disable the extend time for the sensor zone output, as follows:

bit 7	0 = NO, 1 = YES	HIGH on output 1 arming pin to enable extend time for the zone (MSB),
bit 6	0 = NO, 1 = YES	HIGH on output 2 arming pin to enable extend time for the zone,
bit 5	0 = NO, 1 = YES	HIGH on output 3 arming pin to enable extend time for the zone,
bit 4	0 = NO, 1 = YES	HIGH on output 4 arming pin to enable extend time for the zone,
bit 3	0 = NO, 1 = YES	LOW on output 1 arming pin to enable extend time for the zone (MSB),
bit 2	0 = NO, 1 = YES	LOW on output 2 arming pin to enable extend time for the zone,
bit 1	0 = NO, 1 = YES	LOW on output 3 arming pin to enable extend time for the zone,
bit 0	0 = NO, 1 = YES	LOW on output 4 arming pin to enable extend time for the zone (LSB).

Extend time is always enabled for the zone if all bits are zero (0).
<DescriptiveName> Tss.zoneOutputExtendEnable:text
<DataConceptType> Data Element
REFERENCE
NEMA TS2 Clause 6.5.2.8.7, 6.5.2.24 and 6.5.2.25.6"
::= { loopOutputConditioningEntry 5 }

3.5.2.6 Zone Output Delay Enable

zoneOutputDelayEnable OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(1))
ACCESS read-write

STATUS optional
DESCRIPTION
"<Definition> A bit-mapped value as defined below to enable and disable the delay time for the sensor zone output, as follows:

bit 7	0 = NO, 1 = YES	HIGH on output 1 arming pin to enable delay time for the zone (MSB),
bit 6	0 = NO, 1 = YES	HIGH on output 2 arming pin to enable delay time for the zone,
bit 5	0 = NO, 1 = YES	HIGH on output 3 arming pin to enable delay time for the zone,
bit 4	0 = NO, 1 = YES	HIGH on output 4 arming pin to enable delay time for the zone,
bit 3	0 = NO, 1 = YES	LOW on output 1 arming pin to enable delay time for the zone (MSB),
bit 2	0 = NO, 1 = YES	LOW on output 2 arming pin to enable delay time for the zone,
bit 1	0 = NO, 1 = YES	LOW on output 3 arming pin to enable delay time for the zone,
bit 0	0 = NO, 1 = YES	LOW on output 4 arming pin to enable delay time for the zone,

Delay time is always enabled for the zone if all bits are zero (0).
<DescriptiveName> Tss.zoneOutputDelayEnable:text
<DataConceptType> Data Element
REFERENCE
NEMA TS2 Clause 6.5.2.8.7, 6.5.2.24 and 6.5.2.25.6"
::= { loopOutputConditioningEntry 6 }

3.5.3 Loop System Status Table

loopSystemStatusTable OBJECT-TYPE
SYNTAX SEQUENCE OF LoopSystemStatusEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
"<Definition> This table contains inductive loop detector sensor zone status parameters. The number of rows in this table does not exceed maxSensorZones. This table contains instantaneous zone status objects specific to inductive loop detectors. The zoneDetectStatus object may be used by external systems for doing detailed traffic analysis. A zone maps directly to an output on an inductive loop detector - Zones 1 maps to output 1, Zone 2 maps to output 2, and, on a four output inductive loop detector, Zone 3 maps to output 3 and Zone 4 maps to output 4. Table rows are set by the manufacturer, and row creation/deletion is not supported.
<DescriptiveName> Tss.loopSystemStatusTable
<DataConceptType> Entity Type
<TableType> static"
::= { tssInductiveLoop 3 }

loopSystemStatusEntry OBJECT-TYPE
SYNTAX LoopSystemStatusEntry
ACCESS not-accessible
STATUS mandatory
DESCRIPTION
"<Definition> Rows in this table contain inductive loop detector sensor zone status parameters. The number of rows in this table does not exceed maxSensorZones. Table rows are set by the manufacturer, and row creation/deletion is not supported.

<DescriptiveName> Tss.loopSystemStatusEntry
<DataConceptType> Entity Type"
INDEX { sensorZoneNumber }
::= { loopSystemStatusTable 1 }

```
LoopSystemStatusEntry ::= SEQUENCE {
--      sensorZoneNumber            INTEGER,
        zoneInductance              INTEGER,
        zoneFrequency               INTEGER,
        zoneInductanceChange        INTEGER,
        zoneFaultHistory            OCTET STRING,
        zoneFaultCount              INTEGER
        }
```

3.5.3.1 Zone Inductance

zoneInductance OBJECT-TYPE
SYNTAX INTEGER (0..65535)
ACCESS read-only
STATUS optional
DESCRIPTION
"<Definition> The detector unit calculates the inductance of the loop attached to the zone. The resolution is in tenths of a microhenry. For example, 852.4 microhenries will be represented as 8524. Resolution does not imply accuracy, refer to manufacturers data sheet. A value of 65535 shall be returned to represent invalid data or not a physical zone.
<DescriptiveName> Tss.zoneInductance:quantity
<DataConceptType> Data Element
<Unit> tenths of a microhenry"
::= { loopSystemStatusEntry 1 }

3.5.3.2 Zone Frequency

zoneFrequency OBJECT-TYPE
SYNTAX INTEGER (0..16777216)
ACCESS read-only
STATUS optional
DESCRIPTION
"<Definition> This is the frequency of the inductive loop attached to the zone. The frequency resolution is one-tenth hertz. For example, 53240 Hz will be represented as 532400. Resolution does not imply accuracy, refer to manufacturers data sheet. A value of 16777216 shall be returned to represent invalid data or not a physical zone.
<DescriptiveName> Tss.zoneFrequency:quantity
<DataConceptType> Data Element
<Unit> one-tenth hertz"
::= { loopSystemStatusEntry 2 }

3.5.3.3 Zone Inductance Change

zoneInductanceChange OBJECT-TYPE
SYNTAX INTEGER (0.. 8388608)
ACCESS read-only
STATUS optional
DESCRIPTION

“<Definition> The maximum inductance change seen since the last start of sensor zone occupancy is returned. The value is signed, and the resolution is to one nanohenry or one one-thousandth of a percent. Resolution does not imply accuracy. A positive value represents movement in the Call direction
<DescriptiveName> Tss.zoneInductanceChange:quantity
<DataConceptType> Data Element
<Unit> nanohenry”
::= { loopSystemStatusEntry 3 }

3.5.3.4 Zone Fault History

```
zoneFaultHistory          OBJECT-TYPE
SYNTAX          OCTET STRING (SIZE (1))
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"<Definition> A bit-mapped value representing the history of faults in Zone since the last unit reset.
bit 7           0 = NO, 1 = YES          To indicate that a current fault exists on the loop
                                         connected to the zone (MSB);
bit 6           0 = NO, 1 = YES          To indicate that the loop connected to the zone is open
                                         or this was the last fault.  (May be also be called a
                                         Maximum Presence fault by external units.);
bit 5           0 = NO, 1 = YES          To indicate that the loop connected to the zone is
                                         shorted or this was the last fault.  (May also be called a
                                         No Activity fault by external units.);
bit 4           0 = NO, 1 = YES          To indicate that the loop inductance of the loop
                                         connected to the zone is currently ≥ ±25% of reference
                                         or this was the last fault.  (May also be called a Erratic
                                         Count fault by external units.);
bits 3..1                                Reserved;
bit 0           0 = NO, 1 = YES          To indicate that data for this value is invalid data or this
                                         is not a physical zone (LSB).
<DescriptiveName> Tss.loopFaultHistory:text
<DataConceptType> Data Element"
::= { loopSystemStatusEntry 4 }
```

3.5.3.5 Zone Fault Count

```
zoneFaultCount            OBJECT-TYPE
SYNTAX          INTEGER (0..255)
ACCESS          read-only
STATUS          mandatory
DESCRIPTION
"<Definition> Number of faults in the zone since the last unit reset.  These faults include open circuit;
short circuit and ±25% drift faults.  The fault count may also include faults other than those defined in this
standard.  The count after 255 is 255.
<DescriptiveName> Tss.zoneFaultCount:quantity
<DataConceptType> DataElement
<Unit> fault"
::= { loopSystemStatusEntry 5 }

END
```

Section 4
CONFORMANCE

4.1 CONFORMANCE GROUPS

A conformance group is defined in NTCIP 1103 Simple Transportation Management Framework (STMF), clause 3.3.5, as a basic unit of conformance.

Conformance groups are defined as either mandatory or optional. If a conformance group is mandatory, all of the data elements (objects) and subgroups with STATUS “mandatory” that are part of the conformance group shall be present for a device to claim conformance to the MIB defining the Conformance group. If a Conformance group is optional, all of the data elements (objects) and subgroups with the STATUS “mandatory” that are part of the conformance group shall be present if the device supports the Conformance group. Optional data elements (objects) with the STATUS “optional” may be supported.

When a table is included in a conformance group, all data elements (objects) contained in the table are included by reference. This is because a table is defined as a SEQUENCE OF {SEQUENCE}. Thus, all data elements (objects) listed in the sequence are defined as an integral part of the table. Tables are defined as either mandatory or optional. If a table is mandatory, all of the data elements (objects) with STATUS “mandatory” shall be present. If a table is optional, all of the data elements (objects) with the STATUS “mandatory” shall be present if the device supports the table. Optional data elements (objects) within a table with the STATUS “optional” may be supported.

Support for objects within a Subgroup are handled in the same fashion as tables. This is summarized in Table 4-1.

TABLE 4-1: DATA ELEMENT (OBJECT) SUPPORT REQUIREMENTS

DATA ELEMENT (OBJECT) STATUS	TABLE STATUS	CONFORMANCE GROUP STATUS (IF ANY)	DATA ELEMENT (OBJECT) SUPPORT
mandatory	Mandatory	mandatory	mandatory
mandatory	Mandatory	optional	mandatory, if conformance group is supported
mandatory	Optional	mandatory	mandatory, if table is supported
mandatory	Optional	optional	mandatory, if both the conformance group and table are supported
optional	Mandatory	mandatory	optional
optional	Mandatory	optional	optional
optional	Optional	mandatory	optional
optional	Optional	optional	optional

The Conformance Group definitions for Transportation Sensor Systems (TSS) are defined in the following Clauses. A TSS may have multiple capabilities; thus, Conformance Groups are defined for each capability.

4.1.1 TSS System Setup Conformance Group

The TSS System Setup Conformance Group consists of data elements (objects) that specify the configuration parameters of a TSS. The conformance requirement for each data element (object) within the group is shown. Please refer to the Conformance Statement Table 4-2 for the conformance requirement for the group. The TSS System Setup Conformance Group shall consist of the following data elements (objects):

DATA ELEMENT (OBJECT) OR TABLE NAME	REFERENCE	CONFORMANCE REQUIREMENT WITHIN THE GROUP
sensorSystemReset	NTCIP 1209 v01.16	mandatory
sensorSystemStatus	NTCIP 1209 v01.16	mandatory
sensorSystemOccupancyType	NTCIP 1209 v01.18	mandatory
maxSensorZones	NTCIP 1209 v01.18	mandatory
sensorZoneTable	NTCIP 1209 v01.18	mandatory
sensorZoneNumber	NTCIP 1209 v01.18	mandatory
sensorZoneOptions	NTCIP 1209 v01.18	mandatory
sensorZoneOptionsStatus	NTCIP 1209 v01.18	mandatory
sensorZoneSamplePeriod	NTCIP 1209 v01.18	mandatory
sensorZoneLabel	NTCIP 1209 v01.18	optional
sensorZoneAndOperator	NTCIP 1209 v01.18	optional
sensorZoneOrOperator	NTCIP 1209 v01.18	optional
clockAvailable	NTCIP 1209 v01.18	mandatory

4.1.2 TSS Control Conformance Group

The TSS Control Conformance Group consists of data elements (objects) that specify detection outputs within a TSS. The conformance requirement for each data element (object) within the group is shown. Please refer to the Conformance Statement Table 4-2 for the conformance requirement for the group. The TSS Control Conformance Group shall consist of the following data elements (objects):

DATA ELEMENT (OBJECT) OR TABLE NAME	REFERENCE	CONFORMANCE REQUIREMENT WITHIN THE GROUP
maxOutputNumber	NTCIP 1209 v01.18	mandatory
outputConfigurationTable	NTCIP 1209 v01.18	mandatory
outputNumber	NTCIP 1209 v01.18	mandatory
outputSensorZoneNumber	NTCIP 1209 v01.18	mandatory
outputFailsafeMode	NTCIP 1209 v01.18	mandatory
outputModeStatus	NTCIP 1209 v01.18	mandatory
outputLabel	NTCIP 1209 v01.18	optional
maxOutputGroups	NTCIP 1209 v01.18	mandatory
outputGroupTable	NTCIP 1209 v01.18	mandatory
outputGroupNumber	NTCIP 1209 v01.18	mandatory
outputGroupOutputState	NTCIP 1209 v01.18	mandatory

4.1.3 TSS Data Collection Conformance Group

The TSS Data Collection Conformance Group consists of data elements (objects) that specify data collection functions within a TSS. The conformance requirement for each data element (object) within the group is shown. Please refer to the Conformance Statement Table 4-2 for the conformance requirement for the group. The TSS Data Collection Conformance Group shall consist of the following data elements (objects):

DATA ELEMENT (OBJECT) OR TABLE NAME	REFERENCE	CONFORMANCE REQUIREMENT WITHIN THE GROUP
dataCollectionTable	NTCIP 1209 v01.18	mandatory
endTime	NTCIP 1209 v01.18	mandatory
volumeData	NTCIP 1209 v01.18	mandatory
percentOccupancy	NTCIP 1209 v01.18	mandatory
speedData	NTCIP 1209 v01.18	mandatory
zoneStatus	NTCIP 1209 v01.18	mandatory
dataBufferTable	NTCIP 1209 v01.18	mandatory
endTimeBuffer	NTCIP 1209 v01.18	mandatory
VolumeDataBuffer	NTCIP 1209 v01.18	mandatory
percentOccupancyBuffer	NTCIP 1209 v01.18	mandatory
speedDataBuffer	NTCIP 1209 v01.18	mandatory
zoneStatusBuffer	NTCIP 1209 v01.18	mandatory

4.1.4 TSS Inductive Loop Conformance Group

The TSS Inductive Loop Conformance Group consists of data elements (objects) that specify inductive loop functions within a TSS. The conformance requirement for each data element (object) within the group is shown. Please refer to the Conformance Statement Table 4-2 for the conformance requirement for the group. The TSS Inductive loopn Conformance Group shall consist of the following data elements (objects):

DATA ELEMENT (OBJECT) OR TABLE NAME	REFERENCE	CONFORMANCE REQUIREMENT WITHIN THE GROUP
loopSensorSetupTable	NTCIP 1209 v01.18	mandatory
zoneSensitivityMode	NTCIP 1209 v01.18	mandatory
zoneSensitivity	NTCIP 1209 v01.18	mandatory
zoneFrequencyRange	NTCIP 1209 v01.18	mandatory
loopOutputConditioningTable	NTCIP 1209 v01.18	mandatory
zoneOutputMode	NTCIP 1209 v01.18	mandatory
zoneMaxPresenceTime	NTCIP 1209 v01.18	optional
zoneOutputDelayTime	NTCIP 1209 v01.18	optional
zoneOutputExtendTime	NTCIP 1209 v01.18	optional
zoneOutputExtendEnable	NTCIP 1209 v01.18	optional
zoneOutputDelayEnable	NTCIP 1209 v01.18	optional
loopSystemStatusTable	NTCIP 1209 v01.18	mandatory
zoneInductance	NTCIP 1209 v01.18	optional
zoneFrequency	NTCIP 1209 v01.18	optional
zoneInductanceChange	NTCIP 1209 v01.18	optional
zoneFaultHistory	NTCIP 1209 v01.18	mandatory
zoneFaultCount	NTCIP 1209 v01.18	mandatory

4.2 CONFORMANCE STATEMENTS

TSS devices shall adhere to the conformance requirements specified in TABLE 4-2 as a minimum to claim compliance to this standard. Additional data elements (objects) or groups may be supported without being non-compliant with TSS data elements (objects) or NTCIP.

Minimum and maximum ranges of data elements (objects) that differ from the values of the data element's (object's) SYNTAX field may be enforced by an application running on a device.

A device that enforces range limits within the bounds specified by the values of the data element's (object's) SYNTAX field shall not be categorized as being non-compliant with TSS data element's (object's) or NTCIP.

A device that supports a subset of enumerated values for a given data element (object) shall not be categorized as being non-compliant with TSS data elements (objects) or NTCIP.

TABLE 4-2: CONFORMANCE STATEMENT TABLE

CONFORMANCE GROUP	REFERENCE	CONFORMANCE REQUIREMENT
Configuration	NTCIP 1201 v02	mandatory
Time Management	NTCIP 1201 v02	optional
Security	NTCIP 1103 and NTCIP 2301 v02	mandatory
TSS System Setup	NTCIP 1209 v01.18	mandatory
TSS Control	NTCIP 1209 v01.18	mandatory
TSS Data Collection	NTCIP 1209 v01.18	optional
TSS Inductive Loop	NTCIP 1209 v01.18	optional

ANNEX A
INFORMATION PROFILE
(INFORMATIVE)

A Conformance Group is a basic unit of conformance and is used to specify a collection of related managed data elements (objects). The Conformance Group designation applied to a set of data elements (objects) provides a systematic means for determining which data elements (objects) are required to support a function. If a device has multiple functions, a Conformance Group will be defined for each function. Conformance Group definitions will be found in the NTCIP Object Definition Standard documents. The Object Definition Standard may define a Conformance Group with data elements (objects) that are not in lexicographic order and only apply to devices of that type.

The related managed data elements (objects) of a Conformance Group may include mandatory and/or optional data elements (objects). Mandatory data elements (objects) within a Conformance Group shall be implemented. Optional data elements (objects) shall be implemented only if a defined function of the device requires that particular data element (object).

For example, assume a device implements an asynchronous RS-232 interface. It must implement all the mandatory data elements (objects) in the Asynchronous Conformance Group of the RS-232 MIB. It would not have to implement the Synchronous Conformance Group of data elements (objects) unless it also provided a synchronous interface.

Assume also that the Asynchronous Conformance Group has a *CRC error counter* data element (object) that is optional. The *CRC error counter* data element (object) would not have to be implemented unless the device used CRC checking on the asynchronous interface.

Conformance Groups are defined as either mandatory or optional. If a Conformance Group is mandatory, all of the data elements (objects) with STATUS "mandatory" that are part of the Conformance Group shall be present for a device to claim conformance to the Conformance Group. If a Conformance Group is optional, all of the data elements (objects) that are part of the Conformance Group with the STATUS "mandatory" shall be present if the device supports the Conformance Group. Data elements (objects) with the STATUS "optional" may be supported.

When a table is included in a Conformance Group, all data elements (objects) contained in the table are included by reference. This is because a table is defined as a SEQUENCE OF {SEQUENCE}. Thus, all data elements (objects) listed in the sequence are defined as an integral part of the table. Tables are defined as either mandatory or optional. If a table is mandatory, all of the data elements (objects) with STATUS "mandatory" shall be present. If a table is optional, all of the data elements (objects) with the STATUS "mandatory" shall be present if the device supports the table. Data elements (objects) in the table with the STATUS "optional" may be supported.

A.1 NOTATION

The following notations and symbols are used to indicate status and conditional status within this standard.

A.1.1 TYPE Symbols

The following symbols are used to indicate type:

Symbol	Type
C	Control Data Element (Object)- use of 'dbCreateTransaction' in NTCIP 1201 Clause 2.3.1 shall NOT delay a SET to this data element (object).
P	Parameter Data Element (Object)- use of 'dbCreateTransaction' in NTCIP 1201 Clause 2.3.1 to SET this data element (object) is optional.
P2	Parameter Data Element (Object)- use of 'dbCreateTransaction' in NTCIP 1201 Clause 2.3.1 to SET this data element (object) is mandatory.
S	Status / Information Data Element (Object)- this data element (object) is read only therefore a SET is not permitted.

A.1.2 Staus Symbols

The following symbols are used to indicate status:

Symbol	Status
M	Mandatory
M.<n>	Support of every item of the group labeled by the same numeral <n> required, but only one is active at time.
O	Optional
O.<n>	Optional, but support of at least one of the group of options labeled by the same numeral <n> is required
C	Conditional
N/A	Non-applicable (i.e., logically impossible in the scope of the profile)
X	Excluded or prohibited

A.1.3 Conditional Status Notation

The following predicate notations is used:

Notation	Status
"<predicate>: M	Item is conditional on the <predicate>.

The <predicate>: notation means that the Status following it applies only when the feature or features identified by the predicate are supported. In the simplest case, <predicate> is the identifying tag of a single item.

A.1.4 Support Column

This section is in the form of a PICS and, therefore, includes a support column. An implementer claims support of an item by circling the appropriate answer (Yes or No) in the support column:

A.2 TSS REQUIREMENTS

The Conformance Group definitions for Transportation Sensor Systems are defined in this clause. A Transportation Sensor System has multiple functions; thus, Conformance Groups are defined for each function.

The following table lists functional requirements for a Transportation Sensor System, and asks if the listed features have been implemented.

Ref	Areas	Clause of Profile	Status	Support
A.3	TSS System Setup Conformance Group	NTCIP 1209 – 3.2	M	Yes
A.4	TSS Control Conformance Group	NTCIP 1209 – 3.3	M	Yes
A.5	TSS Data Collection Conformance Group	NTCIP 1209 – 3.4	O	Yes / No
A.6	TSS Inductive Loop Conformance Group	NTCIP 1209 – 3.5	O	Yes / No
A.7	Configuration Conformance Group	NTCIP 1201 v02 – 2.2	M	Yes
A.8	Time Management Conformance Group	NTCIP 1201 v02 – 2.4	O	Yes / No
A.9	NTCIP Security Conformance Group	NTCIP 1103 – A.10 and 2301 v02	M	Yes

Transportation Sensor System (TSS) devices shall adhere to the conformance requirements specified in the above table as a minimum to claim compliance to this standard. Additional data elements (objects) or groups may be supported without being non-compliant with TSS data elements (objects) or NTCIP.

Minimum and maximum ranges of data elements (objects) that differ from the values of the data element's (object's) SYNTAX field may be enforced by an application running on a device.

A device which enforces range limits within the bounds specified by the values of the data element's (object's) SYNTAX field shall not be categorized as being non-compliant with TSS data elements (objects) or NTCIP.

A device which supports a subset of data elements (objects) with enumerated values shall not be categorized as being non-compliant with TSS data elements (objects) or NTCIP.

