IP/MPLS Networks for Highways
Infrastructures for highly available mission-critical communications
Alcatel-Lucent delivers a converged IP/MPLS-based network for highways using next-generation products and management tools. The Alcatel-Lucent IP/MPLS network supports network resiliency, quality of service, virtualization, convergence and a management platform that automates and simplifies operations management. Alcatel-Lucent highly available IP/MPLS networks enable highway agencies and state departments of transportation to effectively provide performance guarantees on new ITS applications. Reliable communication is essential to meet key objectives such as providing “always on” services, increasing traveler safety and security, reducing traffic congestion and improving the overall efficiency of the highway infrastructures.
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Introduction

Highway agencies and state departments of transportation in the US are responsible for operating, maintaining and improving road infrastructures. A reliable communications network connecting the various voice, video and data subsystems is very critical in the operation of a highway infrastructure. To increase the efficiency of these highway infrastructures, many agencies are deploying new Intelligent Transport Systems (ITS), which include roadside devices and central traffic management systems, to reduce congestion and pollution and to enhance safety and security.

The deployment of ITS requires a communications network that can reliably support various types of information between the operations center and the thousands of devices alongside the highway infrastructure. Traditionally, communications networks for highways often utilize different communications technologies such as TDM. Now, many ITS applications are IP/Ethernet-based and are much more demanding in terms of bandwidth and quality of service (QoS). Highway agencies and departments of transportation can improve the efficiency of their operations with a highly available Alcatel-Lucent IP/MPLS converged network for all their communications needs, including critical services such as video from closed-circuit television (CCTV) cameras, voice from roadside emergency telephones and mobile radios, as well as data for sensors, weather stations and message signs. A high-speed IP/MPLS network is effective in supporting both IP-based and TDM-based video, voice and data applications.

The Alcatel-Lucent management platform allows highway agencies to improve their efficiency by automating and simplifying operations management for communications services.

Highway and ITS applications

A highway communications network supports a broad range of ITS applications as well as internal communications. The conceptual network architecture of the communications infrastructure for highways, supporting communications for quantities of equipment as well as workers, is shown in Figure 1. This resilient multiservice network provides real-time multimedia communications between a traffic control center and the roadside equipment, the drivers and roadside workers on the highways.

Highway operations include the following applications:
- CCTV
- Emergency telephone
- License plate recognition
- Mobile radio
- Public address
- Traffic flow monitoring
- Traffic signal controller
- Toll collection
- Variable message sign
- Weather station
- Corporate LAN/WAN
Each of these applications has a unique set of requirements in terms of bandwidth, QoS, availability, latency and so on. The ideal communications infrastructure enables the agencies to set parameters (for critical, priority and best-effort data, for example) for each service and traffic type (voice, data and video) according to operational requirements. A network supporting low jitter and delay in a one-to-one or one-to-many topology is required to transport all traffic types effectively and reliably in real time.

A highway operation could include one or multiple traffic control centers for gathering and dispatching traffic information. In addition, the network management subsystems are operated from a network operating center. The following sections provide examples of some of the key services: data services, voice services, video surveillance and Internet access.

**Data services**

Data services include information collected from roadside equipment such as loop sensors, weight detectors and environmental monitors. In terms of outgoing communications, panels display variable messages such as speed limits and accident announcements. Other data services that involve communications with the back office and databases include traffic control systems and automated toll collection, which requires payment traffic to be separated from other communications.

**Voice services**

High-quality voice communications provide an efficient work environment and emergency voice services for travelers. Emergency telephones alongside highways are a critical service to drivers. Inside tunnels, a public address system can be used to convey urgent information. Maintenance personnel rely heavily on the operations voice system to stay in contact with co-workers in order to perform duties.
Video surveillance
Video monitoring provides the highway operators with real-time visual information about traffic flow issues and other incidents, scanning for specific vehicles and license plates. These applications require a reliable high-capacity communications network that can transport video streams with guaranteed on-demand bandwidth in a many-to-few topology. The network needs to be capable of supporting thousands of video streams including IP multicast.

