

# MISSION-CRITICAL COMMUNICATIONS NETWORKS FOR RAILWAY OPERATORS

NETWORK TRANSFORMATION WITH IP/MPLS APPLICATION NOTE

•Alcatel•Lucent 🥢

AT THE SPEED OF IDEAS™

### ABSTRACT

Main line and urban railway operators rely heavily on their communications networks to operate safely and efficiently. These railway operators have traditionally deployed separate networks to support different applications using Synchronous Digital Hierarchy/ Synchronous Optical Network (SDH/SONET)-based time division multiplexing (TDM) network technologies. Alcatel-Lucent delivers a converged IP/Multiprotocol Label Switching (MPLS)-based communications network for railway operators using nextgeneration products and advanced management tools. Alcatel-Lucent IP/MPLS, optics, and microwave products support network resiliency, quality of service (QoS), virtualization, accurate synchronization, convergence, and a management platform that automates and simplifies operations. Deploying a modern, reliable, and flexible Alcatel-Lucent IP/MPLS communications network will enable a railway operator to migrate from a SDH/SONET-based network to a multiservice IP/MPLS network that can concurrently support both new IP/Ethernet-based applications and legacy TDM-based applications, thus reducing both capital expenditures (CAPEX) and operating expenses (OPEX) while maintaining reliability. A converged IP/MPLS network is also the technology of choice for building a new communications network supporting modern IP/Ethernet applications in a greenfield railway project.

## **TABLE OF CONTENTS**

Introduction / 1 Railway applications / 2 Data services / 3 Voice services / 3 Video surveillance / 3 Wireless backhaul / 4 Corporate and Internet access / 4 Preparing for LTE / 4

The Alcatel-Lucent IP/MPLS network / 4 Virtualization / 5 The Alcatel-Lucent solution / 7 The network architecture / 8

Capitalizing on IP/MPLS network capabilities / 11 CAPEX/OPEX and scalability / 11 Multiservice support / 11 High availability through IP/MPLS / 11 Quality of service and traffic management / 12 Network synchronization and timing / 12 Effective management for easier day-to-day operations / 12 Support for key applications / 13

Conclusion / 14

Acronyms / 16

### **INTRODUCTION**

Investments in railway infrastructure projects have been fueled by initiatives dedicated to private vehicle traffic and carbon emission reduction, public transit expansion, and population growth. Other business initiatives propelling investments in the railway sector include increased safety and security, cost reduction, and obsolescence management. Modern railway operators, including those operating main line and urban railways, are focusing on these initiatives while balancing the need to increase customer satisfaction. To ensure their ongoing success, many railway operators are making better use of information and communications technology (ICT) and capitalizing on technological innovations to reduce costs and increase passenger safety and satisfaction. For example, many railway operators worldwide are deploying Communication-Based Train Control (CBTC) or Positive Train Control (PTC) systems. Another factor closely related to both safety and modernization is the requirement to deploy the Global System for Mobile Communications - Railway (GSM-R) as part of the European Rail Traffic Management System (ERTMS). All these initiatives are driving the growing demand for a more intelligent communications network that can support the various applications and greater bandwidth needs — advanced signaling, asset management, and improved video security — all of which put tremendous pressure on existing networks. At the same time, passengers are demanding to be connected, entertained, and informed while using the railway services.

The communications network plays an important part in the mission-critical railway operation because many of the control systems are geographically separated and rely on the communications network for interconnections to function properly. Traditionally, railway operators have managed multiple networks supporting different applications. These networks often utilize SDH/SONET/Plesiochronous Digital Hierarchy (PDH) TDM-based networking technologies. Now, a growing number of applications have changed to IP/Ethernet based. Many of these IP/Ethernet applications are much more demanding in terms of bandwidth, availability and responsiveness. Consequently, this requires many railway operators to consider an evolution of their communications networks that would be very different from their traditional TDM-centric networks.