A.3 TSS SYSTEM SETUP CONFORMANCE GROUP

The TSS System Setup Conformance Group shall consist of the following data elements (objects):

TSS System Setup CONFORMANCE GROUP						
NTCIP 1209 Clause	Data Element (Object) Name	Data Element (Object) Type	Data Element (Object) Status	Data Element (Object) Support	Allowed Values	Supported Values
3.2	**TSS System Setup** Conformance Group	---	M	Yes	---	---
3.2.1	sensorSystemReset	C	3.2 : M	Yes	1-7	
	restart (1)	---	---	Yes / No	---	---
	reinitializeUserSettings (2)	---	---	Yes / No	---	---
	restoreFactoryDefaults (3)	---	---	Yes / No	---	---
	retune (4)	---	---	Yes / No	---	---
	resyncSamplingPeriods (5)	---	---	Yes / No	---	---
	shortDiagnostics (6)	---	---	Yes / No	---	---
	fullDiagnostics (7)	---	---	Yes / No	---	---
3.2.2	sensorSystemStatus	S	3.2 : M	Yes	1-3	
	other (1)	---	---	Yes / No	---	---
	oK (2)	---	---	Yes / No	---	---
	initializing (3)	---	---	Yes / No	---	---
3.2.3	sensorSystemOccupancyType	S	3.2 : M	Yes	1-5	
	normalizedOtherOccupancy (1)	---	---	Yes / No	---	---
	nonNormalizedOccupancy (2)	---	---	Yes / No	---	---
	zoneOccupancy (3)	---	---	Yes / No	---	---
	normalizedSixFootLoopOccupancy (4)	---	---	Yes / No	---	---
	normalizedTwoMeterLoopOccupancy (5)	---	---	Yes / No	---	---
3.2.4	maxSensorZones	S	3.2 : M	Yes	1-255	
3.2.5	sensorZoneTable	---	3.2 : M	Yes	---	---
	sensorZoneEntry	---	3.2 : M	Yes	---	---
3.2.5.1	sensorZoneNumber	S	3.2 : M	Yes	1-255	
3.2.5.2	sensorZoneOptions	C	3.2 : M	Yes	String	
	bit 7 – Sensor Zone Enable	---	---	Yes	---	---
	bit 6 – Reserved	---	---	---	---	---
	bit 5 – Reserved	---	---	---	---	---
	bit 4 – Reserved	---	---	---	---	---
	bit 3 – Reserved	---	---	---	---	---
	bit 2 – Reserved	---	---	---	---	---
	bit 1 – Reserved	---	---	---	---	---
	bit 0 – Reserved	---	---	---	---	---
3.2.5.3	sensorZoneOptionsStatus	S	3.2 : M	Yes	String	
	bit 7 – Sensor Zone Enable Status	---	---	Yes	---	---
	bit 6 – Reserved	---	---	---	---	---
	bit 5 – Reserved	---	---	---	---	---
	bit 4 – Reserved	---	---	---	---	---
	bit 3 – Reserved	---	---	---	---	---
	bit 2 – Reserved	---	---	---	---	---
	bit 1 – Reserved	---	---	---	---	---
	bit 0 – Reserved	---	---	---	---	---
3.2.5.4	sensorZoneSamplePeriod	P	3.2 : M	Yes	0-3600	
3.2.5.5	sensorZoneLabel	P	3.2 : O	Yes / No	String	
3.2.5.6	sensorZoneAndOperator	P	3.2 : O	Yes / No	String	
	Byte 1 – First AND zone number	---	---	---	---	---
	Byte 2 – Second AND zone number	---	---	---	---	---
	Byte 3 – Third AND zone number	---	---	---	---	---
	Byte 4 – Fourth AND zone number	---	---	---	---	---
	Byte 5 – Fifth AND zone number	---	---	---	---	---
	Byte 6 – Sixth AND zone number	---	---	---	---	---
	Byte 7 – Seventh AND zone number	---	---	---	---	---
	Byte 8 – Eighth AND zone number	---	---	---	---	---
3.2.5.7	sensorZoneOrOperator	P	3.2 : O	Yes / No	String	
	Byte 1 – First OR zone number	---	---	---	---	---
	Byte 2 – Second OR zone number	---	---	---	---	---
	Byte 3 – Third OR zone number	---	---	---	---	---
	Byte 4 – Fourth OR zone number	---	---	---	---	---
	Byte 5 – Fifth OR zone number	---	---	---	---	---

TSS System Setup CONFORMANCE GROUP						
NTCIP 1209 Clause	**Data Element (Object) Name**	**Data Element (Object) Type**	**Data Element (Object) Status**	**Data Element (Object) Support**	**Allowed Values**	**Supported Values**
	Byte 6 – Sixth OR zone number Byte 7 – Seventh OR zone number Byte 8 – Eighth OR zone number	--- --- ---	--- --- ---	--- --- ---	--- --- ---	--- --- ---
3.2.6	clockAvailable clockYes (1) clockNo (2)	S --- ---	3.2 : M --- ---	Yes Yes / No Yes / No	1-2 --- ---	--- --- ---

A.4 TSS CONTROL CONFORMANCE GROUP

The TSS Control Conformance Group consists of the following data elements (objects):

TSS Control CONFORMANCE GROUP						
NTCIP 1209 Clause	**Data Element (Object) Name**	**Data Element (Object) Type**	**Data Element (Object) Status**	**Data Element (Object) Support**	**Allowed Values**	**Supported Values**
3.3	**TSS Control Conformance Group**	---	M	Yes	---	---
3.3.1	maxOutputNumber	S	3.3 : M	Yes	1-255	
3.3.2	outputConfigurationTable outputConfigurationEntry	--- ---	3.3 : M 3.3 : M	Yes Yes	--- ---	--- ---
3.3.2.1 3.3.2.2 3.3.2.3	outputNumber outputSensorZoneNumber outputFailsafeMode	P P P	3.3 : M 3.3 : M 3.3 : M	Yes Yes Yes	1-255 0-255 1-5	
	failsafeModeOn (1) failsafeModeOff (2) overrideCommandOn (3)	--- --- ---	--- --- ---	Yes / No Yes / No Yes / No	--- --- ---	--- --- ---
  3.3.2.4	overrideCommandOff (4) normal (5) outputModeStatus	--- --- S	--- --- 3.3 : M	Yes / No Yes / No Yes	--- --- String	--- ---
	bit 7 – Failsafe Mode Status bit 6 – Override Command Status bit 5 – Reserved	--- --- ---	--- --- ---	Yes Yes ---	--- --- ---	--- --- ---
	bit 4 – Reserved bit 3 – Reserved bit 2 – Reserved	--- --- ---	--- --- ---	--- --- ---	--- --- ---	--- --- ---
  3.3.2.5	bit 1 – Reserved bit 0 – Reserved outputLabel	--- --- P	--- --- 3.3 : O	--- --- Yes	--- --- String	--- ---
3.3.3	maxOutputGroups	S	3.3 : M	Yes	1-32	
3.3.4	outputGroupTable	---	3.3 : M	Yes	---	---
3.3.4.1 3.3.4.2	outputGroupEntry outputGroupNumber	--- S	3.3 : M 3.3 : M	Yes Yes	--- 1-32	---
3.3.4.3	outputGroupOutputState	S	3.3 : M	Yes	String	
	bit 7 – Output 8 bit 6 – Output 7 bit 5 – Output 6	--- --- ---	--- --- ---	Yes Yes Yes	--- --- ---	--- --- ---
	bit 4 – Output 5 bit 3 – Output 4 bit 2 – Output 3	--- --- ---	--- --- ---	Yes Yes Yes	--- --- ---	--- --- ---
	bit 1 – Output 2 bit 0 – Output 1	--- ---	--- ---	Yes Yes	--- ---	--- ---

A.5 TSS DATA COLLECTION CONFORMANCE GROUP

The TSS Data Collection Conformance Group consists of the following data elements (objects):

TSS Data Collection CONFORMANCE GROUP						
NTCIP 1209 Clause	**Data Element (Object) Name**	**Data Element (Object) Type**	**Data Element (Object) Status**	**Data Element (Object) Support**	**Allowed Values**	**Supported Values**
3.4	**TSS Data Collection Conformance Group**	---	O	Yes / No	---	---
3.4.1	dataCollectionTable	---	3.4 : M	Yes	----	---
	dataCollectionEntry	---	3.4 : M	Yes	---	---
3.4.1.1	endTime	P	3.4 : M	Yes	Counter	
3.4.1.2	volumeData	S	3.4 : M	Yes	0-65535	
3.4.1.3	percentOccupancy	S	3.4 : M	Yes	0-1000 | 65535	
3.4.1.4	speedData	S	3.4 : M	Yes	0-2550 | 65535	
3.4.1.5	zoneStatus	S	3.4 : M	Yes	1-10	
	other (1)	---	---	Yes / No	---	---
	oK (2)	---	---	Yes / No	---	---
	initializing (3)	---	---	Yes / No	---	---
	noActivity (4)	---	---	Yes / No	---	---
	maxPresence (5)	---	---	Yes / No	---	---
	configurationError (6)	---	---	Yes / No	---	---
	erraticCounts (7)	---	---	Yes / No	---	---
	disabled (8)	---	---	Yes / No	---	---
	overrideActive (9)	---	---	Yes / No	---	---
	sensorFailure (10)	---	---	Yes / No	---	---
3.4.2	dataBufferTable	---	3.4 : M	Yes	----	---
	dataBufferEntry	---	3.4 : M	Yes	---	---
3.4.2.1	endTimeBuffer	S	3.4 : M	Yes	Counter	
3.4.2.2	volumeDataBuffer	S	3.4 : M	Yes	0-65535	
3.4.2.3	percentOccupancyBuffer	S	3.4 : M	Yes	0-1000 | 65535	
3.4.2.4	speedDataBuffer	S	3.4 : M	Yes	0-2550 | 65535	
3.4.2.5	zoneStatusBuffer	S	3.4 : M	Yes	1-10	
	other (1)	---	---	Yes / No	---	---
	oK (2)	---	---	Yes / No	---	---
	initializing (3)	---	---	Yes / No	---	---
	noActivity (4)	---	---	Yes / No	---	---
	maxPresence (5)	---	---	Yes / No	---	---
	configurationError (6)	---	---	Yes / No	---	---
	erraticCounts (7)	---	---	Yes / No	---	---
	disabled (8)	---	---	Yes / No	---	---
	overrideActive (9)	---	---	Yes / No	---	---
	sensorFailure (10)	---	---	Yes / No	---	---

A.6 TSS INDUCTIVE LOOP CONFORMANCE GROUP

The TSS Inductive Loop Conformance Group shall consist of the following data elements (objects):

TSS Inductive Loop CONFORMANCE GROUP						
NTCIP 1209 Clause	Data Element (Object) Name	Data Element (Object) Type	Data Element (Object) Status	Data Element (Object) Support	Allowed Values	Supported Values
3.5	**TSS Inductive Loop Conformance Group**	---	O	Yes / No	---	---
3.5.1	loopSensorSetupTable	---	3.5 : M	Yes	---	---
	loopSensorSetupEntry	---	3.5 : M	Yes	---	---
3.5.1.1	zoneSensitivityMode	S	3.5 : M	Yes	1-3	
	deltaL (1),	---	---	Yes / No	---	---
	deltaLOverSqrtL (2),	---	---	Yes / No	---	---
	deltaLOverL (3)	---	---	Yes / No	---	---
3.5.1.2	zoneSensitivity	P	3.5 : M	Yes	String	
3.5.1.3	zoneFrequencyRange	P	3.5 : M	Yes	String	
3.5.2	loopOutputConditioningTable	---	3.5 : M	Yes	---	---
	loopOutputConditioningEntry	---	3.5 : M	Yes	---	---
3.5.2.1	zoneOutputMode	P	3.5 : M	Yes	1-2	
	other (1)	---	---	Yes / No	---	---
	pulse (2)	---	---	Yes / No	---	---
	presence (3)	---	---	Yes / No	---	---
3.5.2.2	zoneMaxPresenceTime	P	3.5 : O	Yes / No	0-65535	
3.5.2.3	zoneOutputDelayTime	P	3.5 : O	Yes / No	0-65535	
3.5.2.4	zoneOutputExtendTime	P	3.5 : O	Yes / No	0-65535	
3.5.2.5	zoneOutputExtendEnable	P	3.5 : O	Yes / No	String	
	bit 7 – Output 1 Enable Extend Pin HIGH	---	---	Yes / No	---	---
	bit 6 - Output 2 Enable Extend Pin HIGH	---	---	Yes / No	---	---
	bit 5 – Output 3 Enable Extend Pin HIGH	---	---	Yes / No	---	---
	bit 4 – Output 4 Enable Extend Pin HIGH	---	---	Yes / No	---	---
	bit 3 – Output 1 Enable Extend Pin LOW	---	---	Yes / No	---	---
	bit 2 – Output 2 Enable Extend Pin LOW	---	---	Yes / No	---	---
	bit 1 – Output 3 Enable Extend Pin LOW	---	---	Yes / No	---	---
	bit 0 – Output 4 Enable Extend Pin LOW	---	---	Yes / No	---	---
3.5.2.6	zoneOutputDelayEnable	P	3.5 : O	Yes / No	String	
	bit 7 – Output 1 Enable Delay Pin HIGH	---	---	Yes / No	---	---
	bit 6 - Output 2 Enable Delay Pin HIGH	---	---	Yes / No	---	---
	bit 5 – Output 3 Enable Delay Pin HIGH	---	---	Yes / No	---	---
	bit 4 – Output 4 Enable Delay Pin HIGH	---	---	Yes / No	---	---
	bit 3 – Output 1 Enable Delay Pin LOW	---	---	Yes / No	---	---
	bit 2 – Output 2 Enable Delay Pin LOW	---	---	Yes / No	---	---
	bit 1 – Output 3 Enable Delay Pin LOW	---	---	Yes / No	---	---
	bit 0 – Output 4 Enable Delay Pin LOW	---	---	Yes / No	---	---
3.5.3	loopSystemStatusTable	---	3.5 : M	Yes	----	---
	loopSystemStatusEntry	---	3.5 : M	Yes	---	---
3.5.3.1	zoneInductance	S	3.5 : O	Yes / No	0-65535	
3.5.3.2	zoneFrequency	S	3.5 : O	Yes / No	0-16777216	
3.5.3.3	zoneInductanceChange	S	3.5 : O	Yes / No	0-8388608	
3.5.3.4	zoneFaultHistory	S	3.5 : M	Yes / No	String	
	bit 7 – Current Fault Exists	---	---	Yes / No	---	---
	bit 6 - Open	---	---	Yes / No	---	---
	bit 5 – Shorted	---	---	Yes / No	---	---
	bit 4 – Inductance ≥ ±25%	---	---	Yes / No	---	---
	bit 3 – Reserved	---	---	---	---	---
	bit 2 – Reserved	---	---	---	---	---
	bit 1 – Reserved	---	---	---	---	---
	bit 0 – Invalid Data	--	---	Yes / No	---	---
3.5.3.5	zoneFaultCount	S	3.5 : M	Yes / No	0-255	

A.7 GLOBAL CONFIGURATION CONFORMANCE GROUP

The Global Configuration Conformance Group shall consist of the following data elements (objects):

Global Configuration CONFORMANCE GROUP						
NTCIP 1201 Clause	**Data Element (Object) Name**	**Data Element (Object) Type**	**Data Element (Object) Status**	**Data Element (Object) Support**	**Allowed Values**	**Supported Values**
2.2	**Global Config Conformance Group**	---	M	Yes	---	---
2.2.1	globalSetIDParmeter	S	2.2 : O	Yes / No	0-65535	
2.2.2	globalMaxModules	S	2.2 : M	Yes	0-255	
2.2.3	globalModuleTable	---	2.2 : M	Yes	---	---
	moduleTableEntry	---	2.2 : M	Yes	---	---
2.2.3.1	moduleNumber	S	2.2 : M	Yes	1-255	
2.2.3.2	moduleDeviceNode	S	2.2 : M	Yes	OID	
2.2.3.3	moduleMake	S	2.2 : M	Yes	String	
2.2.3.4	moduleModel	S	2.2 : M	Yes	String	
2.2.3.5	moduleVersion	S	2.2 : M	Yes	String	
2.2.3.6	moduleType	S	2.2 : M	Yes	1-3	
	other(1)	---	---	Yes / No	---	---
	hardware(2)	---	---	Yes / No	---	---
	software(3)	---	---	Yes / No	---	---
2.2.4	controller-baseStandards	S	2.2 :O	Yes / No	String	

A.8 TIME MANAGEMENT CONFORMANCE GROUP

The Time Management Conformance Group shall consist of the following data elements (objects):

Time Management CONFORMANCE GROUP						
NTCIP 1201v2 Clause	**Data Element (Object) Name**	**Data Element (Object) Type**	**Data Element (Object) Status**	**Data Element (Object) Support**	**Allowed Values**	**Supported Values**
2.4	**Time Management Conformance Group**	---	O	Yes / No	---	---
2.4.1	globalTme	C	2.4 : M	Yes	Counter	
2.4.2	globalDaylightSavings	P	2.4 : M	Yes	1-3	
2.4.6	controller-standardTimeZone	P	2.4 : M	Yes	-43200 - 43200	
2.4.7	controller-localTime	S	2.4 : M	Yes	Counter	

A.9 NTCIP SECURITY CONFORMANCE GROUP

The NTCIP Security Conformance Group shall consist of the following data elements (objects):

Security CONFORMANCE GROUP						
NTCIP 1103 Clause	**Data Element (Object) Name**	**Data Element (Object) Type**	**Data Element (Object) Status**	**Data Element (Object) Support**	**Allowed Values**	**Supported Values**
A.10	**Security Conformance Group**	--	M	Yes	----	---
A.10.1	adminCommunityName	C	A.10 : M	Yes	String	
A.10.2	maxCommunityNames	C	A.10 : M	Yes	1-255	
A.10.3	communityNameTable	--	A.10 : M	Yes	---	---
	communityNameTableEntry	--	A.10 : M	Yes	---	---
A.10.3.1	communityNameIndex	S	A.10 : M	Yes	1-255	
A.10.3.2	communityNameString	S	A.10 : M	Yes	String	
A.10.3.3	communityNameAccessMask	S	A.10 : M	Yes	Gauge	

§

PRUEBAS DE TRÁFICO DE VIDEO EN UNA RED ETHERNET

1. Objetivos

- Determinar el rendimiento de una red *Ethernet* con tráfico de video.
- Observar el comportamiento del tráfico de video en una topología en cascada con *switches Ethernet*.

2. Materiales y Metodología

Las pruebas de tráfico de video se realizarán en un laboratorio de red, provisto de computadores con Sistema Operativo Windows o Linux, y *switches Ethernet*, de preferencia *Catalyst CISCO* de la Serie 2950. Para la realización de las pruebas, es recomendable tener a disposición un cableado estructurado que permita realizar las conexiones con facilidad entre los equipos.

El tráfico de video se generará a partir de un software de simulación de tráfico, el cual es de código abierto (con licencia GNU). Este software es el ITG, el cual se presenta en versiones para Windows y Linux, y basado en consola. Es recomendable que la ejecución del programa se haga con privilegios de administrador, para cualquier sistema operativo, esto debido a que se necesita acceso a las interfases de red.

Se simulará un tráfico con características de video comprimido, esto es en formato MPEG2, debido a que la mayoría de técnicas de envió de paquetes de video MPEG4 se basan en el MPEG2. Los rasgos más importantes son la cantidad de paquetes por segundo y el tamaño de cada paquete, el cual será constante, así como el tiempo de espaciamiento entre envío de paquetes, los cuales tienen que dar como resultado un tráfico de 2 Mbps para cada conexión o flujo.

La conexión entre computadores se realizará a través de *switches* dispuestos en cascada, tantos como sea posible. La simulación se realizará comenzando con una conexión entre dos computadores, uno que actúa como emisor, el cual simulará ser una cámara de video IP, y el otro que actúa como receptor, el cual simulará ser un servidor de video IP. La cantidad de emisores, y por lo tanto conexiones al mismo receptor, irá aumentando hasta llegar a la máxima capacidad de los *switches,* o hasta obtener un tráfico saturado.

3. **Procedimiento**

a) El primer paso es realizar la instalación del software en el sistema operativo de los computadores que se van a usar, este código ya se encuentra en binario, por lo que no es necesario un compilador.

b) Se debe realizar las conexiones para la simulación de tráfico, para ello se dispondrá de los *swithes Ethernet* en cascada, tal como lo muestra el siguiente gráfico. En los extremos de los *switches* se conectarán los dos computadores que actuarán como emisor y receptor. Luego se procede a realizar la conexión y el envío de paquetes que simulan Video/IP.

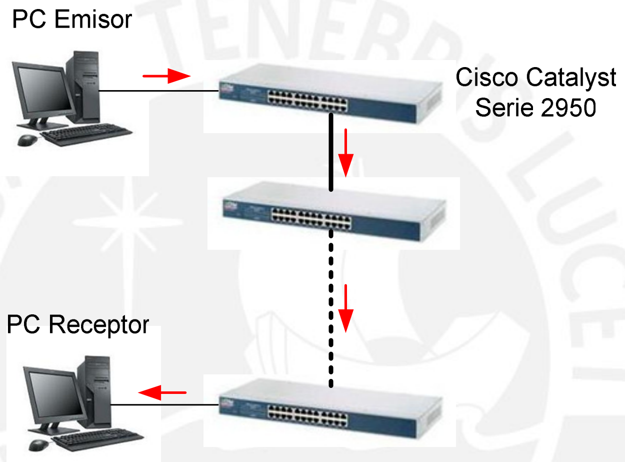


Figura 1. Topología en cascada con *switches Ethernet*

c) Para realizar el envío y recepción de paquetes IP, el software ITG cuenta con una serie de comandos con funcionalidades específicas, los cuales se puede apreciar en el manual proporcionado por el desarrollador, y que además usaremos algunas de ellas.

ITGSend: Permite enviar paquetes IP con ciertas características, por lo que se usará el siguiente comando:

En linux:

./ITGSend –a <IP_reciever_addr> -sp 9400 –rp 9500 –C 184 –c 1356 –t 30000 –x <receive_file>

En Windows:

C:\> ITGSend.exe –a <IP_reciever_addr> -sp 9400 –rp 9500 –C 184 –c 1356 –t 30000 –x <receive_file>

Opciones:

-a Indica la dirección al cual será enviado los paquetes, en este caso la dirección IP del computador que simulara ser el servidor de video

-sp Es el puerto origen que se usará

-rp Es el puerto destino que se usará

-C Indica la cantidad de paquetes por segundo que se transmitirá, y cuyo tiempo entre paquetes es constante

-c Indica el tamaño del paquete que se envía, este tamaño es constante en todos los paquetes enviados

-t Tiempo, en milisegundos, que dura el envío de paquetes

-x nombre del archivo "log" que se crea en el lado del receptor, y que guarda todos los datos de tráfico

ITGRecv: Permite recibir todos los paquetes que llegan en el receptor.

En Linux:
-/ITGRecv

En Windows:
C:\> ITGRecv.exe

El comando no se ejecuta en background, por lo tanto puede ser detenido con CTRL+C.

ITGDec: Permite leer el archivo "log" que crea los comandos anteriores, el cual es binario, y muestra en pantalla los resultados en una forma mas entendible.

En Linux:
./ITGDec <nombre del archivo>

En Windows:

C:\> ITGDec.exe <nombre del archivo>

d) Una vez realizado la simulación para un flujo, se procede a aumentar el número de flujo en la red, para ello se aumenta el número de computadores en el proceso tal como se muestra en la figura, y se repite el procedimiento antes visto.