Internet and external access
Highway agency staff require access to the Internet for various types of information on the job. Information exchanges are also required with external parties such as police, broadcasters or travelers seeking pre-trip advice via the Internet.

The Alcatel-Lucent IP/MPLS network
IP networks have grown significantly in recent years, but they often lack the necessary scalability to support traffic that requires QoS levels beyond best effort. Traditional IP and Ethernet networks also lack the ability to optimize the use of network resources and the capability to react to network events fast enough to guarantee end-to-end QoS per application. By using MPLS, a highway agency gets the best of both worlds — an IP network that has the robustness and predictability of a circuit-based network with high capacity and support for bursty traffic. The IP/MPLS network enables the deployment of new IP/Ethernet applications as well as existing TDM based applications. With an MPLS-enabled IP network, the agency has a system with the following features:
- Is highly scalable and reliable with redundancy and Fast Reroute (FRR) capabilities
- Addresses a range of QoS and service level agreement requirements
- Optimizes bandwidth usage through traffic engineering
- Has extensive OAM tools for troubleshooting and maintenance

Each application on the network has unique requirements in terms of bandwidth, QoS, and availability. The IP/MPLS network enables the agency to set service parameters for each service and traffic type (voice, data and video) and multiple service levels within each traffic type according to operational requirements. This network is also capable of supporting low jitter and delay to handle all traffic types effectively and reliably, in real time.

In addition to those MPLS advantages, the Alcatel-Lucent IP/MPLS network supports advanced capabilities, including non-stop routing, non-stop services and FRR, to provision VPNs based on Virtual Leased Line (VLL), Virtual Private LAN Service (VPLS), and IP VPNs as well. This support allows for virtualization of a single network infrastructure to support different services and traffic types. One service is carried across one VPN while the traffic of different services is securely separated in their own private networks. The Alcatel-Lucent multiservice MPLS network can also support existing TDM traffic with pseudowire services, so an agency can choose when to migrate existing services to IP.

The Alcatel-Lucent IP/MPLS implementation provides a service-oriented approach that focuses on service scalability and quality, as well as per-service OAM. With a service-aware infrastructure, the agency has the ability to tailor services such as mission-critical applications so that it has the guaranteed bandwidth to meet peak requirements. The Alcatel-Lucent service router supports IP routing and switching, which enables the agency to support real-time Layer 2 and Layer 3 applications.
The Alcatel-Lucent IP/MPLS network, which extends MPLS capabilities from the core to access, includes the following main components:

- Alcatel-Lucent 7750 Service Router (SR)
- Alcatel-Lucent 7705 Service Aggregation Router (SAR)
- Alcatel-Lucent 7450 Ethernet Service Switch (ESS)
- Alcatel-Lucent 7210 Service Access Switch (SAS)
- Alcatel-Lucent OmniSwitch™ 6855 Hardened LAN Switch (HLS)
- Alcatel-Lucent 5620 Service Aware Manager (SAM)
- Alcatel-Lucent 5650 Control Plane Assurance Manager (CPAM)

The administration of the Alcatel-Lucent IP/MPLS network is handled by the Alcatel-Lucent 5620 SAM, which automates routine tasks and makes it easy to provision new services, maintain operations and troubleshoot or avoid faults in the network (Figure 2).

Microwave can be used to provide connectivity coverage to one or several sections of the road where no other means of transmission is available. An optical layer, Coarse Wavelength Division Multiplexing (CWDM) and Dense Wavelength Division Multiplexing (DWDM) can also be used for increasing backbone network capacity to transfer video, voice and data.