A modern, reliable, and flexible communications network allows a railway operator to route the IP/Ethernet-based monitoring, control and status data effectively, efficiently and on time. Alcatel-Lucent has state-of-the-art, highly reliable, communications equipment that can form a single converged IP/MPLS network for guaranteed delivery of the various mission-critical operational and corporate voice, data, and video services vital to a railway operation. This converged network will allow a railway operator to maximize the cost effectiveness and efficiency of its network without jeopardizing reliability while enabling the deployment of new devices and applications that can improve operational and workflow efficiency. This approach provides an effective solution for managing new IP/Ethernet-based applications while continuing to support existing applications and legacy systems.

In addition, the Alcatel-Lucent network and service management platform allows railway operators to improve their efficiency by automating and simplifying operations management for communications services, thus reducing any barriers of introducing IP/MPLS-based technologies and services.

### **RAILWAY APPLICATIONS**

A railway operator's communications network supports a broad range of applications, including those related to the internal operations of the railway system, and those that support customer-oriented services (see Figure 1).

The railway operator's typical applications include:

- Access control
- Alarm
- Corporate local area network (LAN)
- Interlocking
- Mobile radio
- Passenger information display
- Public address
- Public Internet access
- Signaling
- Telephony
- Ticketing
- Video conference
- Video surveillance

#### Figure 1. Typical applications supported by a railway operator's communications network



Each of these applications has a unique set of requirements for bandwidth, QoS, availability, latency, and so on. The ideal communications network will enable the railway operator to set parameters (for example, critical, priority, and best-effort data) for each service and traffic type (multiples of voice, data, and video) according to operational and business requirements. A communications network supporting low jitter and delay in a point-to-point or point-to-multipoint topology is required to transport all traffic types effectively and reliably in real time.

The following sections provide examples of some of the key service areas (for example, data services, voice services, video surveillance, wireless backhaul, and corporate and Internet access) followed by a clear explanation of how the Alcatel-Lucent IP/MPLS communications network supports these areas.

#### **Data services**

Signaling and interlocking systems require interconnections between field and central elements. This is an important data service, one that needs to be treated as a missioncritical priority, as it is used to convey critical information about the state of the railway line, to control traffic flow, and to ensure safety. Similarly, Supervisory Control and Data Acquisition (SCADA) and telemetry data are also vital information for monitoring and management of other subsystems such as power. Specific urban railway signaling systems often use Wi-Fi® as the train-to-ground communication technology, leveraging the bandwidth available to transport critical and sometimes non-critical applications on the same radio media.

Another data service is the distribution of regular and ad hoc announcements and passenger information at station terminals. The content may be generated at central operations or at a regional center, and may be specific to one station or broadcast to all stations. Newer systems are now combined with digital signage to provide real-time multimedia contents from passenger information to security alerts to advertising.

Other data services such as ticketing and access control require information from all stations to be aggregated back to central operations for processing.

#### **Voice services**

Voice communication is an integral part of railway operation management by signalers and dispatchers. Maintenance personnel also rely on the operations voice system to stay in contact with co-workers in order to perform routine duties. Voice services can be within a station or span several stations, and can be wired or wireless (for example, TETRA, P25). High-quality voice services must be supported to provide a well-organized work environment and to keep staff informed in the event of an emergency. The railway operator also operates a public address system to convey routine and urgent information to passengers. Many systems for these voice services have moved from circuit switched to IP and often are incorporated with multimedia conferencing and collaboration applications.

#### Video surveillance

Video surveillance has become paramount for railway operators to safeguard critical assets and to ensure the safety of personnel and passengers. Often operated on a separate network in the past, video surveillance has now become one of the railway operator's many IP applications. A typical railway operation has many stations, and at each station, high-quality closed-circuit television (CCTV) systems generate multicast IP video streams. These video streams can generate bandwidths up to several Mb/s, which are transported in real time to multiple operations centers. This application requires a cost-effective and reliable high-capacity communications network that can transport multicast streams

in a many-to-few topology. Modern CCTV cameras and CODECs have Ethernet and IP interfaces and support Internet Group Management Protocol (IGMP) to register in a multicast group. The network must be able to handle traffic of several Mb/s per camera and thousands of multicast streams.