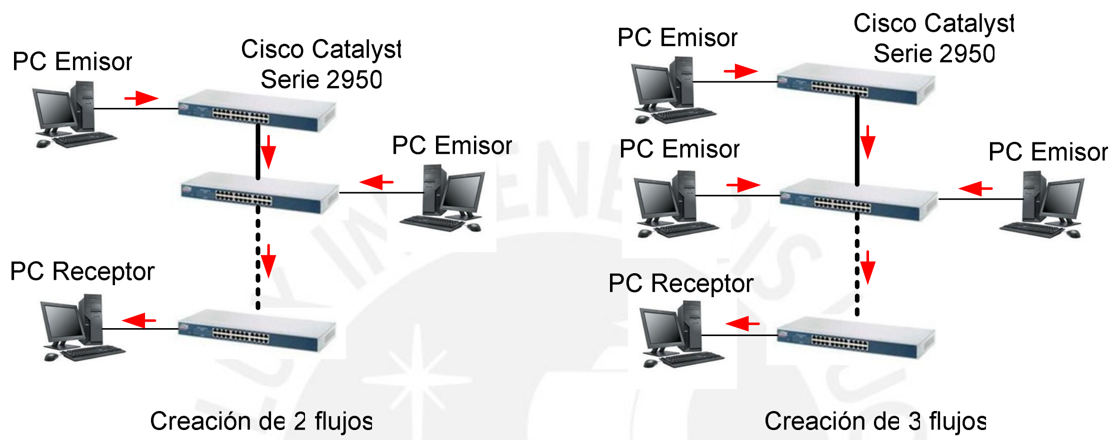


Figura 2. Procedimiento para la evaluación del tráfico de red.

e) Con los archivos que contiene los datos de la simulación, se procede a procesarlos y graficarlos, para ello se usa el programa "Octave", el cual es de código abierto y bajo los términos de licencia GNU. Este software es un procesador matemático (con las mismas características que el Matlab), y permite graficar las características de los flujos que se han simulado, ello es el retardo, el jitter, la velocidad de transmisión, y la pérdida de paquetes. En este caso se analizará el retardo, para ello solo se verificará la variación de retardo con respecto al tiempo, y no el nivel de retardo, ya que en esta simulación solo se necesita determinar si el flujo de paquetes es constante, característica importante en aplicaciones de video y voz en tiempo real. Como se ha podido apreciar, no se ha tomado en cuenta la sincronización de relojes entre computadores, esto debido a que solo se necesita la variación del retardo, como ya se había mencionado.

4. Resultados Esperados

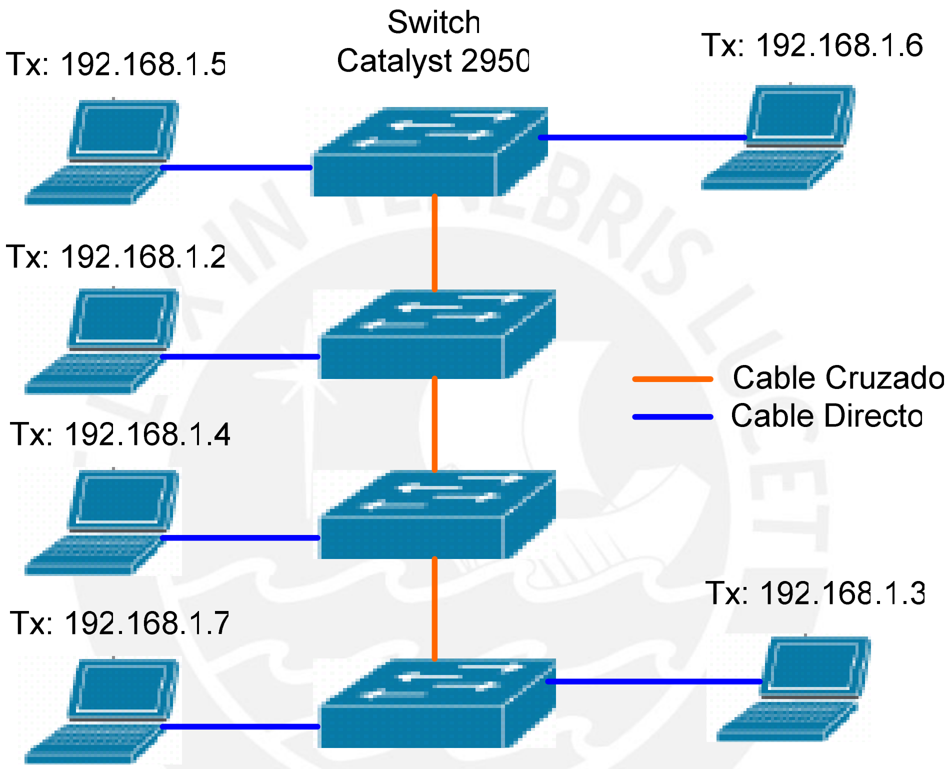
Con estas pruebas se pretende determinar la cantidad máxima de flujos de video/IP con compresión MPEG4 que puede haber en una red *Ethernet* con *switches* dispuestos en topología cascada, sin perder el rendimiento necesario en una aplicación de video en tiempo real, esto es mantener constante el flujo de paquetes. El objetivo no es obtener una cantidad exacta de tráfico en el cual se tenga un QoS aceptable, sino observar la cantidad de tráfico en el cual el comportamiento del *jitter* cambia drásticamente.

Los resultados que se obtendrán servirán de guía para observar el comportamiento de una red dispuesto en topología en cascada. Esto es de suma importancia ya que permite visualizar las limitaciones que puede tener la red en cuanto al transporte de datos en tiempo real. Depende considerablemente del sistema de video en tiempo real que se pretende instalar, para la obtención del *jitter* máximo, ya que solo la capacidad de los *encoder/decoder* de video (los buffers para ser mas exactos), las que definirá las características de red.

RESULTADOS DE LA SIMULACIÓN DE TRÁFICO DE VIDEO EN UNA RED ETHERNET CON TOPOLOGÍA EN CASCADA

1. Acciones preliminares

Para la realización de las pruebas, la disposición y configuración de la red es como se muestra a continuación:



Se han usado los equipos del laboratorio de redes de la especialidad de las Telecomunicaciones, principalmente los *switches Catalyst* 2950, el cual se asemeja en características de nivel 2 al *switch Catalyst* 2955.

Los parámetros que se miden mediante software, a través del programa ITG, son el retardo, el *jitter*, la velocidad de transmisión y la pérdida de paquetes. Para ello se simulará un flujo de video MPEG4 con las siguientes características:

- Tamaño de paquete IP: 1372 bytes
- Flujo de paquetes IP: 180 paquetes/segundo

Para ello se ha supuesto que los paquetes MPEG4 son enviados de la misma manera que los paquetes MPEG2, como suele suceder en la mayoría de aplicaciones. Los paquetes MPEG2 constan de 188 bytes, más 4 bytes de cabecera. Asimismo, estos paquetes son transportados en una trama UDP/IP en grupos de 7 paquetes. Por lo tanto, sumando el tamaño de los paquetes MPEG2 y lo que corresponde a la cabecera UDP/IP, da como resultado un paquete de tamaño 1372 bytes. Para lograr un flujo de aproximadamente 2Mbps, se necesita enviar 180 paquetes por segundo.

Las pruebas se realizarán cada 30 segundos, para seis casos, ello es la generación de un flujo de video MPEG4, hasta seis flujos de video MPEG4 por cada máquina; todas las máquinas transmitirán al mismo tiempo para todos los casos.

2. Resultados Obtenidos

De los parámetros obtenidos en los resultados, solo se va a considerar el *jitter* y la pérdida paquetes, ya que son los que influyen en la calidad de video en tiempo real. Los resultados que se mostrarán solo son respecto al *jitter*, ya que no se obtuvo pérdida de paquetes en las pruebas, esto debido a las características robustas de los *switches*.

Los resultados muestran que cada flujo genera una velocidad de 1984.54 Kbps. Además, el promedio del jitter de los flujos enviados por cada computador es el siguiente:

Jitter por computador	192.168.1.2 al 192.168.1.3	192.168.1.4 al 192.168.1.3	192.168.1.5 al 192.168.1.3	192.168.1.6 al 192.168.1.3	192.168.1.7 a 192.168.1.3
Un flujo	611 us	621 us	517 us	595 us	616 us
Dos flujos	860 us	572 us	630 us	665 us	627 us
Tres flujos	801 us	719 us	590 us	646 us	770 us
Cuatro flujos	822 us	713 us	778 us	773 us	652 us
Cinco flujos	1016 us	941 us	Indeterminado	838 us	717 us
Seis flujos	892 us	813 us	Indeterminado	761 us	762 us

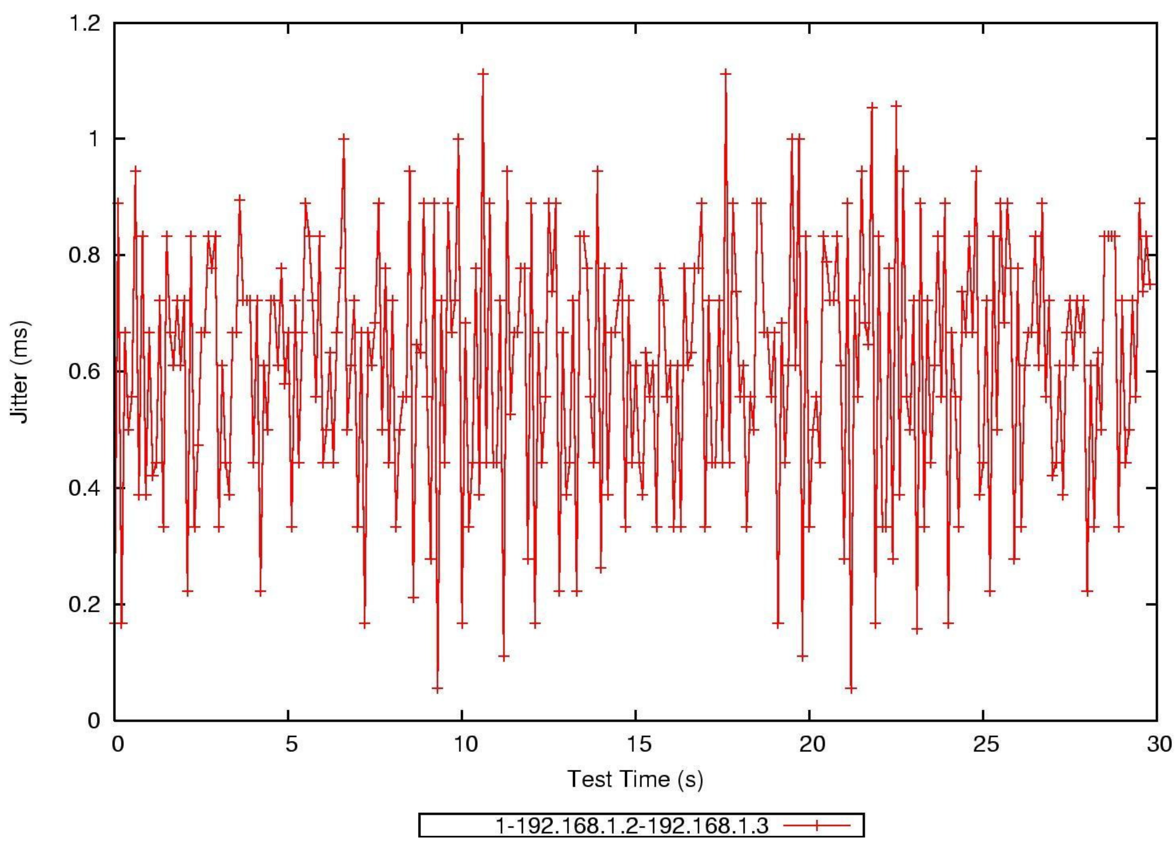
Se debe tener en cuenta que solo se tenía un computador para la recepción, por lo que existen casos en que no se obtuvo bien los datos por el alto tráfico recibido, hasta 60Mpbs. A continuación los resultados en gráficos.

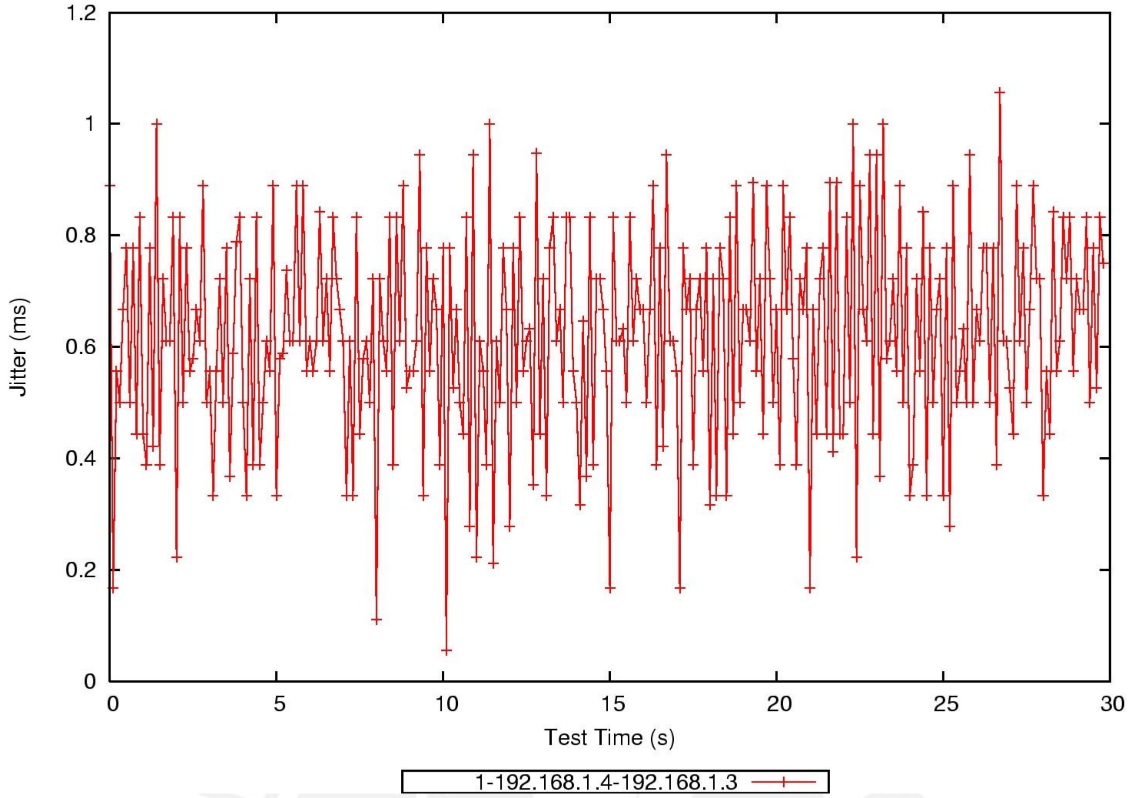
A. **RESULTADOS PARA UN FLUJO DE SIMULACIÓN DE VIDEO POR MÁQUINA**

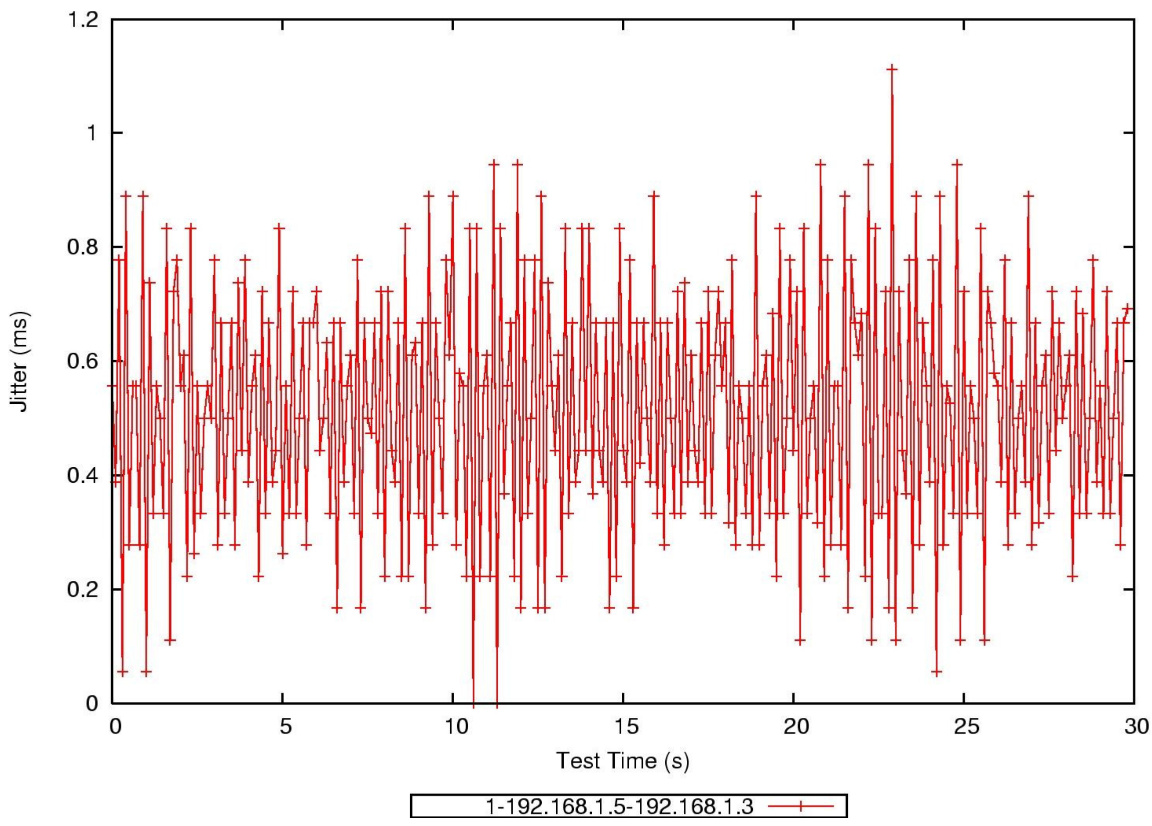
Los gráficos que se muestran a continuación corresponden al tráfico obtenido por cada computador. En este caso se realizó con un solo flujo, por lo que cada gráfico corresponde a cada computador. Debido a que el tráfico resultante en la red es de apenas 10 Mbps, se puede considerar que las características del *jitter* obtenidas son normales, y las más bajas que se pueden obtener.

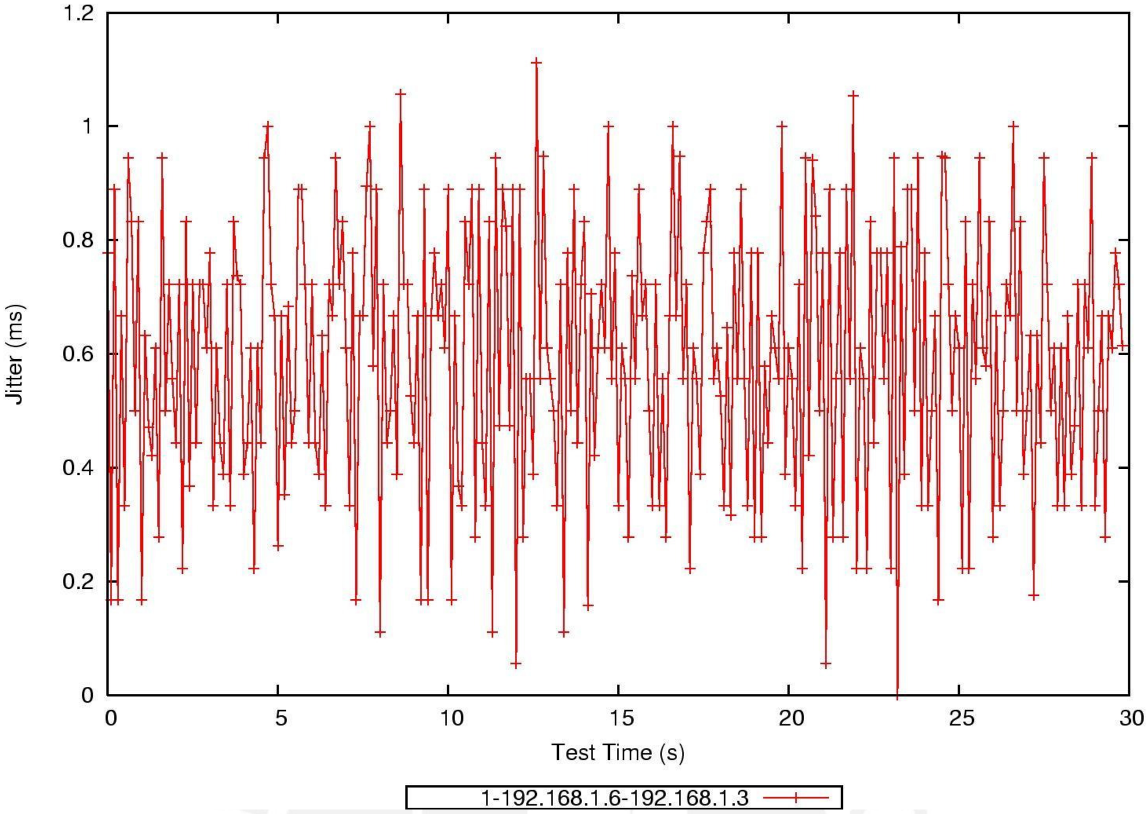
El eje vertical corresponde al *jitter* obtenido en milisegundos (ms), y el eje horizontal corresponde al tiempo en que se realiza las pruebas, el cual llega hasta los 30 segundos. Cabe resaltar que el *jitter* del gráfico es obtenido promediando el *jitte*r entre paquetes consecutivos, en un intervalo de tiempo. El intervalo elegido fue de 50 ms, el cual nos promedia aproximadamente el *jitter* de 10 paquetes, suficiente para obtener un resultado aceptable.

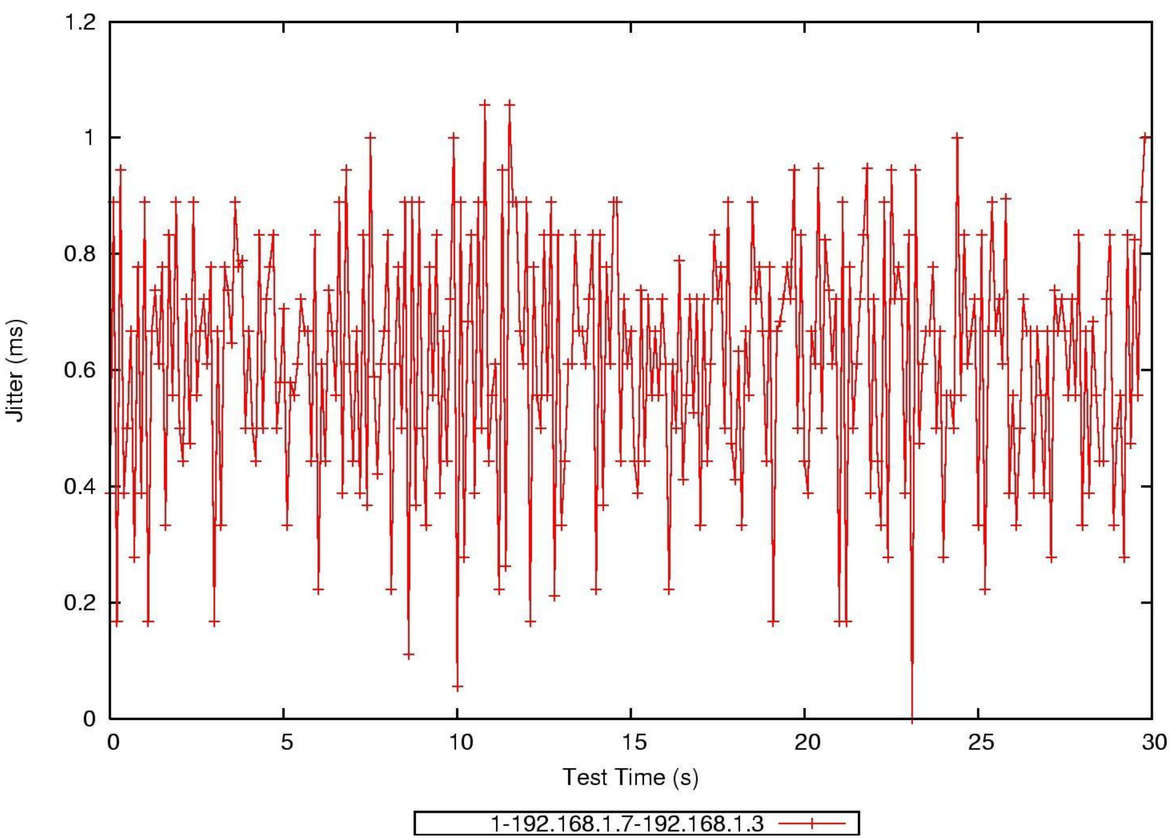
Como se puede apreciar, el *jitter* promedio es de 600 us, llegando a superar levemente 1 ms. en algunos casos. En conclusión, el comportamiento en una red con poco tráfico tiene un *jitter* entre 0 y 1.1 ms.