![Figure 2. Alcatel-Lucent IP/MPLS communications network for highways](image-url)
IP video surveillance

Modern video surveillance systems are IP-based and are integrated with the IP backbone using a network-based architecture. Managing video traffic can be a challenge for highway agencies that are still using traditional networks. Adding CCTV traffic onto an IP network unprepared for video traffic can adversely impact all services on the network. Therefore, it is critical for highway agencies to select a network that can technically address their video surveillance requirements. They need a reliable, “always-on” network that can handle many high-quality video streams and accommodate the convergence of voice and data traffic. The network architecture must be capable of handling current video traffic levels and future growth, including significant increases in bandwidth. Video streams from a single IP camera can be as high as 4 Mb/s and more. The Alcatel-Lucent advanced IP/MPLS network can meet the requirement for guaranteed delivery of mission-critical CCTV video traffic and concurrent support of other critical data and voice traffic on a single converged network.

Distributed video surveillance offers many advantages, including support for real-time video streaming to many locations and the flexibility to deploy video analytics software remotely. Because access and distribution of CCTV streams can be very dynamic and mission-critical in nature, the highly scalable and reliable Alcatel-Lucent IP/MPLS network is ideal for handling thousands of video streams now required in modern CCTV applications.

A modern video surveillance operation can have many high-quality CCTV cameras generating multicast IP video streams. These video streams are transported in real time to multiple locations. CCTV cameras and CODECs have Ethernet and IP interfaces and support Internet Group Management Protocol (IGMP) to register these devices to a multicast group. Each CCTV channel belongs to a different multicast group; therefore, each has a different multicast IP address assigned to the packets carrying footage for the channel. IGMP is used by the video management workstation to communicate to the edge routers for the channel the operator is requesting.

Using the multicast capabilities of VPLS technology in the aggregation network provides a powerful and cost-effective solution for the delivery of CCTV traffic to the local monitoring stations and for central video management (Figure 3).

Figure 3. Video surveillance with VPLS
Converged voice, video and data communications

A service-aware IP/MPLS network supports convergence of voice, video and data traffic on a single high-capacity network where different applications are managed through configurable QoS levels. This facilitates the deployment of advanced ITS applications in CCTV, roadside data collection, information displays and emergency telephones. Using MPLS, network virtualization is possible with separate virtual networks for different voice, video and data applications. These virtual networks are securely separated as if they were individual networks. Using MPLS VPN technologies, it is possible to provision virtual networks with controlled levels of security and QoS for different applications or agencies.

An Alcatel-Lucent IP/MPLS network supports advanced Layer 2 and Layer 3 VPNs that provide secure traffic separation and customized service levels for mission-critical services, while leveraging the common network infrastructure (Figure 4).

Figure 4. Multiservice converged communications

Synchronous Ethernet

Highway agencies are looking to migrate to a single, converged network with synchronized infrastructures and want a familiar and manageable model. To enable rapid migration of these networks, Synchronous Ethernet may be the easiest way to achieve (frequency) synchronization and to allow the benefits of an Ethernet network infrastructure to be realized without changing the existing TDM network applications. The concept behind Synchronous Ethernet is similar to SONET/SDH system timing capabilities.

With Synchronous Ethernet, the network elements derive the physical layer transmitter clock from a high-quality frequency reference via the physical Ethernet interfaces. This does not affect the operation of any of the Ethernet layers, for which this capability would be transparent. The receiver at the far end of the link locks onto the physical layer clock of the received signal, and thus gains
access to a highly accurate and stable frequency reference. Then, in a way similar to conventional hierarchical master-slave network synchronization, this receiver locks the transmission clock of its other ports to the frequency reference and a fully time-synchronous network is established.

The implementation of Synchronous Ethernet will allow highway agencies to gracefully integrate their existing systems and future deployments into a conventional industry-standard synchronization hierarchy. The Alcatel-Lucent IP/MPLS portfolio supports Synchronous Ethernet, which has proven to out-perform the standards requirements used by SONET/SDH, allowing migration from SONET/SDH to a full IP/MPLS network as desired.