#### Wireless backhaul

Wireless networks are now standard on most railways. For example, to improve safety and overall communications, many railway operators are deploying GSM-R. GSM-R is a secure platform for voice and data communications among railway operational staff, including drivers, dispatchers, shunting team members, train engineers, and station controllers. It is part of a major initiative being undertaken by railways around the world to introduce a cost-effective digital replacement for existing incompatible in-track cable and analog radio networks. GSM-R also serves as the bearer system for the European Train Control System Level 2, as part of the ERTMS implementation. The ERTMS project has been set up to create unique signaling standards throughout Europe. The deployment of GSM-R over a single, unified communications network significantly increases the network's requirements for synchronization.

#### **Corporate and Internet access**

Railway personnel working in the operations centers and administration buildings require access to the railway company's corporate data, intranet and the Internet. A wireless LAN (WLAN) would be particularly helpful for the railway operator's mobile workforce, allowing them to easily access, for example, maintenance manuals and work orders while on the move.

For passengers, railway stations are being equipped with WLAN broadband services. This data traffic would be considered non-critical, so the communications network should have the option to transport this traffic in a best-effort mode, maximizing use of available bandwidth but backing down to ensure transport of higher priority traffic.

#### **Preparing for LTE**

The railway industry has started to consider Long Term Evolution (LTE) as a potential future replacement system for GSM-R to take advantage of the performance and throughput benefits of LTE. It is envisioned that LTE will be deployed along tracks to deliver wireless broadband services to trains and passengers. Therefore, the communications network being deployed today needs to be able to accommodate the future backhaul requirement to effectively support LTE deployment.

### THE ALCATEL-LUCENT IP/MPLS NETWORK

Many railway operators have deployed or are deploying IP-based core networks to support all of their railway communications needs. Not all IP-based solutions are appropriate for railway operators. To simultaneously support all mission-critical and non-mission-critical traffic of a railway operation, an IP/MPLS-based communications network is needed. Non-MPLS-based IP networks have grown significantly in recent years, but they often lack the necessary scalability to support traffic that requires QoS levels for mission-critical operations. 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 IP/MPLS, the railway operator

gets the best of both worlds — an IP network that has the robustness and predictability of a circuit-based network along with high capacity and support for bursty traffic. The IP/MPLS network enables the deployment of new IP/Ethernet applications as well as support of existing TDM-based applications, allowing the railway operator to improve services for both internal and external users. A railway operator can continue to support existing TDM services and flexibly choose when to migrate them to IP. With an IP/MPLS network, the railway operator has a network with the following features:

- Highly scalable and reliable with redundancy and Fast Reroute (FRR) capabilities
- Addresses a range of QoS and service level agreement (SLA) requirements
- Optimizes bandwidth usage and avoids common modes through traffic engineering
- Extensive operations, administration, and maintenance (OAM) tools for troubleshooting and maintenance
- Advanced network and service management to simplify operations
- Supports future LTE deployments and other technologies

Each application on the network has unique requirements for bandwidth, QoS, and availability. The IP/MPLS network enables the railway operator to set service parameters for each service and traffic type (for example, multiple types of voice, video and data traffic) 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, the Alcatel-Lucent IP/MPLS network supports advanced capabilities, including non-stop routing, non-stop services and FRR, to maintain high network resiliency.

#### Virtualization

The Alcatel-Lucent IP/MPLS network provides for the virtual isolation of various traffic types on a single infrastructure using virtual private networks (VPNs). These VPNs enable the full separation of traffic from different applications or operations within the railway company, allowing for a secure environment and effective bandwidth allocation. Advanced IP/MPLS VPNs — such as Circuit Emulation Service (CES), virtual private LAN service (VPLS), and IP VPNs — are supported which can then be used to provide different applications and user groups with an environment that is private and unaffected by other traffic. One service is carried across one VPN while the traffic of different services is securely separated in their own VPN, effectively providing separate private networks. With advanced IP/MPLS VPNs, a railway operator can also leverage the same IP/MPLS network to offer business communications services.

#### **Circuit Emulation Service**

Railway operators need to consider that they can leverage new IP/MPLS network technologies when migrating legacy TDM systems and services. Railway operators can take advantage of the IP/MPLS CES functionality and transition their legacy applications gradually. CES delivers the same quality of service 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.