Jitter (ms)
Test Time (s)
1-192.168.1.4-192.168.1.3


Jitter (ms)
Test Time (s)
1-192.168.1.5-192.168.1.3

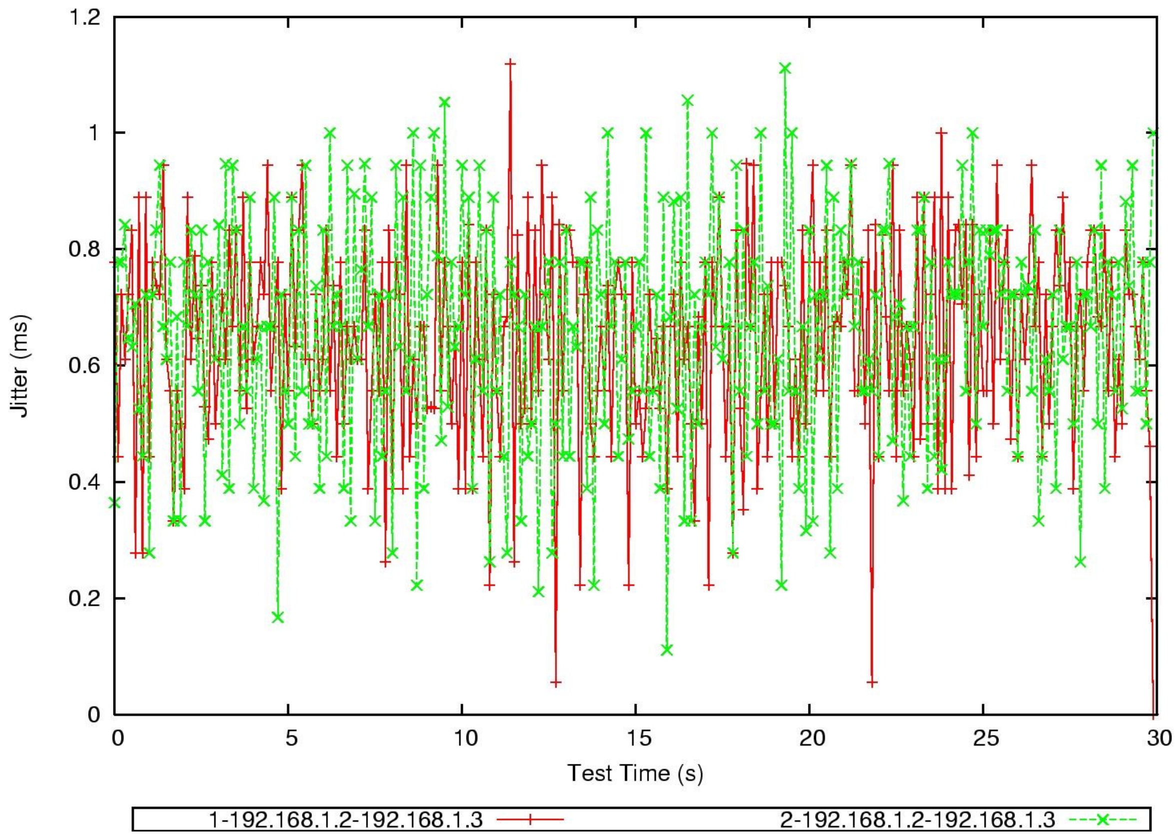

1.2
1
0.8
0.6
0.4
0.2
0
Jitter (ms)
0
5
10
15
20
25
30
Test Time (s)
1-192.168.1.6-192.168.1.3

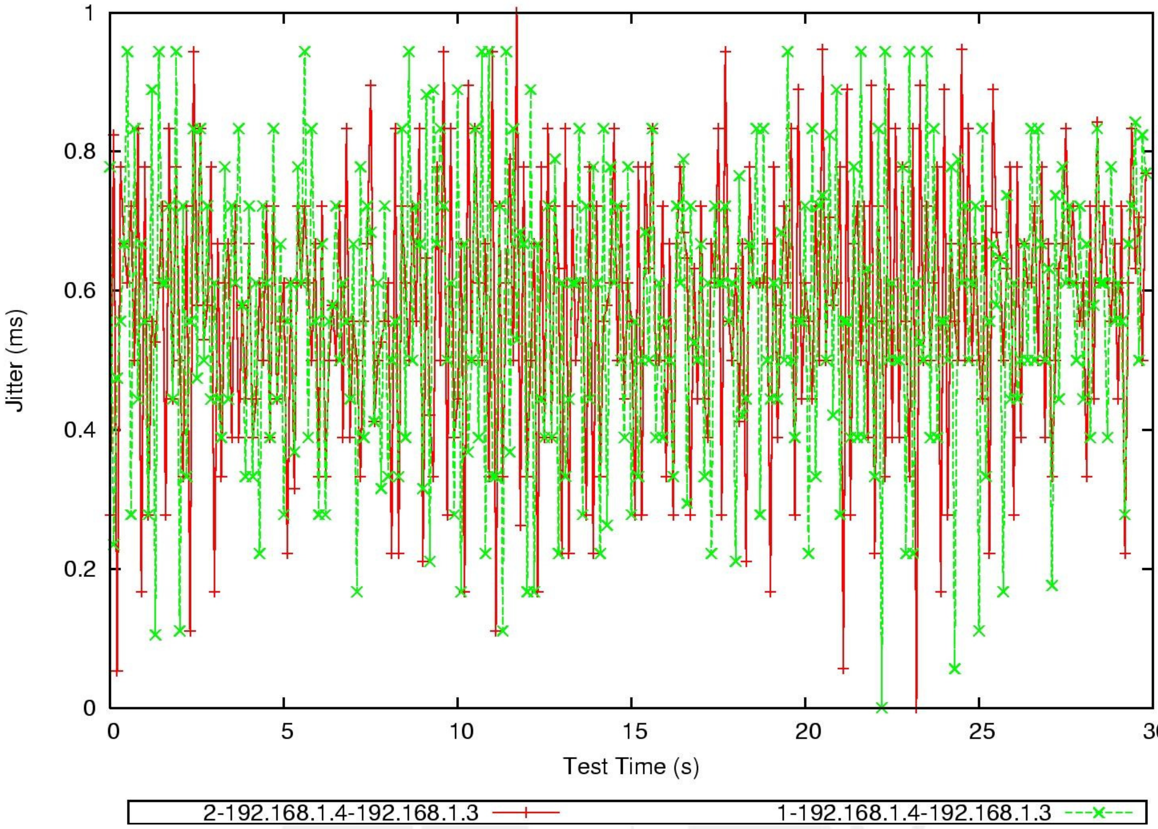

1.2
1
0.8
0.6
0.4
0.2
0
Jitter (ms)
0
5
10
15
20
25
30
Test Time (s)
1-192.168.1.7-192.168.1.3

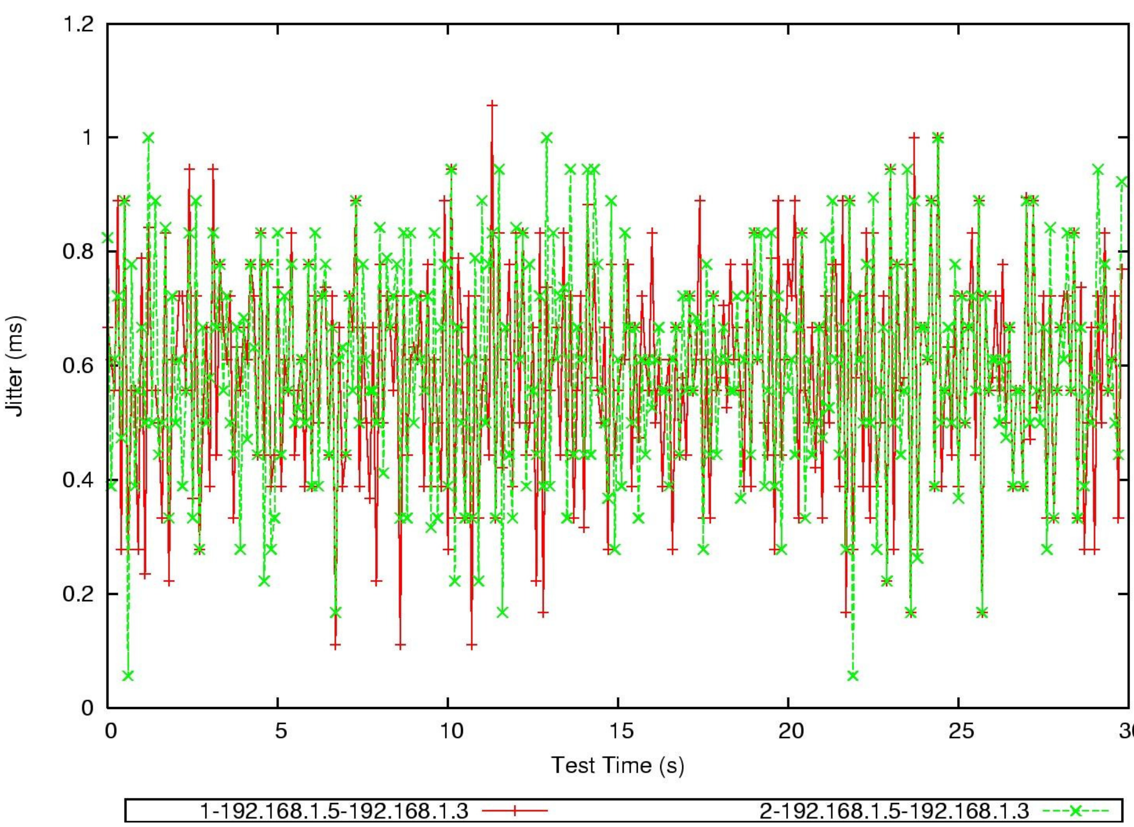
B. <u>RESULTADOS PARA DOS FLUJOS DE SIMULACIÓN DE VIDEO POR MÁQUINA</u>

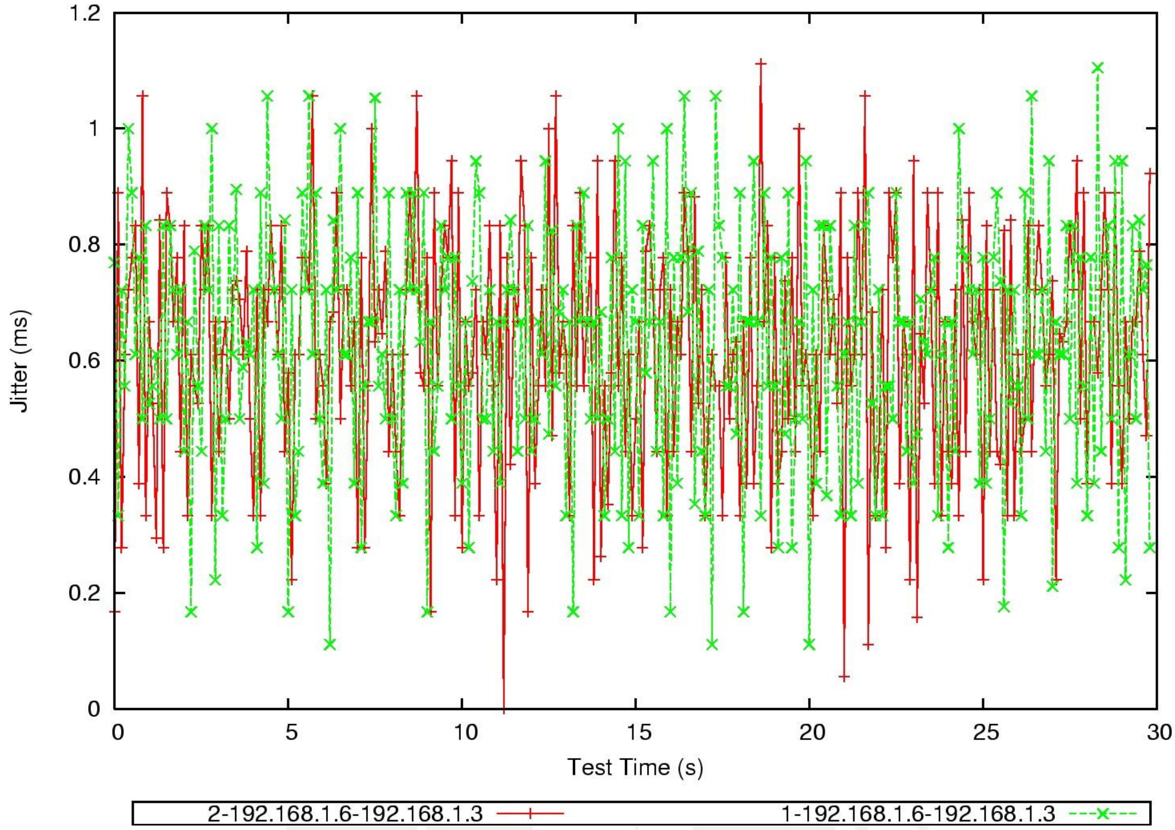
Tenemos como segundo resultado, el caso en que se envía dos flujos por cada computador. Esto duplica los valores de la prueba anterior. Entonces, el tráfico de la red total se duplica. Como se puede apreciar el los gráficos, el comportamiento del *jitter* es muy similar a los resultados anteriores. Por lo tanto, se puede decir que los *switches Catalyst* con las características mencionadas pueden soportar sin dificultad 10 flujos de video MPEG4 de 2 Mbps cada uno. Esto hace un total de casi 20 Mbps de tráfico total, sin perder las características del *jitter*, y por lo tanto manteniendo el QoS necesario para servicios en tiempo real.

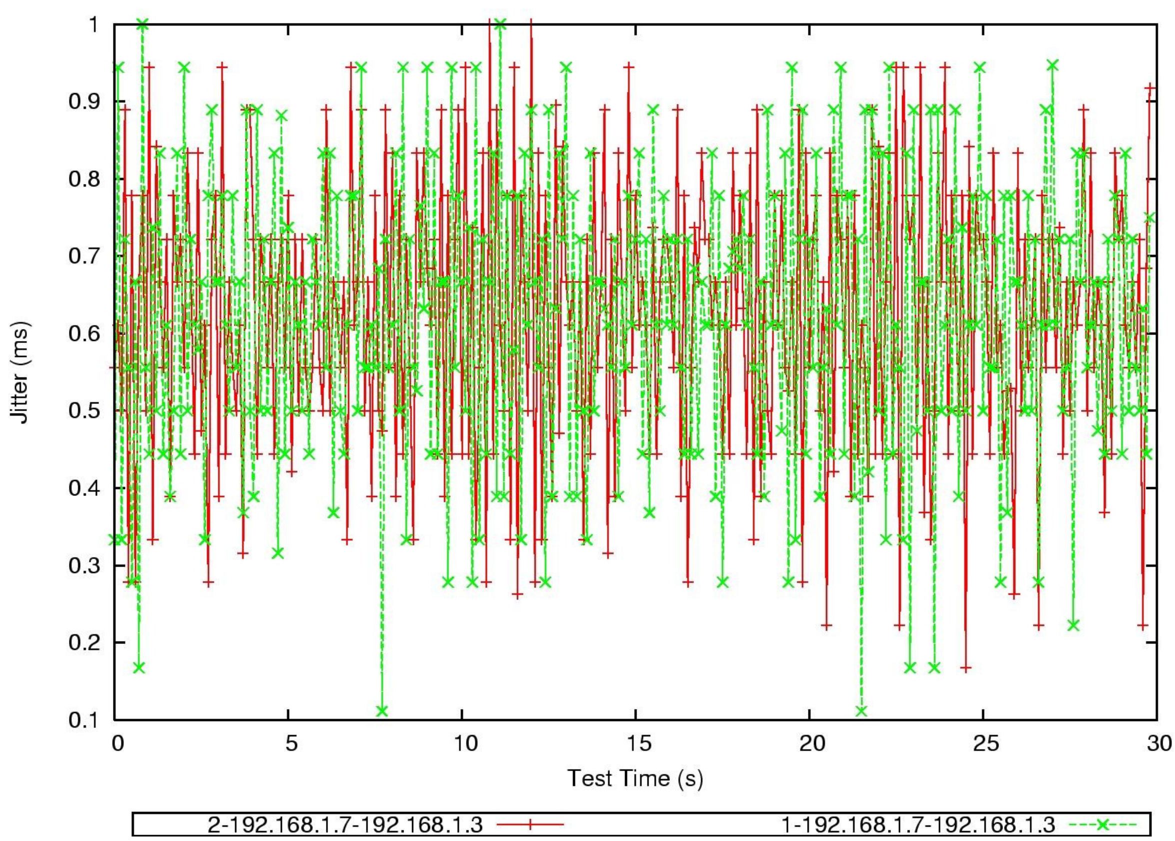
Se puede decir que el jitter en este caso se encuentra entre 0 y 1.1 ms.