**Circuit Emulation Service over MPLS**

Highway agencies must consider how to leverage new IP/MPLS network technology when migrating legacy TDM systems and services. These agencies can take advantage of the IP/MPLS Circuit Emulation Service (CES) functionality and transition their legacy applications gradually. CES delivers the same quality of experience as the existing TDM network infrastructure with the same level of predictability. The Alcatel-Lucent IP/MPLS network has a circuit emulation interworking function that ensures all information required by a TDM circuit is maintained across the packet network. This provides a full transition to a packet network over time while providing TDM service continuity.

**Capitalizing on MPLS capabilities**

An increasing number of highway agencies are deploying their own MPLS-based networks. MPLS brings the advantages of a circuit-based network to an IP network, and enables network convergence, virtualization and resiliency.

MPLS is used to transport different types of traffic using pseudowire, VLL, VPLS and IP VPNs. In an MPLS network, Open Shortest Path First (OSPF) is commonly used as the Interior Gateway Protocol (IGP) supporting the setup of MPLS paths.

**High Availability through MPLS**

The IP/MPLS network assures High Availability through fast path restoration and network reconvergence within 50 ms. Network resiliency is achieved by means of the end-to-end restoration capabilities of the MPLS FRR feature. High Availability is essential to a highway communications network, which carries mission-critical voice, video and data information. With MPLS FRR, voice and data service interruption is minimized during network failures. To protect the network against node or interconnection failures, end-to-end standby MPLS paths are provisioned. MPLS offers the flexibility to provision hot or cold-standby paths to protect an active path.

The Alcatel-Lucent IP/MPLS implementation includes the unique additional High Availability features of non-stop routing and non-stop services supported on the Alcatel-Lucent service router portfolio. The benefits are unparalleled availability and reliability:

- Non-stop routing ensures that a control card failure has no service impact. Label Distribution Protocol (LDP) adjacencies, sessions and the database remain intact if there is a switchover.
- Non-stop service ensures that VPLS and IP VPN services are not affected when there is a Control Fabric Module switchover.

**MPLS traffic engineering**

MPLS supports traffic engineering, which allows for the selection of the best path across the network, taking the physical paths of the links and interfaces into account. Traffic engineering is used in networks to ensure that the best links are chosen to optimize network bandwidth.
Hierarchical QoS

The Alcatel-Lucent implementation of Hierarchical QoS (H-QoS) is service-aware, allowing lower priority traffic to burst to fill available bandwidth when higher priority applications go idle. Typical routers offer QoS levels per port with either strict priority or weighted fair queuing. In contrast to this, the Alcatel-Lucent IP/MPLS network implements service-based queuing; each logical port (virtual LAN or a virtual circuit) within a physical port has a dedicated queue. The Alcatel-Lucent network also supports queues and QoS for traffic classes within the logical port, and provides each service with committed information rate and peak information rate type guarantees.

Effective management for easier day-to-day operations

A key element of reliable and flexible MPLS-based networks is a set of effective, simplified management tools that provide easy configuration and control of the network, effective problem isolation and resolution, and support of new management applications. The Alcatel-Lucent IP/MPLS network supports OAM tools that simplify the deployment and day-to-day operation of a highway communications network. For example, service tests, interface tests and tunnel tests allow for rapid troubleshooting and enable proactive awareness of the state of traffic flows to help minimize service down time.

The Alcatel-Lucent IP/MPLS network is fully managed by the industry-leading Alcatel-Lucent 5620 Service Aware Manager. The Alcatel-Lucent 5620 SAM is an integrated application that covers all aspects of element, network and service management on one platform. It automates and simplifies operations management on a converged MPLS network, driving network operations to a new level of efficiency. The Alcatel-Lucent 5620 SAM product suite supports element management, network commissioning, service provisioning and service assurance.