Two principal types of circuit emulation can be used: Circuit Emulation Service over Packet Switched Network (CESoPSN) and Structure Agnostic TDM over Packet (SAToP). CESoPSN allows NxDS0 service, including full T1/E1 capability. SAToP provides the ability to carry unstructured T1/E1 circuits across the IP/MPLS network. In an IP/MPLS network, the MPLS tunnel is used as the transport layer (Figure 2). A pseudowire is created to identify the specific TDM circuit within the MPLS tunnel. The circuit emulation service interworking function (CES IWF) ensures that all information required by the TDM circuit is maintained across the packet network. This function provides a transparent service to the end devices.

#### Figure 2. Circuit Emulation Service functionality overview



A pseudowire encapsulates traffic over label switched paths (LSPs) to create a point-topoint service. An MPLS pseudowire is analogous to a private line within the IP/MPLS network. It offers a point-to-point connection between any two end devices. Figure 3-1 depicts three different types of pseudowires — TDM, frame relay (FR), and Ethernet. The pseudowire can be used for applications that require dedicated point-to-point connectivity. For example, pseudowires support the transport of applications running over E1, serial, E&M, FXO, FXS, and G.703 interfaces to enable the migration of SDH/SONET networks to IP without impacting the long life cycle of traditional applications.

#### Figure 3. IP/MPLS-based VPN services



Mission-critical Communications Networks for Railway Operators ALCATEL-LUCENT APPLICATION NOTE

#### Virtual private LAN service

VPLS is a bridged multipoint service that forwards traffic based on the media access control (MAC) address. A VPLS is protocol-independent and enables multipoint connectivity at Layer 2 within the IP/MPLS network. Figure 3-2 depicts two VPLS instances within a network. VPLS is composed of virtual bridges at each node. Each virtual bridge performs MAC learning and constructs a table that maps MAC addresses and corresponding MPLS paths. The VPLS concept is similar to a logical LAN connection where all end devices connected to the VPLS appear as if they are within the same LAN segment.

#### IP VPN

An IP VPN is a Layer 3 VPN, a routed service that forwards traffic based on the IP address and is implemented specifically for IP traffic only. An IP VPN enables multipoint connectivity at Layer 3 within the IP/MPLS infrastructure (Figure 3-3), with each IP/MPLS node supporting virtual routing and forwarding (VRF) instances.

#### The Alcatel-Lucent solution

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 railway operator 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 routers support IP routing and switching, which enables the railway operator to support real-time Layer 2 and Layer 3 applications.

The Alcatel-Lucent converged IP/MPLS network leverages multiple state-of-the-art technologies. The network extends IP/MPLS capabilities from the core to access and can include 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 1830 Photonic Service Switch (PSS)
- Alcatel-Lucent 9500 Microwave Packet Radio (MPR)
- Alcatel-Lucent 5620 Service Aware Manager (SAM)

The Alcatel-Lucent IP/MPLS products provide routing, switching and multiservice capabilities, enabling the railway operators to support real-time applications across the full extent of the network. The Alcatel-Lucent IP/MPLS implementation includes non-stop routing and non-stop service capabilities that provide unparalleled reliability.

Microwave transmission systems can be used to provide connectivity coverage to one or several sections of the network where wireline connectivity is unavailable or impractical. The native packet microwave architecture of the Alcatel-Lucent 9500 MPR is optimized for a predominantly data-driven traffic mix by providing native packet transport over the radio link. Simplified deployments are enabled through common outdoor units (ODUs) that can be deployed across all microwave applications including all-outdoor, split-mount and all-indoor applications.

An optical transport layer using coarse wavelength division multiplexing (CWDM) and/or dense wavelength division multi ¬ plexing (DWDM) can also be used for increasing backbone network capacity or for Data Center Connect. WDM enables railway operators to cost

effectively scale their communications networks and services by maximizing fiber utilization and performance. As a highly integrated packet-optimized WDM solution, the Alcatel-Lucent 1830 PSS simplifies the aggregation and transport network by aggregating packet traffic efficiently, packing wavelengths to offer massive scalability and networking efficiency.