Jitter (ms)
Test Time (s)
2-192.168.1.4-192.168.1.3
1-192.168.1.4-192.168.1.3


Jitter (ms)
Test Time (s)
1-192.168.1.5-192.168.1.3
2-192.168.1.5-192.168.1.3

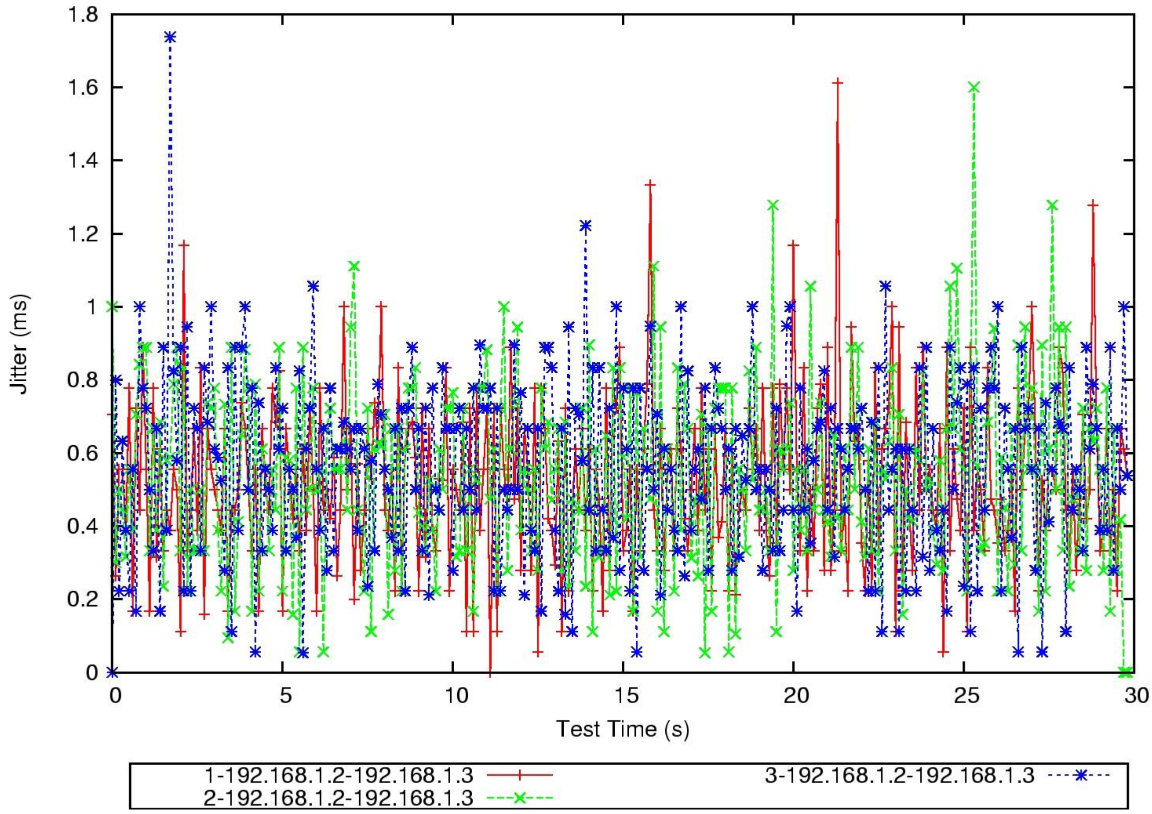

Jitter (ms)
Test Time (s)
2-192.168.1.6-192.168.1.3
1-192.168.1.6-192.168.1.3

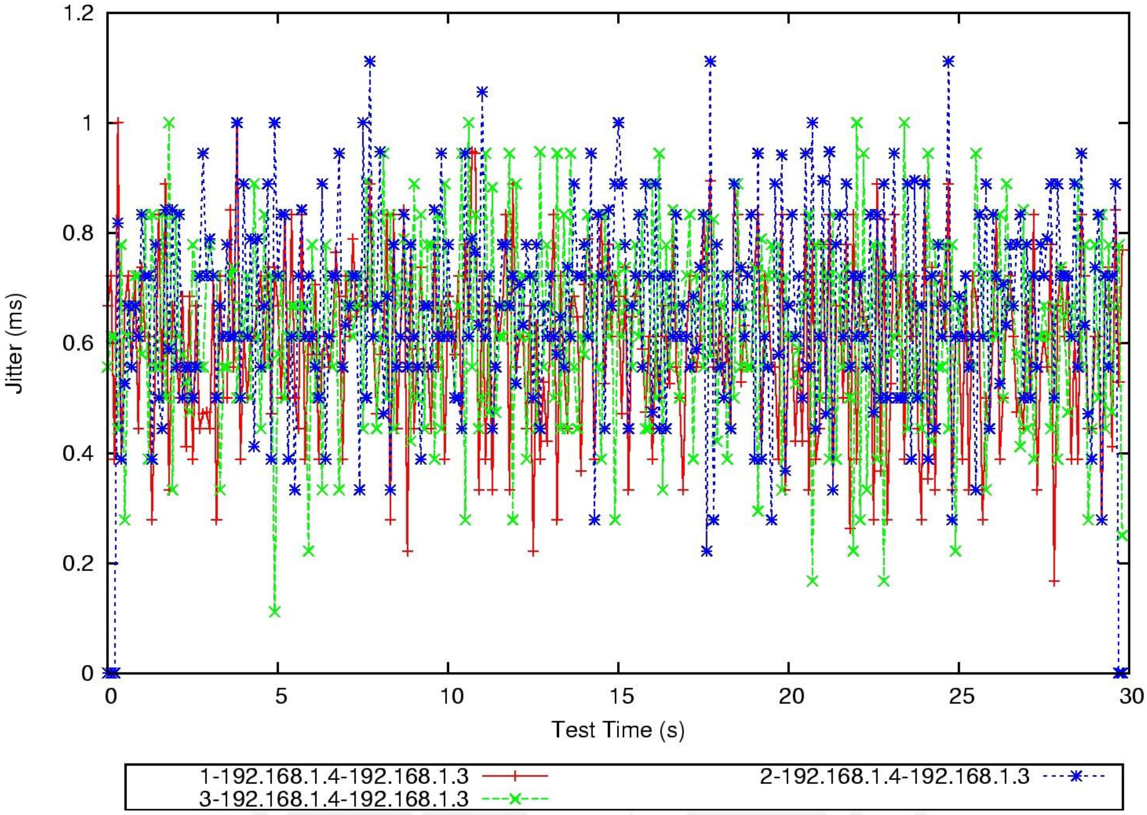

Jitter (ms)
Test Time (s)
2-192.168.1.7-192.168.1.3
1-192.168.1.7-192.168.1.3

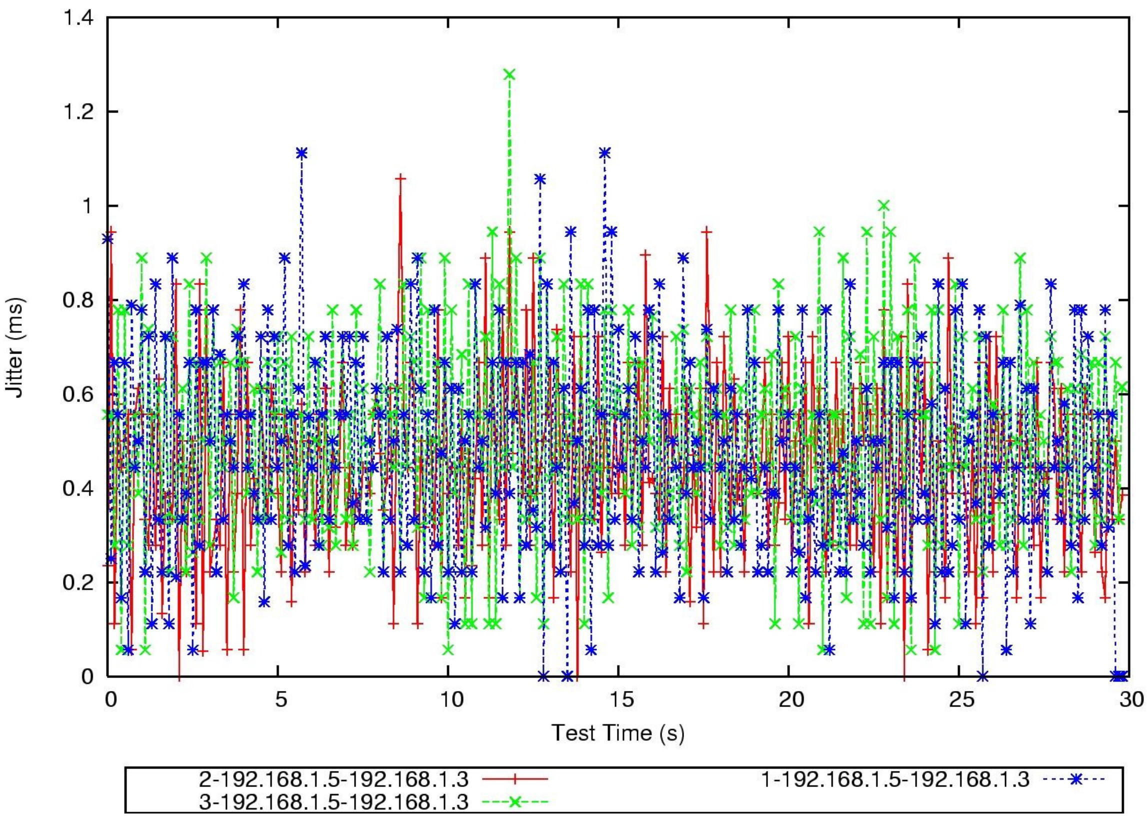
C. RESULTADOS PARA TRES FLUJOS DE SIMULACIÓN DE VIDEO POR MÁQUINA

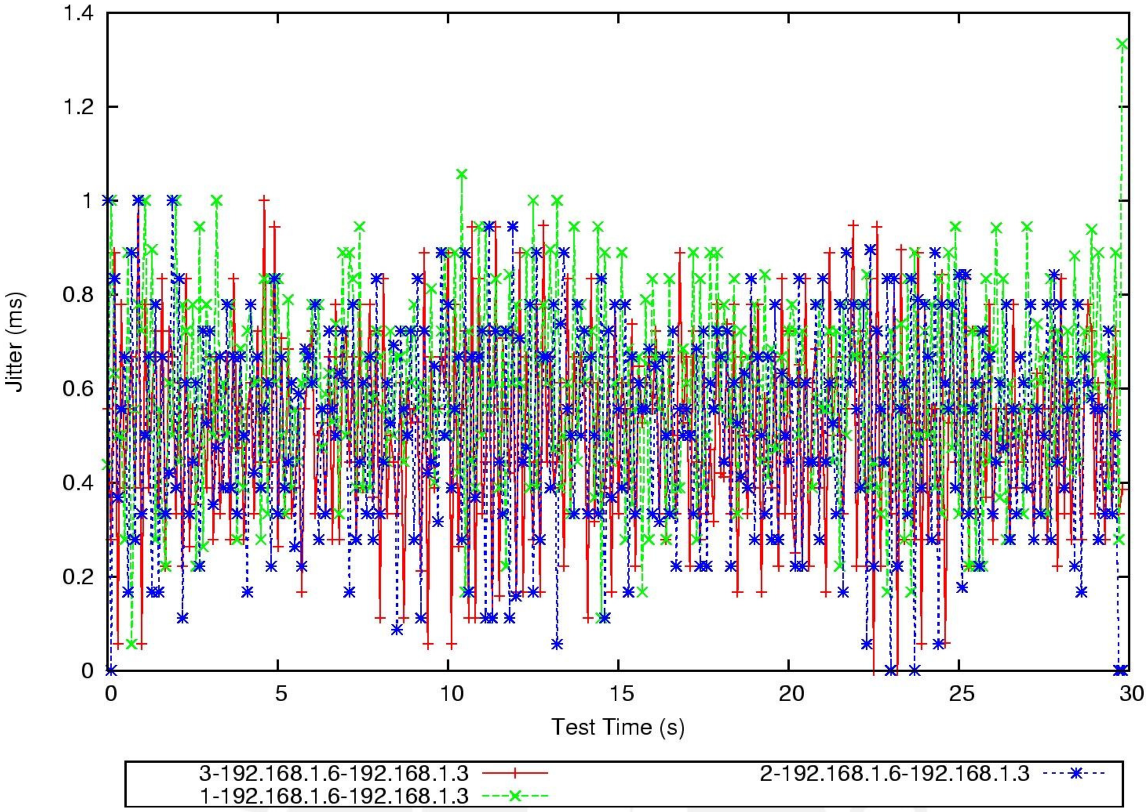
El tercer paso para las pruebas es aumentar en uno el flujo de cada computador, esto dará un total de 15 flujos de video MPEG4, con un total de tráfico de red de casi 30 Mbps. Como se puede apreciar en el gráfico, vemos que las características del jitter empiezan a cambiar.

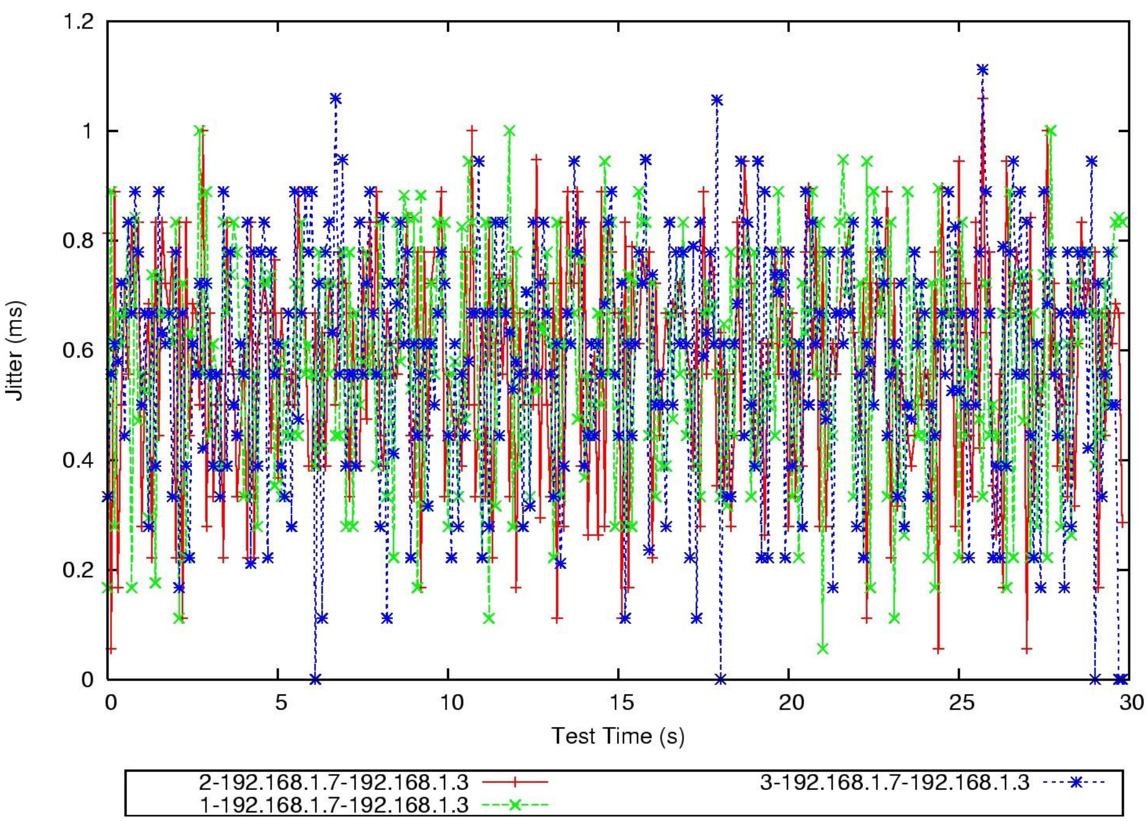
Se aprecia notoriamente algunos picos de *jitter* en solo uno de los computadores que envían tráfico, mientras que en el resto se puede apreciar un comportamiento similar a las anteriores pruebas. No se puede deducir nada concreto en cuanto al QoS de la red, ya que no se aprecia un *jitter* cambiante en todos los casos. Se debe aclarar que los picos en *jitter* constantes ocasionan distorsión en la QoS de los servicios en tiempo real, que en este caso es el envío de video. Para el caso del computador con IP 192.168.1.12, vemos que el jitter se da por instantes, y no es tan constante, además que los picos no llegan a superar los 2 ms. Un *jitter* que ocasiona distorsión en el servicio de video supera como mínimo los 4 ms, dependiendo de la capacidad del encoder/decoder del sistema.




Jitter (ms)
Test Time (s)
1-192.168.1.4-192.168.1.3
2-192.168.1.4-192.168.1.3
3-192.168.1.4-192.168.1.3


Jitter (ms)
Test Time (s)
2-192.168.1.5-192.168.1.3
1-192.168.1.5-192.168.1.3
3-192.168.1.5-192.168.1.3

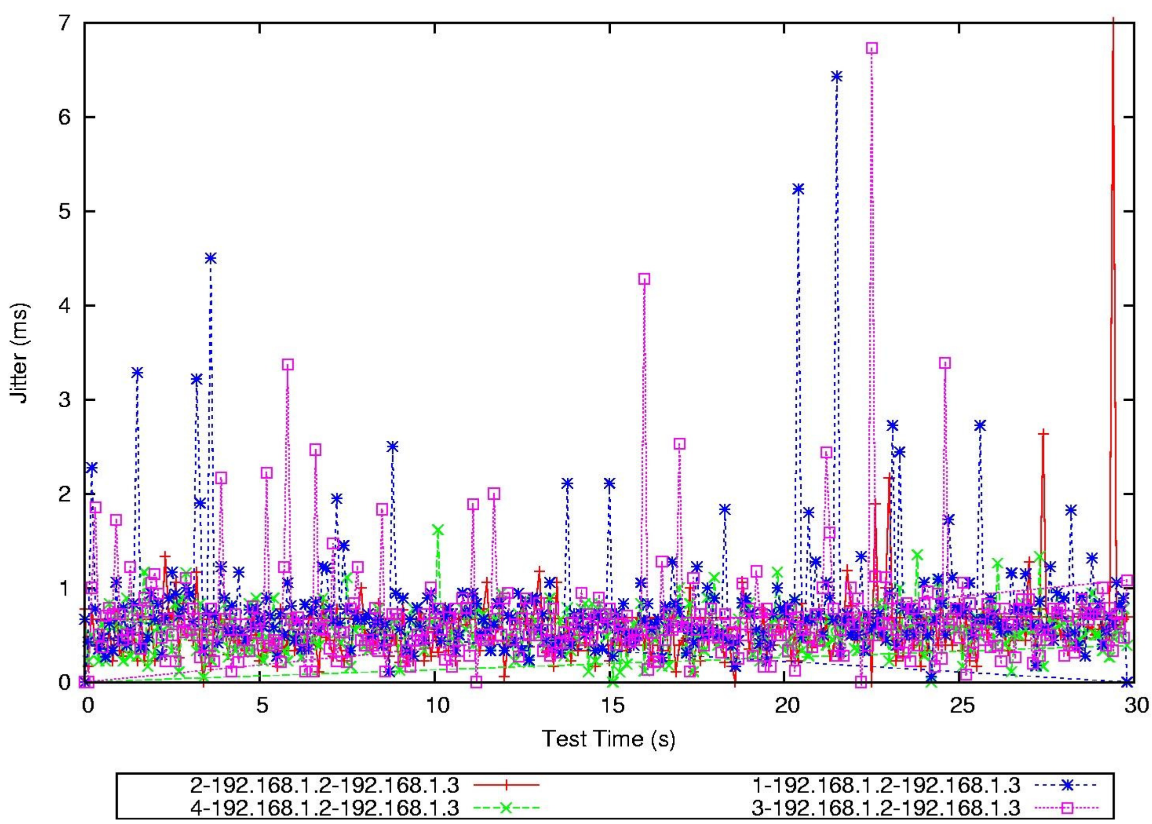

1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jitter (ms)
0
5
10
15
20
25
30
Test Time (s)
3-192.168.1.6-192.168.1.3
1-192.168.1.6-192.168.1.3
2-192.168.1.6-192.168.1.3

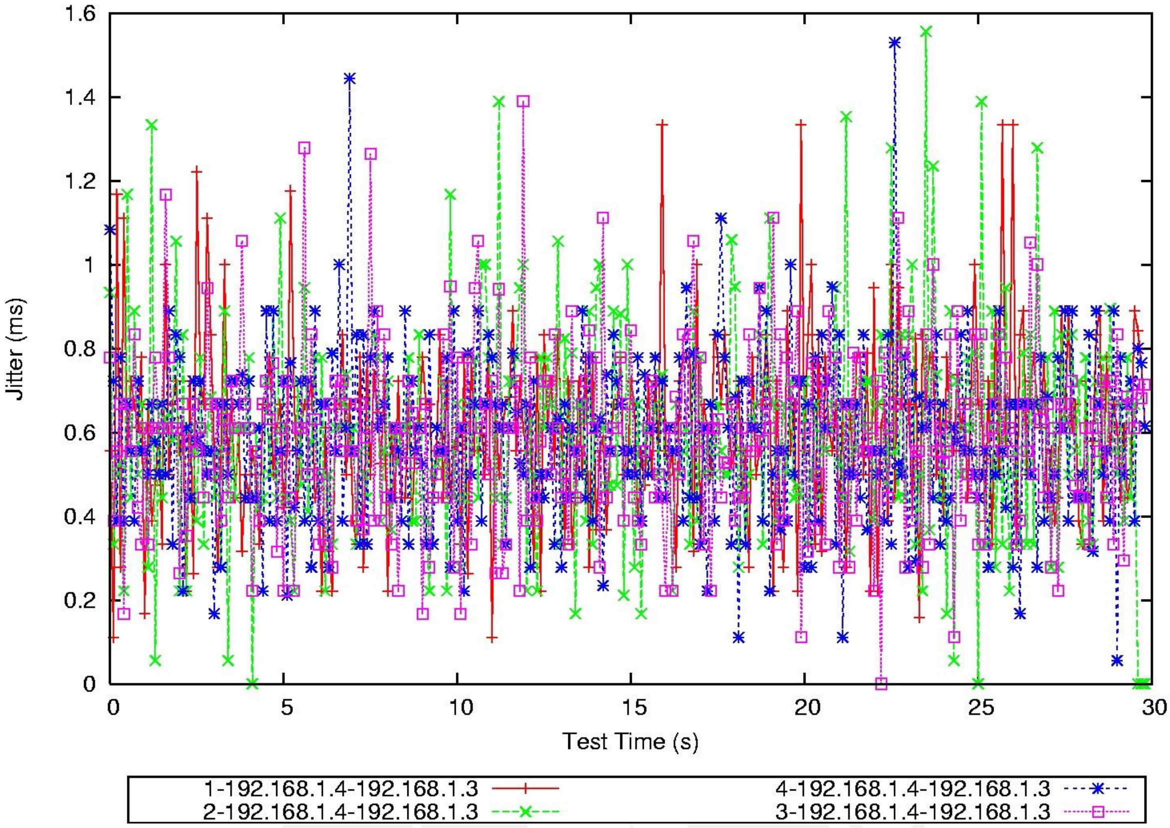

1.2
1
0.8
0.6
0.4
0.2
0
Jitter (ms)
0
5
10
15
20
25
30
Test Time (s)
2-192.168.1.7-192.168.1.3
1-192.168.1.7-192.168.1.3
3-192.168.1.7-192.168.1.3

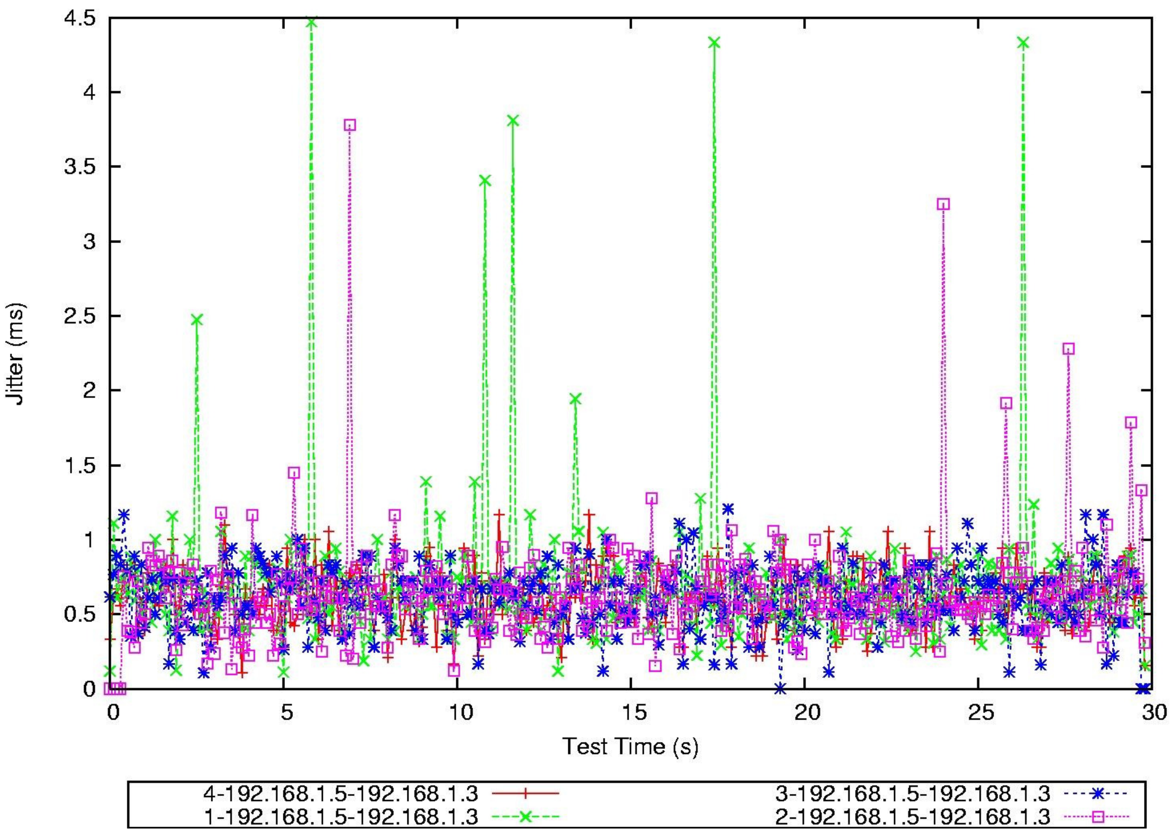
D. **RESULTADOS PARA CUATRO FLUJOS DE SIMULACIÓN DE VIDEO POR MÁQUINA**

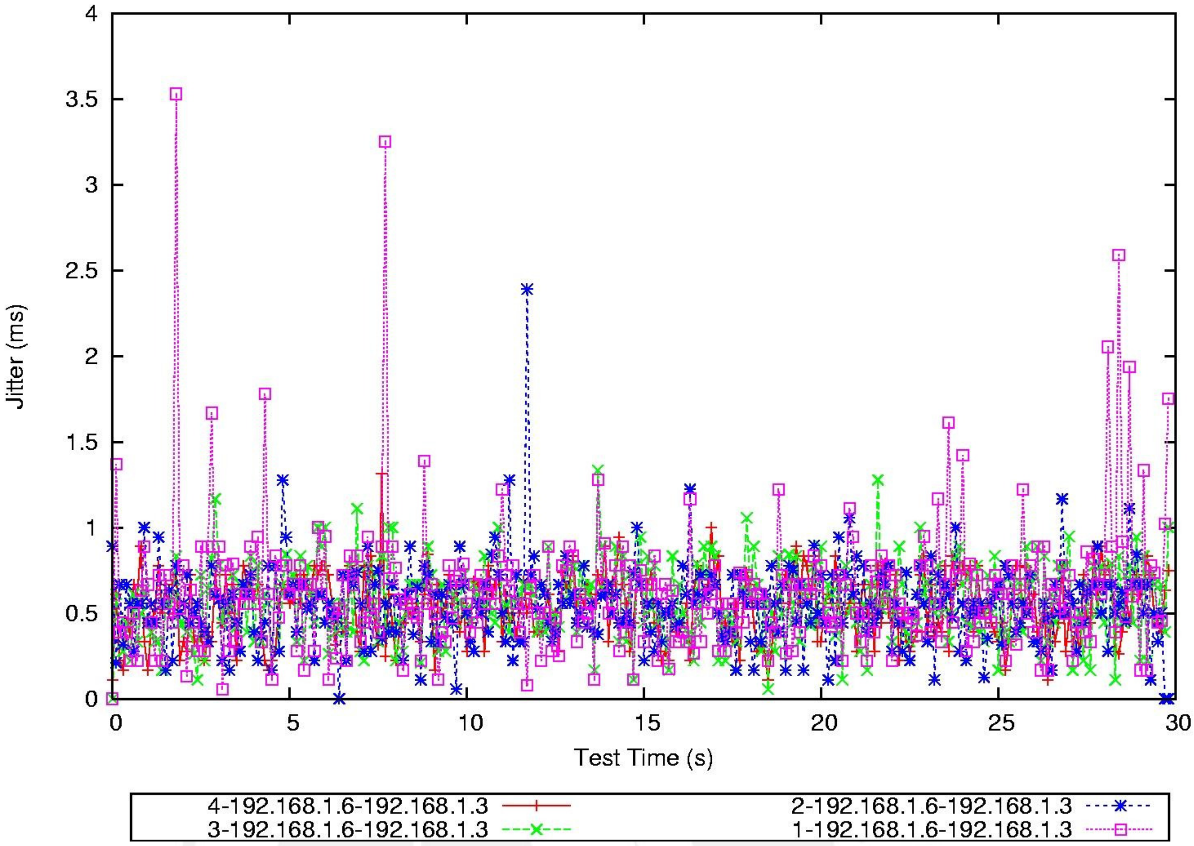
Siguiendo con las pruebas de tráfico, se ha aumentado en este caso hasta en 40 Mbps. Como se puede apreciar en los resultados, vemos que algunos de los computadores experimentan picos en el jitter bastante altos. Debido a que en algunos de ellos se dan por instantes, esto puede ser imperceptible para el servicio de video, pero si se da de manera constante, tal como se puede apreciar en el primer gráfico, correspondiente al computador con IP 192.168.1.2, puede afectar en gran medida el QoS del servicio.