IP routing management control

The Alcatel-Lucent 5650 Control Plane Assurance Manager offers real-time control plane visualization, proactive control plane surveillance, configuration, validation and control plane diagnosis. In addition, it provides simplified diagnosis and intuitive visualization of the relationship between services, the MPLS infrastructure and the routing plane. Integrated control plane and service management is an innovative development in service routing. It enables network administrators to overlay Layer 2 and Layer 3 services, MPLS tunnels and various OAM traces on the control plane map, which simplifies problem resolution, reduces control plane configuration errors and reduces troubleshooting time.

Summary

Only MPLS can provide the highly reliable packet-based infrastructure needed for mission-critical services. A service-aware IP/MPLS network supports converged voice, data and video applications that are managed through configurable QoS levels. The Alcatel-Lucent IP/MPLS product portfolio leads the industry in reliability and OAM tools, which are key enablers for meeting the “always-on” requirement for mission-critical operations. The Alcatel-Lucent IP/MPLS network can do the following to help address highway communications challenges:

- Provide high network availability
- Implement network virtualization with QoS guaranteed for priority traffic
- Reduce operating and maintenance costs

A highly available communications network enables a highway agency to do the following,

- Reduce traffic congestion and pollution
- Enable safe roads
- Improve traveler information and satisfaction
The Alcatel-Lucent advantage

Alcatel-Lucent has years of experience in the development of MPLS-based technologies and is a leader in IP/MPLS and VPLS networking. Alcatel-Lucent supports a complete MPLS offering, which includes solutions for Layer 2 (VLL, VPLS) and Layer 3 (IP VPN) services and a broad and scalable IP/MPLS portfolio: the Alcatel-Lucent 7750 Service Routers, 7705 Service Aggregation Router, 7450 Ethernet Service Switch, 7210 Service Access Switch, 5620 Service Aware Manager and 5650 Control Plane Manager.

With the broadest portfolio of products and services in the telecommunications industry, Alcatel-Lucent has the ability to design and deliver end-to-end solutions that drive integrated communications for highways. Alcatel-Lucent provides the following in its comprehensive services portfolio: Consult and Design, Integrate and Deploy, and Maintain and Operate.

For further information on the Alcatel-Lucent solution for Highways, please go to www.alcatel-lucent.com.

Abbreviations

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<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CCTV</td>
<td>closed-circuit television</td>
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<td>CES</td>
<td>Circuit Emulation Service</td>
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<td>CPAM</td>
<td>Control Plane Assurance Manager</td>
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<tr>
<td>CWDM</td>
<td>Coarse Wavelength Division Multiplexing</td>
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<td>DWDM</td>
<td>Dense Wavelength Division Multiplexing</td>
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<td>ESS</td>
<td>Ethernet Service Switch</td>
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<td>FRR</td>
<td>Fast Reroute</td>
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<td>H-QoS</td>
<td>Hierarchical Quality of Service</td>
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<td>IGMP</td>
<td>Internet Group Management Protocol</td>
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<td>IGP</td>
<td>Interior Gateway Protocol</td>
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<td>IP VPN</td>
<td>IP virtual private network</td>
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<td>ITS</td>
<td>Intelligent Transport Systems</td>
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<td>LDP</td>
<td>Label Distribution Protocol</td>
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<td>MPLS</td>
<td>Multiprotocol Label Switching</td>
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<td>OAM</td>
<td>operations, administration and maintenance</td>
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<td>OSPF</td>
<td>Open Shortest Path First</td>
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<td>QoS</td>
<td>Quality of Service</td>
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<td>SAM</td>
<td>Service Aware Manager</td>
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<td>SAR</td>
<td>Service Aggregation Router</td>
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<td>SAS</td>
<td>Service Access Switch</td>
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<td>SDH</td>
<td>Synchronous Digital Hierarchy</td>
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<td>SONET</td>
<td>Synchronous Optical Network</td>
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<td>SR</td>
<td>Service Router</td>
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<td>TDM</td>
<td>Time Division Multiplexing</td>
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<td>VLL</td>
<td>Virtual Leased Line</td>
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<td>VPLS</td>
<td>Virtual Private LAN Service</td>
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