Se puede deducir que se ha llegado al límite en el que una red en topología cascada puede ofrecer un QoS aceptable. Pero como se dijo anteriormente, esto depende de las características del sistema encoder/decoder. Si el sistema es suficientemente bueno, puede llegar a manejar bien el *jitter* que se presenta con esta cantidad de tráfico. Si el sistema de video que se pretende implementar debe tener un tráfico de estas características, y no llegase a obtener un buen Qos, se puede pensar en migrar la capacidad de los enlaces entre *switches*, esto es enlaces *Gigabit Ethernet*.

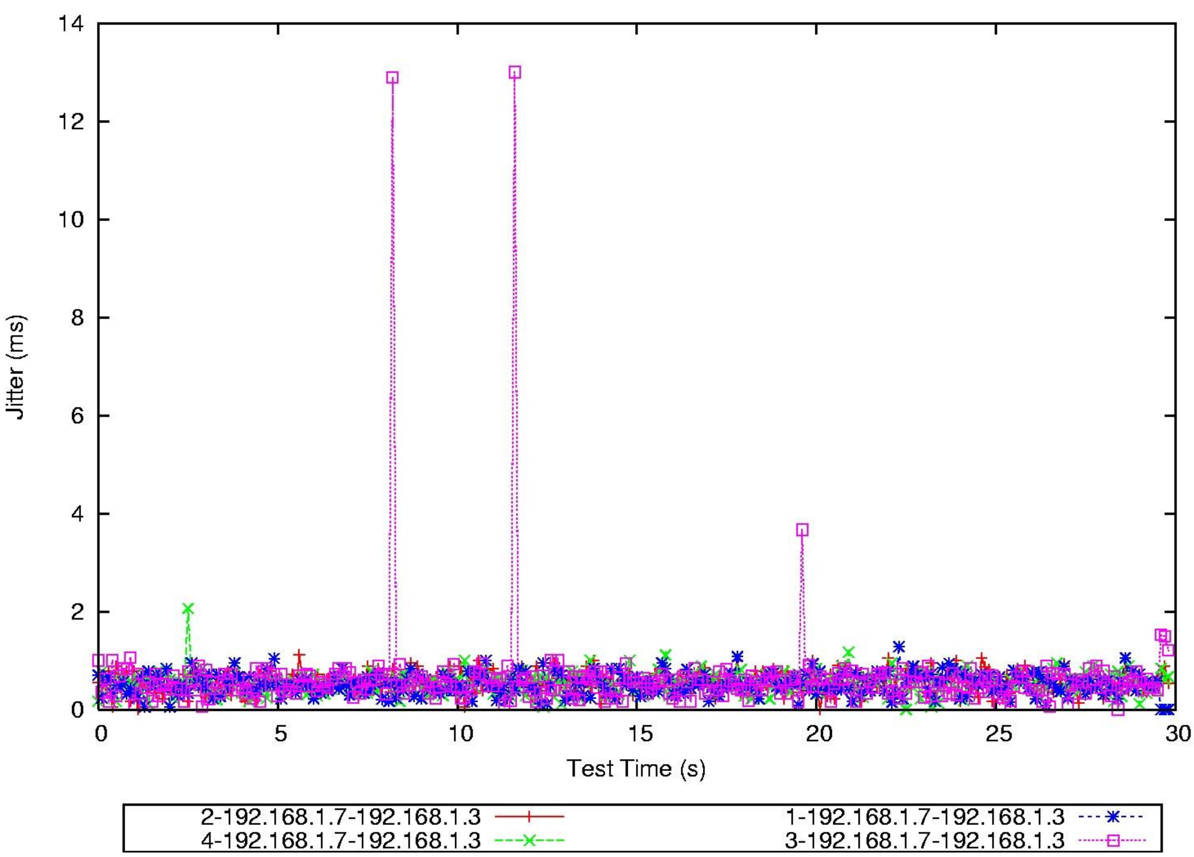



Jitter (ms)
Test Time (s)
1-192.168.1.4-192.168.1.3
2-192.168.1.4-192.168.1.3
4-192.168.1.4-192.168.1.3
3-192.168.1.4-192.168.1.3


Jitter (ms)
Test Time (s)
4-192.168.1.5-192.168.1.3
1-192.168.1.5-192.168.1.3
3-192.168.1.5-192.168.1.3
2-192.168.1.5-192.168.1.3



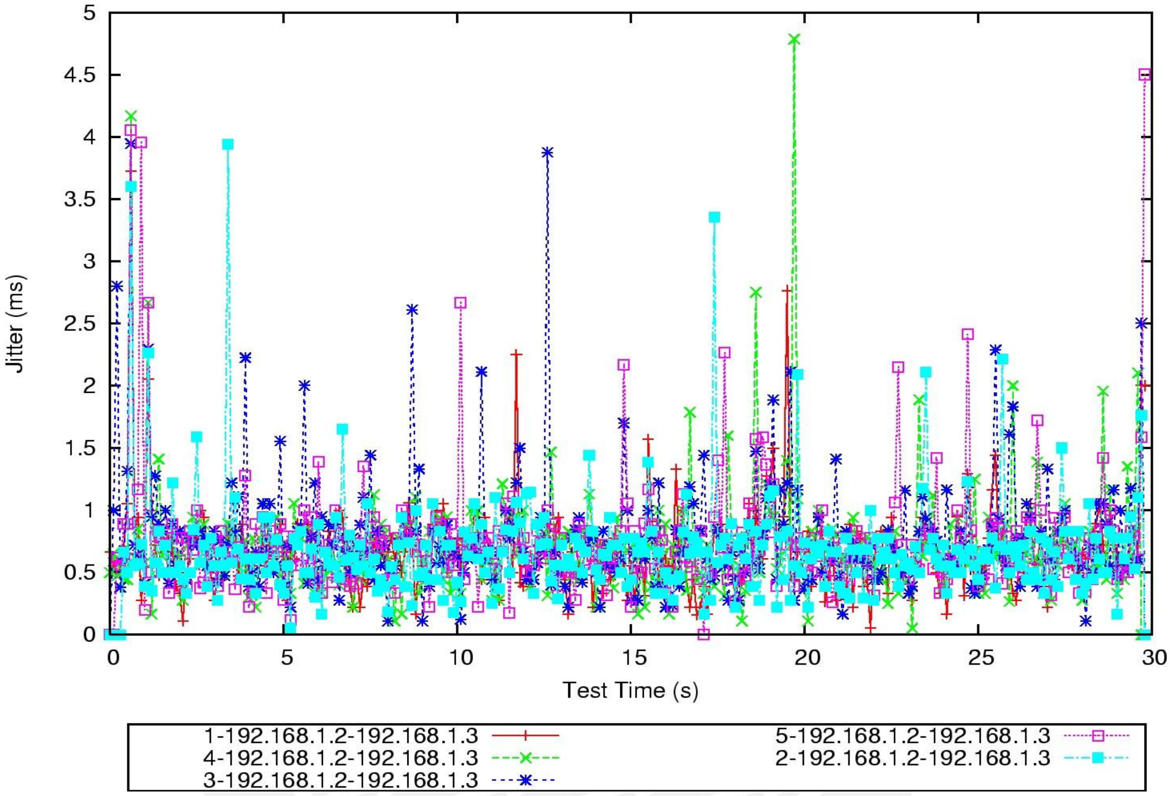
Jitter (ms)
Test Time (s)
4-192.168.1.6-192.168.1.3
3-192.168.1.6-192.168.1.3
2-192.168.1.6-192.168.1.3
1-192.168.1.6-192.168.1.3

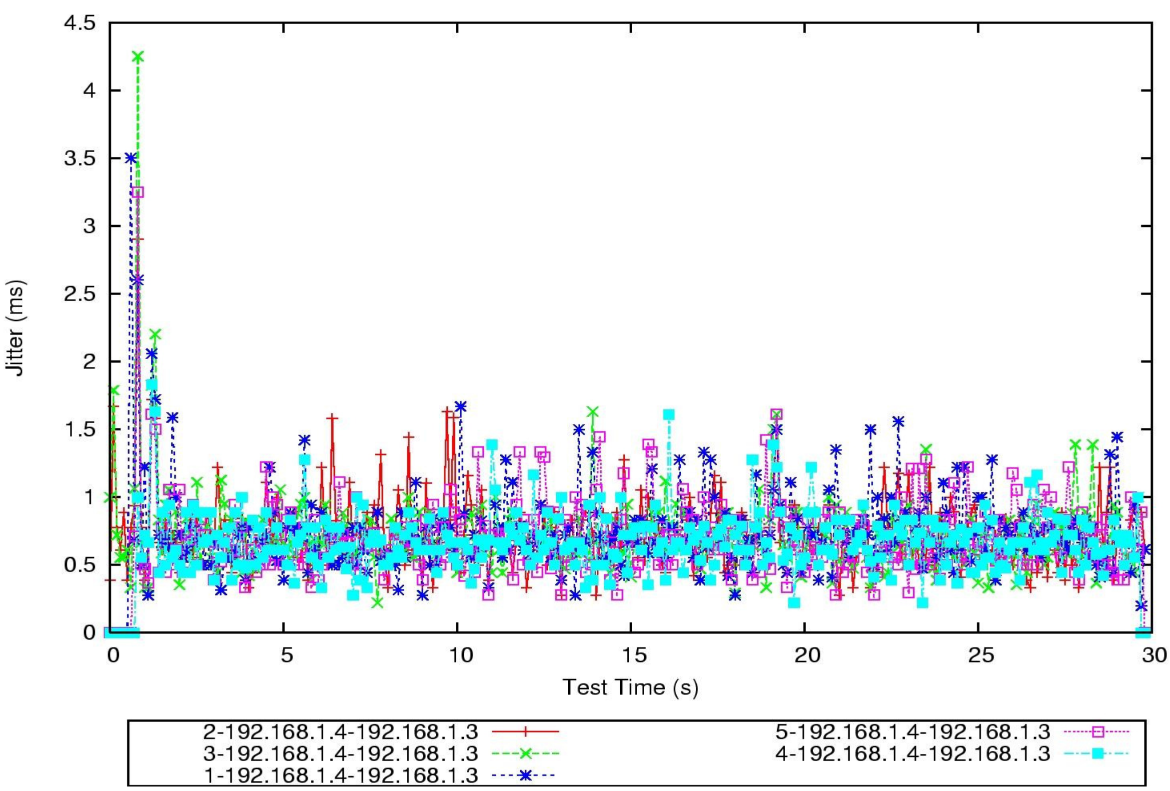


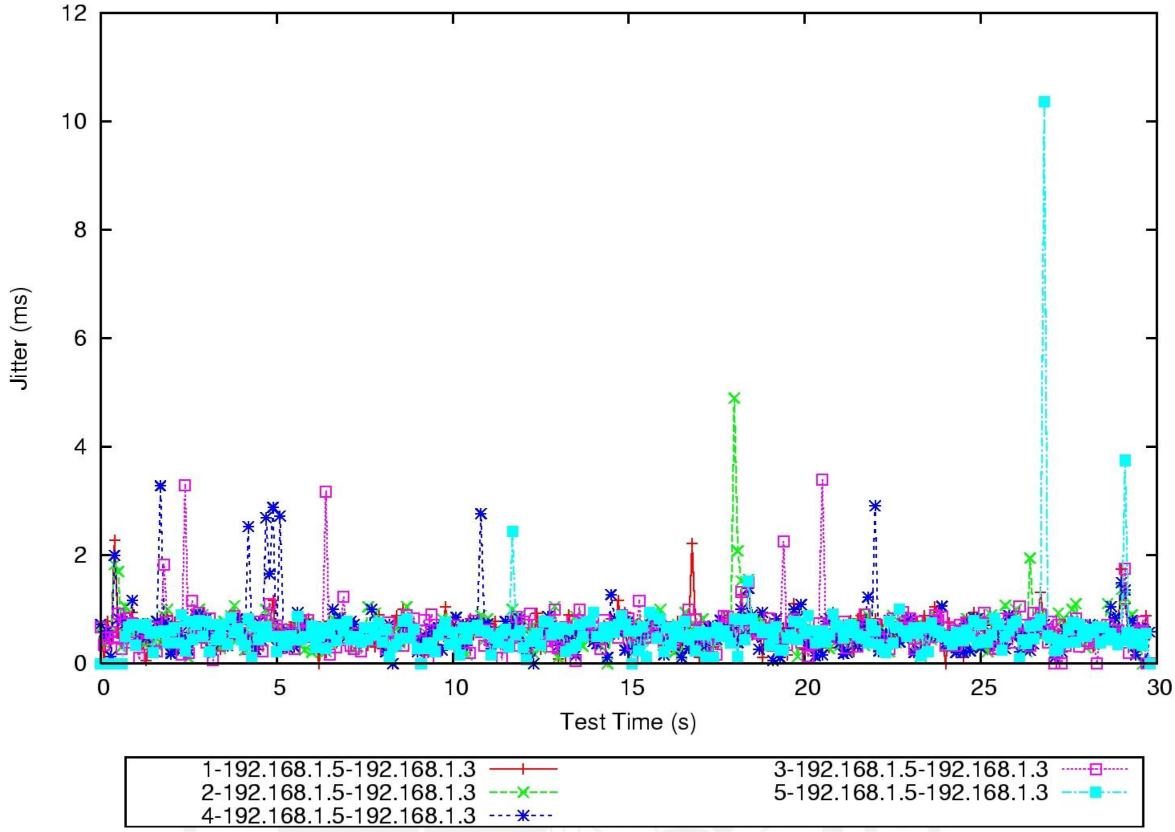
Jitter (ms)
Test Time (s)
2-192.168.1.7-192.168.1.3
4-192.168.1.7-192.168.1.3
1-192.168.1.7-192.168.1.3
3-192.168.1.7-192.168.1.3

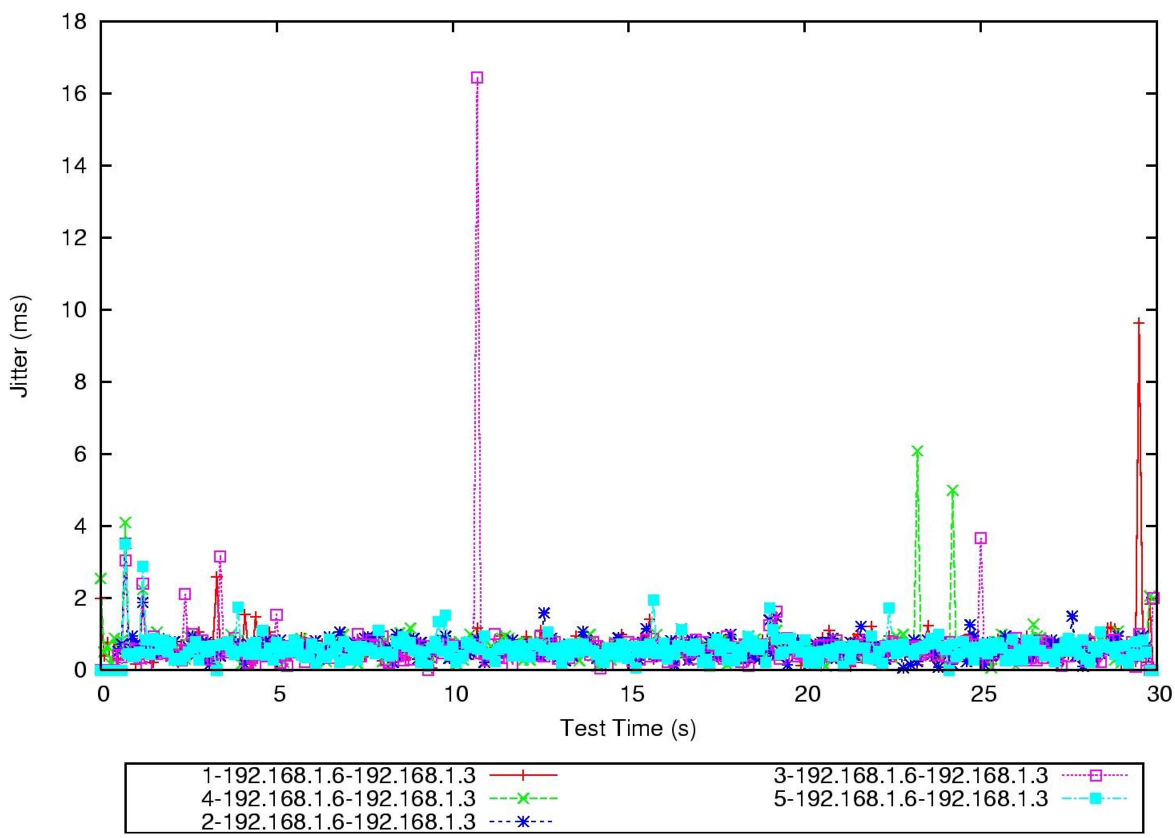
E. <u>RESULTADOS PARA CINCO FLUJOS DE SIMULACIÓN DE VIDEO POR MÁQUINA</u>

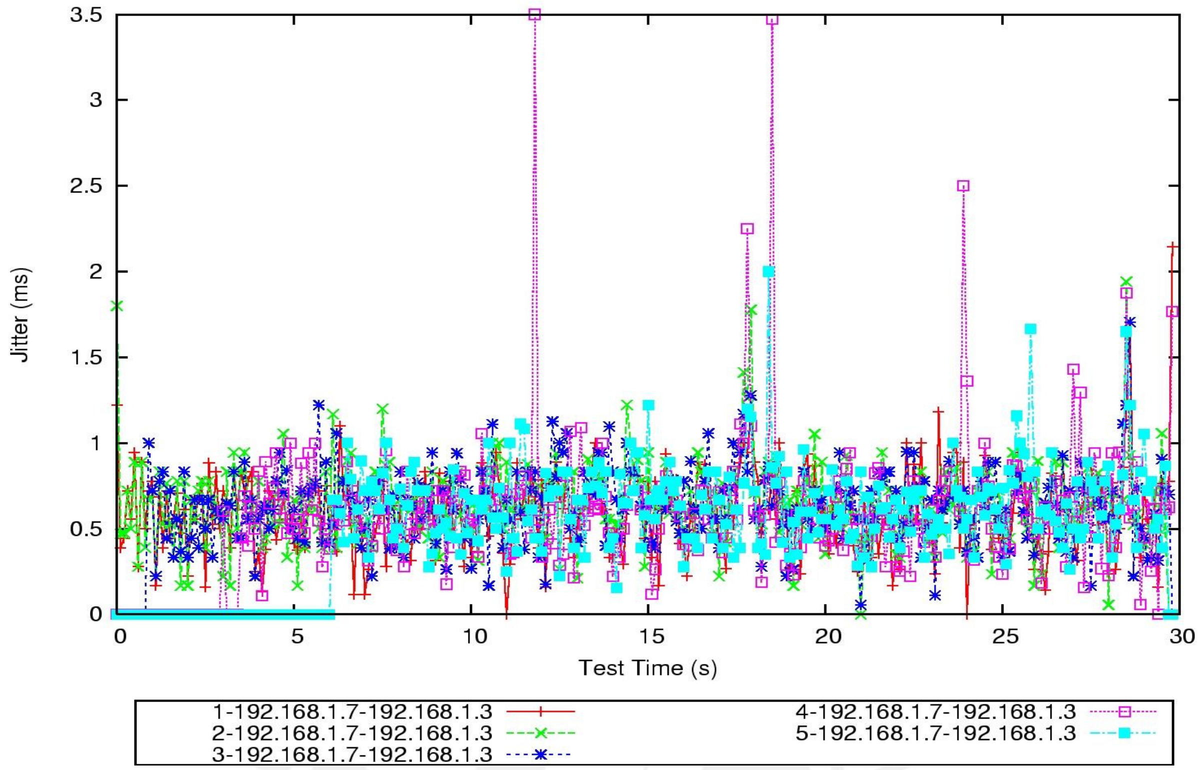
En este caso se llega a un tráfico de 50 Mbps, lo cual no es recomendable para ofrecer un buen QoS, ya que se presenta picos de *jitter* bastante altos.





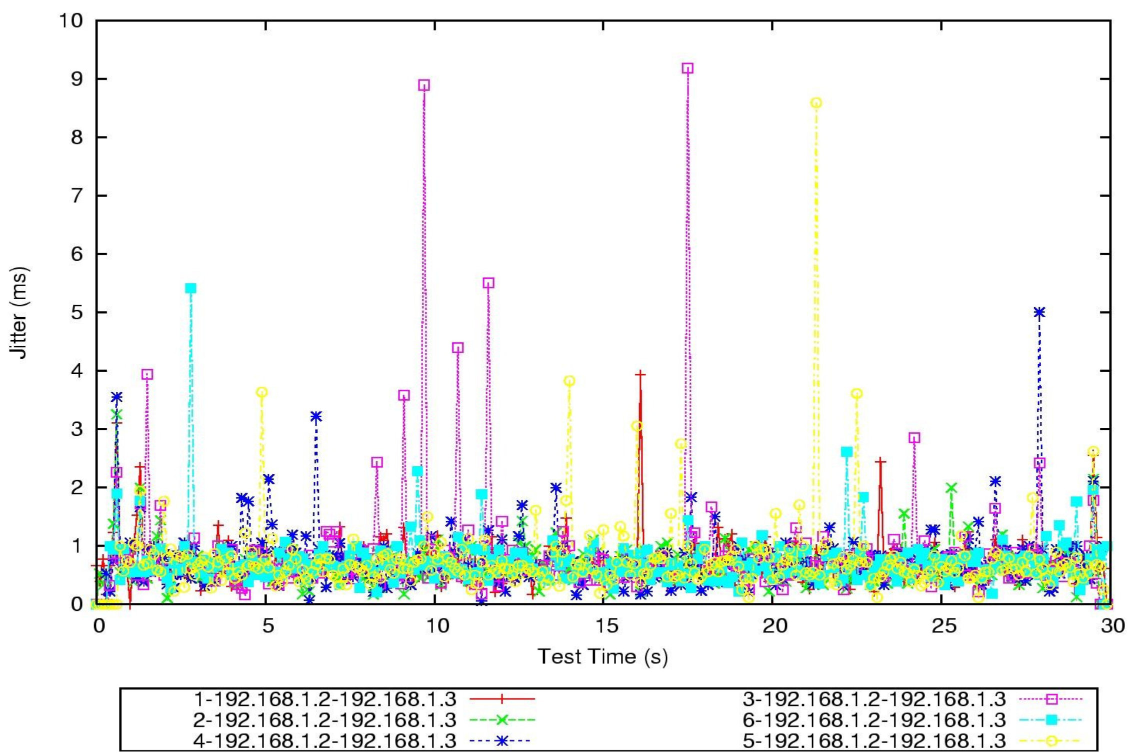

Jitter (ms)
Test Time (s)
1-192.168.1.5-192.168.1.3
2-192.168.1.5-192.168.1.3
4-192.168.1.5-192.168.1.3
3-192.168.1.5-192.168.1.3
5-192.168.1.5-192.168.1.3

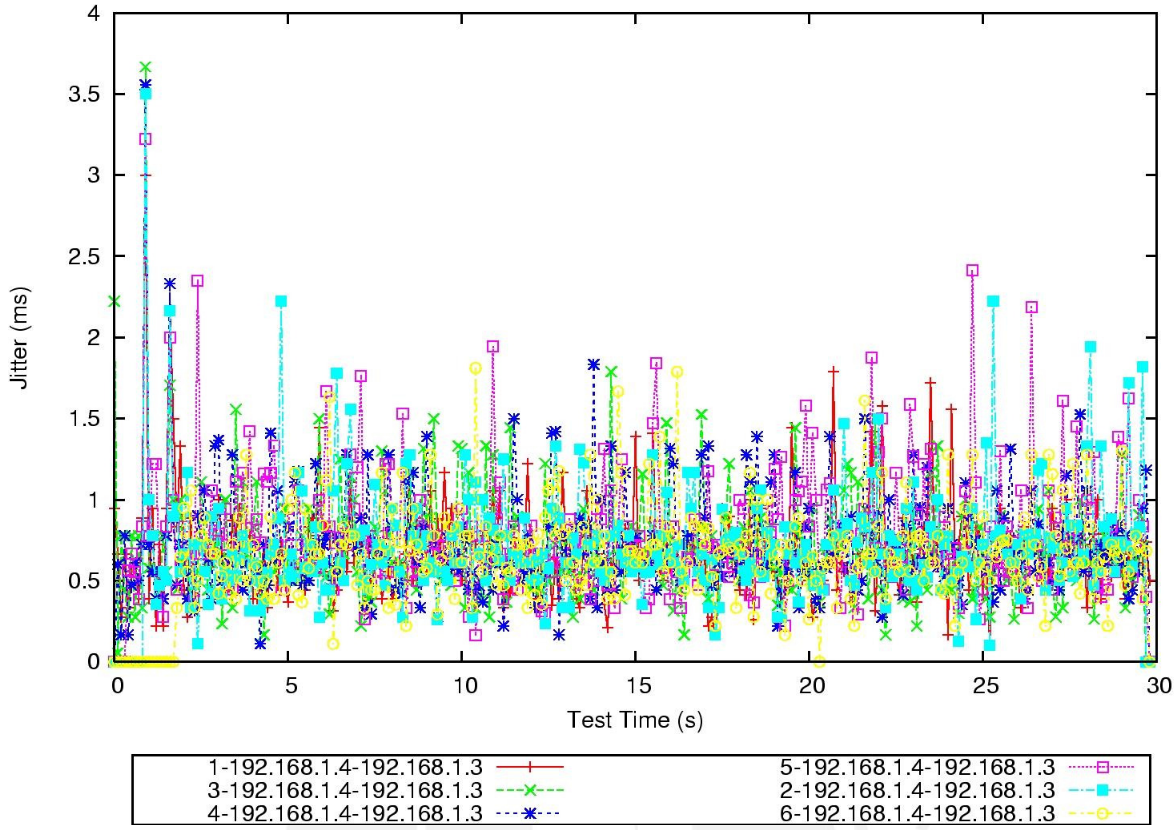

Jitter (ms)
Test Time (s)
1-192.168.1.6-192.168.1.3
4-192.168.1.6-192.168.1.3
2-192.168.1.6-192.168.1.3
3-192.168.1.6-192.168.1.3
5-192.168.1.6-192.168.1.3

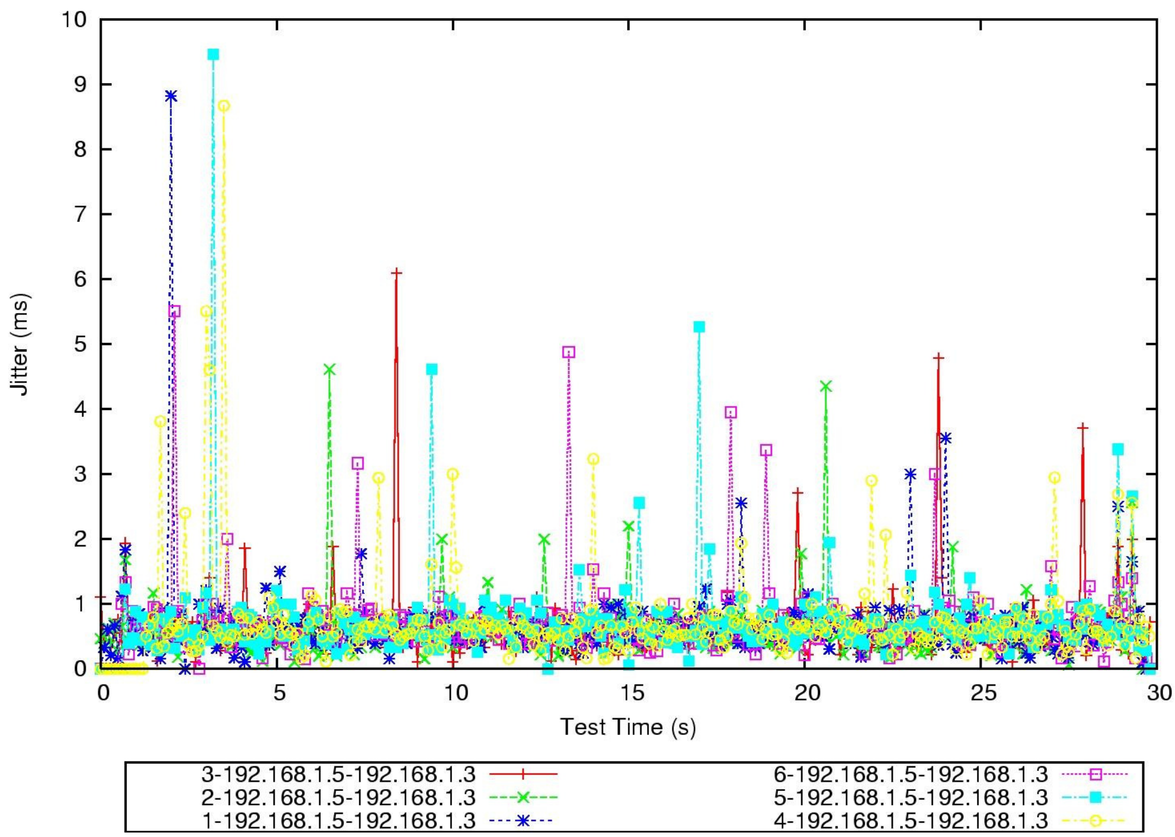


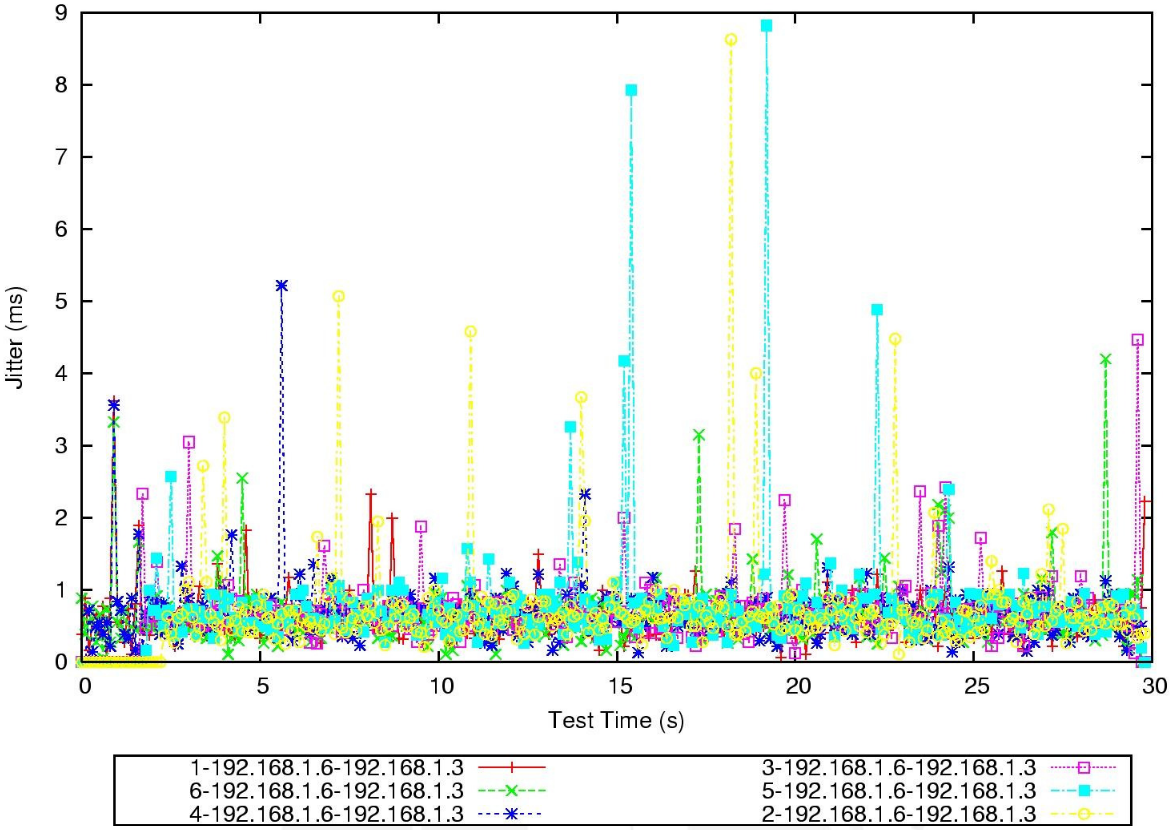
F. RESULTADOS PARA SEIS FLUJOS DE SIMULACIÓN DE VIDEO POR MÁQUINA

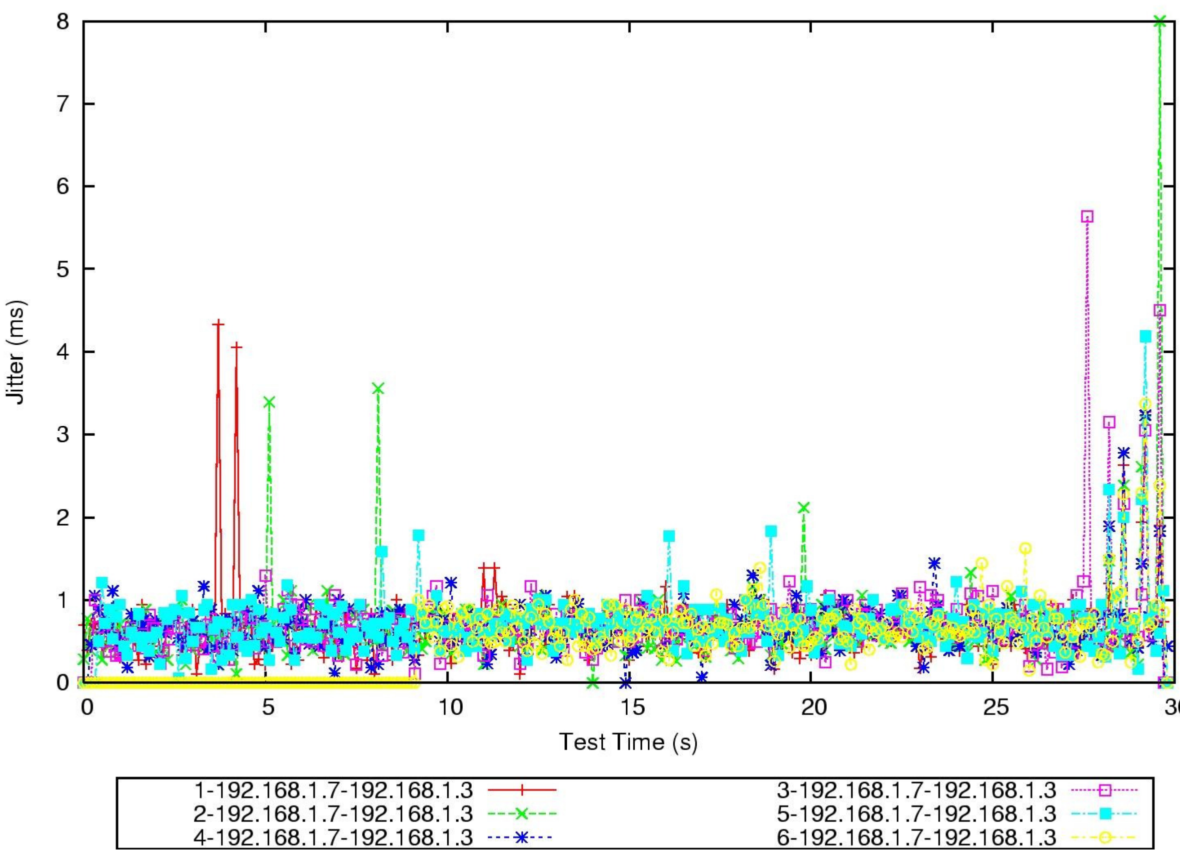
En este caso, se llega hasta 60 Mbps, finalizando estas pruebas debido a que los errores son similares al anterior, esto es picos de *jitter* altos.




Jitter (ms)
Test Time (s)
1-192.168.1.4-192.168.1.3
3-192.168.1.4-192.168.1.3
4-192.168.1.4-192.168.1.3
5-192.168.1.4-192.168.1.3
2-192.168.1.4-192.168.1.3
6-192.168.1.4-192.168.1.3


Jitter (ms)
Test Time (s)
3-192.168.1.5-192.168.1.3
2-192.168.1.5-192.168.1.3
1-192.168.1.5-192.168.1.3
6-192.168.1.5-192.168.1.3
5-192.168.1.5-192.168.1.3
4-192.168.1.5-192.168.1.3


Jitter (ms)
Test Time (s)
1-192.168.1.6-192.168.1.3
6-192.168.1.6-192.168.1.3
4-192.168.1.6-192.168.1.3
3-192.168.1.6-192.168.1.3
5-192.168.1.6-192.168.1.3
2-192.168.1.6-192.168.1.3


Jitter (ms)
Test Time (s)
1-192.168.1.7-192.168.1.3
2-192.168.1.7-192.168.1.3
4-192.168.1.7-192.168.1.3
3-192.168.1.7-192.168.1.3
5-192.168.1.7-192.168.1.3
6-192.168.1.7-192.168.1.3

Data Sheet

Supervisor Engine II-Plus-TS for the Cisco Catalyst 4503

Enterprise-Class Security and Reliability for the Medium-Sized Business

OVERVIEW

Exclusive to the Cisco® Catalyst® 4503 Switch chassis, the Catalyst 4500 Series Supervisor Engine II-Plus-TS (Figure 1) is a 64 Gbps, 48-million packets per second (Mpps) Layer 2 through 4 switching engine with 12-ports of wire-speed 10/100/1000 802.3af Power over Ethernet (PoE) and 8 wire-speed Small Form-Factor Pluggable (SFP) ports directly on the supervisor faceplate. These additional ports scale the maximum density of the Catalyst 4503 to 116 ports when deployed with a Catalyst 4500 Series Supervisor Engine II-Plus-TS. The addition of this new supervisor engine allows the Catalyst 4503 to deliver scalability, innovative security, integrated reliability, and flexibility that is affordable and easy to use for the medium-sized business.

Optimized for small offices, the Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS (Figure 2) provides a highly flexible and scalable deployment alternative to medium-sized businesses for end-user and server connectivity.

Figure 1. Cisco Catalyst 4503 Switch with Catalyst 4500 Series Supervisor Engine II-Plus-TS and Two Line Cards

Figure 2. The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS

INNOVATIVE SECURITY DELIVERED AT WIRE SPEED FOR SELF-DEFENDING NETWORKS

The Cisco Catalyst 4500 Series offers a rich set of industry-leading, integrated security features to proactively lock down your critical network infrastructure. It reduces network security risks with a rich set of Network Admission Control (NAC) capabilities and 802.1x-based user authentication, authorization, and accounting (AAA). The security policy enforcement is uncompromised with the wire-rate, dedicated access control lists (ACLs) to fend off ever-increasing virus and security attacks. The Cisco Catalyst 4500 Series offers powerful, easy-to-use tools to effectively prevent untraceable man-in-the-middle attacks, control plane resource exhaustion, IP spoofing, and flooding attacks, without any change to the end-user or host configurations. Secure remote access, file transfers, and network management are accomplished with the Secure Shell (SSH Version 1 and Version 2) Protocol, Secure Copy Protocol (SCP) and Simple Network Management Protocol (SNMP) Version 3, respectively.

Network Admission Control (NAC) is a foundational component of the Cisco Self-Defending Network strategy, improving the network's ability to automatically identify, prevent, and respond to security threats. NAC enables Cisco Catalyst switches to collaborate with third-party solutions for security-policy compliance and enforcement before a host is permitted to access the network.

NAC performs posture validation at the Layer 2 network edge for hosts with or without 802.1x enabled. Vulnerable and noncompliant hosts can be isolated, given reduced network access, or directed to remediation servers based on organizational policy. By helping ensure that every host complies with security policy, organizations can significantly reduce the damage caused by infected hosts. NAC is available through standard software upgrades or Cisco SMARTnet® contracts on Cisco Catalyst switches.

INTEGRATED RELIABILITY AND SERVICEABILITY

The Cisco Catalyst 4503 minimizes network downtime with 1+1 redundant hot-swappable power supplies, a hot-swappable fan tray with redundant fans, and hot-swappable line cards. The centralized switching architecture of the Catalyst 4500 Series helps ensure consistent backplane performance, even if a line card should fail.

The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS includes a dedicated 10/100 copper RJ-45 management port located on the supervisor faceplate for disaster recovery. If all the flash storage devices local to the switch are corrupted or completely full, the supervisor engine can download an image from a Trivial File Transfer Protocol (TFTP) server within seconds, minimizing network disruptions.

Nonstop Forwarding with Stateful Switchover (NSF/SSO) offers continuous packet forwarding during supervisor engine switchover. Information is fully synchronized between supervisors to allow the standby supervisor to immediately take over in subsecond time if the primary fails. NSF/SSO dramatically improves the network reliability and availability in a Layer 2 or Layer 3 environment. NSF/SSO is essential for business-critical applications such as voice over IP (VoIP). As a result, VoIP calls are not dropped.

SCALABLE PERFORMANCE

The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS extends enterprise-class switching capacity and predictable performance to the medium-sized business. A robust 64 Gbps backplane delivers 48 Mpps of forwarding throughput in hardware to support high-density gigabit to the desktop and server connections. Extensive Ternary Content Addressable Memory (TCAM) resources provide extensive capacity for concurrent wire-rate intelligent services and help enable new services quickly.

COMPREHENSIVE MANAGEMENT FOR EASE OF USE

The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS can be managed with Cisco Network Assistant, embedded CiscoView, or command-line interface (CLI). Cisco Network Assistant is a GUI-based management tool that offers not only single-box management, but management of a group of switches as a cluster at no additional charge. This Web-based application provides wizards that perform easy setup and configuration of one or more switches. Data, voice, video, and security wizards allow quick configuration of advanced enterprise features.

SmartPorts provide easy configuration of advanced features on a per-port basis. This facilitates a fast and easy setup, even for advanced features. SmartPort macros help ensure that all features are installed correctly and help prevent misconfiguration.

The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS offers several alternatives to access the switch for ease of management. The console port is used for connecting and configuring the supervisor engine through a management terminal. The supervisor engine also can accommodate optional Compact Flash cards (64 MB and 128 MB options) that can store multiple software images for ease of deployment across many switches.

Table 1 compares the features of the Cisco Catalyst 4500 Series supervisor engines 11-Plus and II-Plus-TS.

Table 1. Cisco Catalyst Supervisor Engines II-Plus and II-Plus-TS

Feature	Supervisor Engine II-Plus	Supervisor Engine II-Plus-TS
Platform Support	Cisco Catalyst 4006, 4503, 4506, and 4507R chassis	Cisco Catalyst 4503 chassis
Maximum Switching Capacity When Deployed in a Cisco Catalyst 4503 Switch	28 Gbps	64 Gbps
Maximum Throughput When Deployed in a Cisco Catalyst 4503	21 Mpps	48 Mpps
Supervisor Engine Faceplate Ports	2 gigabit interface converter (GBIC) slots	Twelve 10/100/1000 802.3af PoE ports, 8 SFP slots
Redundant Capable	Yes (Catalyst 4507R only)	No

CISCO CATALYST 4500 SERIES SUPERVISOR ENGINE II-PLUS-TS FEATURES AT A GLANCE

Layer 2 Features

- Layer 2 hardware forwarding at 48 Mpps
- Layer 2 switch ports and VLAN trunks
- IEEE 802. 1Q VLAN encapsulation
- Inter-Switch Link (ISL) VLAN encapsulation (excluding blocking ports on WS-X4418-GB)
- Dynamic Trunking Protocol (DTP)
- VLAN Trunking Protocol (VTP) and VTP domains
- Support for 2048 active VLANs and 4096 VLAN IDs per switch
- Spanning-Tree PortFast and PortFast guard
- Spanning-Tree UplinkFast and BackboneFast
- 802.1s
- 802.1w
- 802.3ad
- Spanning-Tree root guard
- Cisco Discovery Protocol
- Internet Group Management Protocol (IGMP) snooping versions 1, 2, and 3
- Cisco EtherChannel® technology, Fast EtherChannel, and Gigabit EtherChannel technology across line cards
- Port Aggregation Protocol (PAgP)
- Link Aggregation Protocol (LACP)
- Unidirectional link detection (UDLD) and aggressive UDLD
- Q-in-Q pass-through

- Jumbo Frames (up to 9216 bytes)
- Baby Giants (up to 1600 bytes)
- Unidirectional Ethernet
- Storm control (formally known as broadcast and multicast suppression)
- Forced 10/100 autonegotiation
- Web Content Communication Protocol Version 2 Layer 2 Redirect
- Private VLAN Promiscuous Trunk

Layer 3 Features

- Hardware-based IP Cisco Express Forwarding routing at 48 Mpps
- Static IP routing
- Routing Information Protocol (RIP) and RIP2
- Hot Standby Router Protocol (HSRP)
- IGMP versions 1, 2, 3
- IGMP filtering on access and trunk ports
- IP multicast routing protocols (Protocol Independent Multicast [PIM], Source Specific Multicast [S SM], Distance Vector Multicast Routing Protocol [DVMRP])
- Cisco Group Multicast Protocol server
- Full Internet Control Message Protocol (ICMP) support
- ICMP Router Discovery Protocol
- IPv6 software switched
- EIGRP stub
- Non-Stop Forwarding with Stateful Switchover (NSF/SSO)
- SSO-Aware Hot Standby Router Protocol
- Virtual Router Redundancy Protocol (VRRP)

Sophisticated Quality of Service and Traffic Management

- Per-port quality of service (QoS) configuration
- Support for four queues per port in hardware
- Strict priority queuing
- IP differentiated service code point (DSCP) and IP Precedence
- Classification and marking based on IP type of service (ToS) or DSCP
- Classification and marking based on full Layer 3 and Layer 4 headers (IP only)
- Input and output policing based on Layer 3 and Layer 4 headers (IP only)
- Support for 512 policers on ingress and 512 policers on egress configured as aggregate or individual
- Shaping and sharing output queue management
- Dynamic Buffer Limiting (DBL): congestion-avoidance feature
- No performance penalty for granular QoS functions
- Auto-QoS CLI for voice-over-IP (VoIP) deployment
- Per-port, per-vlan QoS

Predictable Performance

- 64 Gbps switching fabric
- Layer 2 hardware forwarding at 48 Mpps
- Layer 3 hardware-based IP Cisco Express Forwarding routing at 48 Mpps

- Layer 4 TCP/UDP hardware-based filtering at 48 Mpps
- No performance penalty with advanced Layer 3 and Layer 4 services enabled
- Software-based learning at a sustained rate of 500 hosts per second
- Support for 32K MAC addresses
- Support for 32K entries in routing table (shared between unicast and multicast)
- Bandwidth aggregation up to 16 Gbps through Cisco Gigabit EtherChannel technology
- Hardware-based multicast management
- Hardware-based ACLs, router ACLs (RACLs), VLAN ACLs

Comprehensive Management

- Manageable through Cisco Network Assistant
- Single console port and single IP address to manage all system features
- Software configuration management, including local and remote storage
- Manageable through CiscoWorks Windows network-management software on a per-port and per-switch basis, providing a common management interface for Cisco routers, switches, and hubs
- SNMPv1, v2, and v3 instrumentation, delivering comprehensive in-band management
- CLI-based management console to provide detailed out-of-band management
- Remote Monitoring (RMON) software agent to support four RMON groups (history, statistics, alarms, and events) for enhanced traffic management, monitoring, and analysis
- Support for all nine RMON groups through the use of a Cisco SwitchProbe® analyzer (Switched Port Analyzer [SPAN]) port, which permits traffic monitoring of a single port, a group of ports, or the entire switch from a single network analyzer or RMON probe
- Analysis support, including ingress port, egress port, and VLAN SPAN
- Layer 2 traceroute
- Remote SPAN (RSPAN)
- Cisco SmartPort macros
- SPAN ACL filtering
- SPAN CPU port
- Dynamic Host Configuration Protocol (DHCP) client autoconfiguration
- Enhanced SNMP MIB support
- HTTPS
- Time Domain Reflectometry (TDR)
- MAC Address Notification

Advanced Network Security

- TACACS+ and RADIUS, which help enable centralized control of the switch and restrict unauthorized users from altering the configuration
- Standard and extended ACLs on all ports
- 802. 1x user authentication (with VLAN assignment, voice VLAN, port security, guest VLAN, private guest VLAN, private VLAN, RADIUS Supplied Session Timeout extensions)
- 802.1x accounting
- 802. 1x authentication failure
- 802. 1x Private VLAN assignment
- 802. 1x Private Guest VLAN
- 802. 1x Radius-supplied time out
- NAC L2 802.1x
- NAC L2 IP

- Trusted boundary
- Router ACLs (RACLs) on all ports (no performance penalty)
- VLAN ACLs (VACLs)
- Port ACLs (PACLs)
- Private VLANs (PVLANs) on access and trunk ports
- DHCP snooping
- DHCP Option 82
- DHCP Option 82 insertion
- DHCP Option 82 Pass Through
- Port security
- Sticky port security
- SSHv1 and SSHv2
- VLAN Management Policy Server (VMPS) client
- Unicast MAC filtering
- Unicast port flood blocking
- Dynamic Address Resolution Protocol (ARP) inspection
- IP source guard
- Community Private VLANs
- Trunk Port Security
- 802.1x Inaccessible Authentication Bypass
- MAC Authentication Bypass
- Control Plane Policing
- 802.1x Unidirectional Controlled Port
- Voice VLAN Sticky Port Security
- Secure Copy Protocol (SCP)

Software Requirements

The minimum 12.2SG software versions are as follows:

- **Cisco Catalyst 4500 Series Supervisor Engine II-Plus:** Cisco IOS Software Release 12.2(25)SG or later

Hardware Requirements

- The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS can only be used with the Cisco Catalyst 4503 chassis
- PoE-enabled power supplies are required to support PoE on the twelve 10/100/1000 supervisor faceplate ports* and PoE-enabled line cards added to the Cisco Catalyst 4503

* Up to 160 Watts (W) maximum –48 volt DC PoE can be allocated to the 12 faceplate ports in any combination (up to 15.4W maximum on a single port). PoE can be enabled on the twelve 10/100/1000 faceplate ports with a 1000W or 1400W AC power supply; however, PoE-enabled line cards would require a PoE-enabled power supply.

TECHNICAL SPECIFICATIONS

Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS Performance and Switching Specifications

The supervisor engine includes the following:

- 64 Gbps nonblocking switch fabric
- 48 Mpps Layer 2 forwarding (hardware)
- 48 Mpps Layer 3 and Layer 4 forwarding, Cisco Express Forwarding-based (hardware)

- Layers 2 through 4 hardware-based switch engine (ASIC-based)
- Centralized design
- **Unicast and multicast routing entries:** 32,000
- **Layer 2 multicast addresses:** 16,384
- **MAC addresses:** 32,768
- **VLANs:** 2048 active VLANs
- Per-VLAN Spanning Tree (PVST+), and Per-VLAN Rapid Spanning Tree Protocol (PVRST)

Traffic and Congestion Management

The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS offers the following:

- **Number of queues:** four queues per port
- **Type of buffers:** dynamic

Switch Architecture Specifications

The switch architecture of the Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS is as follows:

- Store-and-forward switching, fast 1.4-microsecond latency
- Functionally transparent line-card architecture
- **Packet buffering:** dynamic, 16-MB shared memory
- **SDRAM:** 256 MB
- **Onboard Flash memory:** 32 MB
- **Startup configuration:** onboard Flash memory
- CPU 266 MHz

MANAGEMENT

The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS offers the following management features:

- CiscoWorks LAN Management Solution (LMS); includes CiscoWorks Resource Manager Essentials
- Cisco Network Assistant
- CiscoView
- BGP4-MIB.my
- BRIDGE-MIB.my* (RFC 1493)
- CISCO-BULK-FILE-MIB.my
- CISCO-CDP-MIB.my
- CISCO-CLASS-BASED-QOS-MIB.my
- CISCO-CONFIG-COPY-MIB.my
- CISCO-CONFIG-MAN-MIB.my
- CISCO-ENTITY-ASSET-MIB.my
- CISCO-ENTITY-EXT-MIB.my
- CISCO-ENTITY-FRU-CONTROL-MIB.my
- CISCO-ENTITY-SENSOR-MIB.my
- CISCO-ENTITY-VENDORTYPE-OID-MIB.my
- CISCO-ENVMON-MIB.my
- CISCO-FLASH-MIB.my
- CISCO-FTP-CLIENT-MIB.my

- CISCO-HSRP-MIB.my
- CISCO-IETF-IP-MIB.my
- CISCO-IETF-IP-FORWARD-MIB.my
- CISCO-IETF-ISIS-MIB.my
- CISCO-IF-EXTENSION-MIB.my
- CISCO-IGMP-FILTER-MIB.my
- CISCO-IMAGE-MIB.my
- CISCO-IPMROUTE-MIB.my
- CISCO-L2-TUNNEL-CONFIG-MIB.my
- CISCO-L2L3-INTERFACE-CONFIG-MIB.my
- CISCO-LAG-MIB.my
- CISCO-MEMORY-POOL-MIB.my
- CISCO-NDE-MIB.my
- CISCO-PAGP
- MIB.my
- CISCO-PAE-MIB.my
- CISCO-PING-MIB.my
- CISCO-PORT-SECURITY-MIB.my
- CISCO-PORT-STORM-CONTROL-MIB.my
- CISCO-PRIVATE-VLAN-MIB.my CISCO-PROCESS-MIB.my
- CISCO-PRODUCTS-MIB.my CISCO-RF-MIB.my
- CISCO-RMON-CONFIG-MIB.my CISCO-RTTMON-MIB.my
- CISCO-STP-EXTENSIONS-MIB.my CISCO-SYSLOG-MIB.my
- CISCO-VLAN-IFTABLE-RELATIONSHIP-MIB.my
- CISCO-VLAN-MEMBERSHIP-MIB.my CISCO-VTP-MIB.my
- DOT3-MAU-MIB.my (RFC 3636) ENTITY-MIB.my
- ETHERLIKE-MIB.my
- EXPRESSION-MIB.my
- HC-RMON-MIB.my
- IEEE8021-PAE-MIB.my
- IEEE8023-LAG-MIB.my (802.3ad)
- IF-MIB.my
- IGMP-MIB.my
- IPMROUTE-MIB.my
- NOVELL-IPX-MIB.my
- NOVELL-RIPSAP-MIB.my
- OLD-CISCO-TS-MIB.my
- PIM-MIB.my
- RFC1213-MIB.my (MIB-II)
- RFC1243-MIB.my (APPLETALK MIB)
- RFC1253-MIB.my (OSPF-MIB)
- RMON-MIB.my (RFC 1757)
- RMON2-MIB.my (RFC 2021)

- SMON-MIB.my (Internet-Draft)
- SNMP-FRAMEWORK-MIB.my (RFC 2571)
- SNMP-MPD-MIB.my (RFC 2572)
- SNMP-NOTIFICATION-MIB.my (RFC 2573)
- SNMP-TARGET-MIB.my (RFC 2573)
- SNMP-USM-MIB.my (RFC 2574)
- SNMP-VACM-MIB.my (RFC 2575)
- SNMPv2-MIB.my
- TCP-MIB.my
- UDP-MIB.my
- RIP SNMP MIB

INDUSTRY STANDARDS

The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS meets the following industry standards:

- **Ethernet:** IEEE 802.3, 10BASE-T
- **Fast Ethernet:** IEEE 802.3u, 100BASE-TX, 100BASE-FX
- **Gigabit Ethernet:** IEEE 802.3z, 802.3ab
- IEEE 802.3af Power over Ethernet (PoE)
- IEEE 802. 1D Spanning Tree Protocol
- IEEE 802.1w rapid reconfiguration of Spanning Tree Protocol
- IEEE 802. 1s multiple VLAN instances of Spanning Tree Protocol
- IEEE 802.3 ad Link Aggregation Control Protocol (LACP)
- IEEE 802. 1p class-of-service (CoS) prioritization
- IEEE 802.1Q VLAN
- IEEE 802. 1x user authentication
- 1000BASE-SX
- 1000BASE-LX/LH
- 1000BASE-ZX
- RMON I and II standards

SUPPORTED LINE CARDS AND MODULES

The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS supports the following:

- **WS-X4124-FX-MT**—Cisco Catalyst 4000 Series Fast Ethernet switching module, 24-port 100BASE-FX (MT-RJ)1
- **WS-X4148-FX-MT**—Cisco Catalyst 4500 Series Fast Ethernet switching module, 48-port 100BASE-FX multimode fiber (MMF) (MT-RJ)
- **WS-X4148-FE-LX-MT**—Cisco Catalyst 4500 Series Fast Ethernet switching module, 48-port 100BASE-LX10 single-mode fiber (SMF) (MT-RJ)
- **WS-X4148-FE-BD-LC**—Cisco Catalyst 4500 Series Fast Ethernet switching module, 48-port 100BASE-BX-D SMF (LC)
- **WS-X4124-RJ45**—Cisco Catalyst 4500 Series 10/100 module, 24-ports (RJ-45)
- **WS-X4148-RJ**—Cisco Catalyst 4500 Series 10/100 module, 48-ports (RJ-45)
- **WS-X4148-RJ21**—Cisco Catalyst 4500 Series 10/100 module, 48-port telco (4 x RJ-21)
- **WS-X4148-RJ45V**—Cisco Catalyst 4500 Series Cisco prestandard PoE 10/100, 48-ports (RJ-45)
- **WS-X4224-RJ45V**—Cisco Catalyst 4500 Series PoE 803.3af 10/100, 24-ports (RJ-45)
- **WS-X4248-RJ45V**—Cisco Catalyst 4500 Series PoE 802.3af 10/100, 48-ports (RJ45)

- **WS-X4232-GB-RJ**—Cisco Catalyst 4500 Series 32-port 10/100 (RJ-45), 2-Gigabit Ethernet (GBIC) module
- **WS-X4232-RJ-XX**—Cisco Catalyst 4500 Series 32-port 10/100 (RJ-45), plus modular uplink slot
- **WS-X4302-GB**—Cisco Catalyst 4500 Series 2-port 1000BASE-X (GBIC)
- **WS-X4306-GB**—Cisco Catalyst 4500 Series Gigabit Ethernet module, 6-ports (GBIC) and 2-port 1000BASE-X (GBIC)
- **WS-X4506-GB-T**—Cisco Catalyst 4500 Series Gigabit Ethernet module, 6-ports 10/100/1000 802.3af PoE or 1000BASE-X (SFP)
- **WS-X4418-GB**—Cisco Catalyst 4500 Series Gigabit Ethernet module, server switching 18-ports (GBIC)
- **WS-X4448-GB-LX**—Cisco Catalyst 4500 Series 48-port 1000BASE-LX (SFP)
- **WS-X4448-GB-SFP**—Catalyst 4500 Gigabit Ethernet Module, 48-Ports 1000X (Optional SFPs)
- **WS-X4424-GB-RJ45**—Cisco Catalyst 4500 Series 24-port 10/100/1000 module (RJ-45)
- **WS-X4448-GB-RJ45**—Cisco Catalyst 4500 Series 48-port 10/100/1000 module (RJ-45)
- **WS-X4548-GB-RJ45**—Cisco Catalyst 4500 Series enhanced 48-port 10/100/1000 module (RJ-45)
- **WS-X4524-GB-RJ45**—Cisco Catalyst 4500 Series PoE 802.3af 10/100/1000, 24-ports (RJ-45)
- **WS-X4548-GB-RJ45V**—Cisco Catalyst 4500 Series PoE 802.3af 10/100/1000, 48-ports (RJ45)
- **WS-U4504-FX-MT**—Cisco Catalyst 4500 Series Fast Ethernet uplink daughter card, 4-port 100BASE-FX (MT-RJ)
- **WS-X4248-FE-SFP**—Cisco Catalyst 4500 Fast Ethernet Switching Module, 48-port 100BASE-X (Optional SFP optics)
- **WS-G5483**—Cisco 1000BASE-T GBIC
- **WS-G5484**—Cisco 1000BASE-SX short-wavelength GBIC (multimode only)
- **WS-G5486**—Cisco 1000BASE-LX/LH long-haul GBIC (single mode or multimode)
- **WS-G5487**—Cisco 1000BASE-ZX extended-reach GBIC (single mode)
- **GLC-T**—1000BASE-T SFP
- **GLC-SC-MM**—Gigabit Ethernet SFP, LC connector, SX transceiver
- **GLC-LH-SM**—Gigabit Ethernet SFP, LC connector, LX/LH transceiver
- **GLC-ZX-SM**—1000BASE-ZX SFP
- **GLC-FE-100FX**—FE SFP, LC connector FX transceiver, 2 kilometers
- **GLC-FE-100LX**—FE SFP, LC connector LX10 transceiver, 10 kilometers
- **GLC-FE-100BX-D**—FE SFP, LC connector BX-D transceiver, 10 kilometers
- **GLC-FE-100BX-U**—FE SFP, LC connector BX-U transceiver, 10 kilometers
- Cisco coarse wavelength-division multiplexing (CWDM) SFP solution

Indicator and Port Specifications

The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS has the following indicator and port specifications:

- **System status:** green (operational)/red (faulty)
- **Switch utilization load:** 1- to 100-percent aggregate switching usage
- **Console:** RJ-45 female
- Reset (switch recessed protected)
- **SFP and 10/100/1000 PoE ports:** link and active
- **Image management port:** 10/100BASE-TX (RJ-45 female) data terminal equipment (DTE); green (good), orange (disabled), off (not connected)

Environmental Conditions

The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS requires the following environmental conditions:

- **Operating temperature:** 32 to 104ºF (0 to 40ºC)
- **Storage temperature:** -40 to 167ºF (-40 to 75ºC)
- **Relative humidity:** 10 to 90 percent, noncondensing

- **Operating altitude:** -60 to 2000 meters (m) Regulatory Standards Compliance

The Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS complies with the regulatory standards listed in Table 2.

Table 2. Regulatory Standards Compliance Details

Specification	Standard
Regulatory Compliance	CE marking
Safety	• UL 60950 • CAN/CSA-C22.2 No. 60950 • EN 60950 • IEC 60950 • TS 001 • AS/NZS 3260
EMC	• FCC Part 15 (CFR 47) Class A • ICES-003 Class A • CISPR22 Class A • AS/NZS 3548 Class A • VCCI Class A • EN 55022 • EN 55024 • EN 61000-6-1 • EN 50082-1 • EN 61000-3-2 • EN 61000-3-3 • ETS 300 386

New Cisco IOS Software Packaging for the Cisco Catalyst 4500 Series

Cisco Systems® announces a new Cisco IOS Software package for the Cisco Catalyst 4500 Series switches. This package creates a new foundation for features and functionality, and provides consistency across all Catalyst switches. The new Cisco IOS Software release train is designated as 12.2SG.

Prior Cisco IOS Software images for the Catalyst 4500 Series, formally known as “Basic L3” and “Enhanced L3” images, now map to “IP Base” and “Enterprise Services,” respectively. Border Gateway Protocol (BGP) is now included in the “Enterprise Services” image. Unless otherwise specified, all currently shipping Catalyst 4500 software features based on Cisco IOS Software are supported in the 12.2(25)SG, IP Base image with a few points to note:

- The IP Base image will not support the following routing related features: BGP, EIGRP, OSPF, IS-IS, IPX, Apple Talk, Virtual Route Forwarding [VRF]-lite, and Policy-Based Routing [PBR])
- The IP Base image will support EIGRP-Stub for Layer 3 routing on all Catalyst 4500 Series Supervisor Engines. For more information on EIGRP¬Stub functionality, go to http://www.cisco.com/en/US/tech/tk365/technologies_white_paper0900aecd8023df6f.shtml.

Table 3 lists the ordering information for the Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS.

Table 3. Ordering Information

Product Number	Description
WS-X4013+TS(=)	Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS, 12 10/100/1000 802.3af PoE, 8 SFP, console RJ-45 (based on Cisco IOS Software)
S45IPB-12231SG	Cisco IOS Software for the Cisco Catalyst 4500 Series (IP Base image with EIGRP-stub support)
S45IPBK9-12231SG	Cisco IOS Software for the Cisco Catalyst 4500 Series (IP Base image with Triple Data Encryption Standard [3DES] and EIGRP-stub support)
MEM-C4K-FLD64M	Compact Flash memory, 64-MB option, for Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS
MEM-C4K-FLD128M	Compact Flash memory, 128-MB option, for Cisco Catalyst Supervisor Engine II-Plus-TS

WARRANTY

The warranty for the Cisco Catalyst 4500 Series Supervisor Engine II-Plus-TS is 90 days and it includes hardware replacement with a 10-day turnaround from receipt of a return materials authorization (RMA).

CISCO TECHNICAL SUPPORT SERVICES—EXTENDING NETWORK INTELLIGENCE THAT PROTECTS YOUR NETWORK INVESTMENT NOW.

CiscoTechnical Support Services help to ensure that your Cisco products operate efficiently, remain highly available, and benefit from current system software to assist you in effectively managing your network service while controlling operational costs.

Cisco Technical Support Services (Table 4) provide significant benefits that go beyond what is offered under the Cisco warranty policy. Services available under a Cisco SMARTnet® service contract that are not covered under a warranty are:

- Latest software updates
- Rapid replacement of hardware in next-day, 4-hour, or 2-hour dispatch options
- Ongoing technical support through Cisco Technical Assistance Center (TAC)
- Registered access to Cisco.com

Table 4. Technical Support Services—Components

Service Feature Overview	Benefits and Advantages
Software Support	Offers maintenance and minor and major updates for licensed feature set. Downloading new maintenance releases, patches, or updates of Cisco IOS Software helps to enhance and extend the useful life of Cisco devices. Through major software updates it is possible to extend the life of equipment and maximize application technology investments by: • Increasing the performance of current functions • Adding new capability that, in many cases, requires no additional hardware investment • Enhancing network or application availability, reliability, and stability
TAC Support	With more than 1000 highly trained customer support engineers, 390 CCIE® certified engineers, and access to 13,000 research and development engineers, Cisco TAC complements your in-house staff with a high level of knowledge in voice, video, and data communications networking technology. Its sophisticated call-routing system quickly routes calls to the correct technology personnel. The Cisco TAC is available 24 hours a day, 365 days a year.
Cisco.com	This award-winning Website provides 24-hour access to an extensive collection of online product and technology information, interactive network management and troubleshooting tools, and knowledge-transfer resources that can help customers reduce costs by increasing staff self-sufficiency and productivity.

Service Feature Overview	Benefits and Advantages
Advance Hardware Replacement	Advance-replacement and onsite field engineer options supply fast access to replacement hardware and field resources for installing hardware, minimizing the risk of potential network downtime.

Table 5 lists the benefits of Cisco Technical Support Services.

Table 5. Cisco Technical Support Services—Competitive Differentiators

Feature	Benefits and Advantages
Worldwide Virtual Lab	This extensive lab of Cisco equipment and Cisco IOS Software releases provides an invaluable engineering resource and knowledge base for training, product information, and recreation and testing of selected network issues to help decrease time-to-resolution.
Cisco TAC Training • **Boot camps** • **Tech calls** • **Tech forums**	Cisco is committed to providing customers the latest in technology support. These TAC training programs assist customers in case-avoidance as well as provide knowledge transfer of Cisco networking expertise.
Cisco Live	Provides a powerful suite of Internet-enabled tools with firewall-friendly features; these secure, encrypted Java applets can turn a simple phone call into an interactive collaboration session, allowing a customer and Cisco TAC support engineer to work together more effectively.
Global Logistics	Delivers award-winning, worldwide hardware-replacement support with 650 depots, covering 120 countries, at a US$2.3 billion investment in inventory, with 10,000 onsite field engineers.
Cisco IOS Software	Employs 100 discrete technologies with more than 2000 features. 400 new features are added each year. Cisco IOS Software is installed in more than 10 million devices and is running on more than 10,000 networks worldwide. It operates on the world's largest IPv6 and VoIP networks and in all major service provider networks worldwide.

FOR MORE INFORMATION

To learn more about how you can take advantage of Cisco Technical Support Services, talk to your Cisco representative or visit Cisco Technical Support Services at: http://www.cisco.com/en/US/products/svcs/ps3034/ps2827/serv_group_home.html

For additional information on the Cisco Catalyst 4500 Series, visit: http://www.cisco.com/go/catalyst4500

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Printed in the USA

C78-339516-00 03/06