The network and service administration of the Alcatel-Lucent converged IP/MPLS communications network is handled by the industry-leading Alcatel-Lucent 5620 SAM, an integrated application that covers all aspects of element, network and service management on one platform. It simplifies the provisioning and management of the network, including automating routine tasks, correlating alarms to problems, managing the assignment of end-to-end connections, and facilitating the introduction and administration of new services, all through a user-friendly point-and-click interface. The Alcatel-Lucent 5620 SAM not only manages the Alcatel-Lucent IP/MPLS, optics, and microwave equipment, but it also is capable of managing third-party elements within the network. In addition, the Alcatel-Lucent LTE solution is also managed by the 5620 SAM to enhance and maximize the benefits of the multiservice IP/MPLS network.

#### The network architecture

Figure 4 shows the conceptual architecture of the Alcatel-Lucent IP/MPLS communications network for railway operations.



Figure 4. Alcatel-Lucent IP/MPLS communications network for railway operations

Mission-critical Communications Networks for Railway Operators ALCATEL-LUCENT APPLICATION NOTE The architecture illustrates how the subsystems and devices, and a wide area network (WAN) are tied together along with the key capabilities utilized in each layer of the network to support the mix of video, data and voice traffic. The network supports aggregation of mixed services coming from different applications (for example, signaling, interlocking, CCTV, alarms, telephony, GSM-R, TETRA, SCADA, WLAN, Internet traffic, and more) using different types of physical interfaces including E1/T1 TDM, Ethernet, serial data, and even legacy or specific interfaces such as E&M. The core nodes are able to connect to the SCADA master using TDM or IP, and to optimize data transport for all other applications. The network also supports optimized traffic delivery for multicast applications such as CCTV.

To leverage the advanced resiliency, traffic isolation, and traffic engineering features of IP/MPLS, the architecture uses a full end-to-end IP/MPLS network, from the stations to the control center. Traffic is carried using different types of VPN services depending on the requirement of the individual applications.

Figure 5 shows a typical network topology. The station LAN segments use virtual LANs (VLANs) to create network virtualization. Unique VLAN IDs are assigned to identify separate virtual networks for different applications. Alcatel-Lucent 7705 SAR and Alcatel-Lucent 7210 SAS products aggregate traffic from applications in a station LAN segment. The stations are typically interconnected using optical fibers alongside the tracks.

Figure 5. Typical network topology



Mission-critical Communications Networks for Railway Operators ALCATEL-LUCENT APPLICATION NOTE Alternatively, microwave wireless is used at the physical layer to connect remote sites or where fiber optics deployment is impractical. Stations belonging to one line of a railway system typically make up one segment of the network. Typically, depending upon the criticality of the applications, railway operators can select to deploy at each station a fully redundant IP/MPLS node, a non-redundant IP/MPLS node, or even two non-redundant IP/MPLS nodes. This provides railway operators with several levels of resiliency at different cost targets. Alcatel-Lucent IP/MPLS nodes at stations and track sides are certified against railway standard EN-50121-4 for the operating environment.

In many cases, either in large stations or along the tracks, the railway application devices are connected to a standard Ethernet switch before traversing the IP/MPLS network. To extend the high network availability to all the applications Alcatel-Lucent has developed a set of features to allow a better integration of the IP/MPLS network with the standard Ethernet access LAN. Access resiliency of the first IP/MPLS provider edge (PE) node is extended with protocols such as the Ethernet Ring Protection Switching (ERPS) protocol G.8032 or the Link Aggregation Control Protocol (LACP). With such interaction between LAN and IP/MPLS protocols, Alcatel-Lucent can support end-to-end resiliency for IP and non-IP data applications, providing at least 99.999 percent availability which is a solid foundation to achieving EN-50129 certification.

The IP/MPLS routers/switches in the stations are connected not in a physical loop, but in a logical loop, where station N-1 is connected to station N + 1. With this architecture, there is no requirement to close the loop by connecting the two end stations together, which would require a long reach optical interface.

In the control center, the resiliency is provided by a pair of 7750 SRs, which provide the necessary resiliency and services at the central site. Head-end servers are connected to Ethernet switches which dual home to the two 7750 SRs.

Pseudowire, VPLS, and IP VPN are used to provide network virtualization. The Alcatel-Lucent IP/MPLS network has proven very successful in helping railway operators to deploy a converged network for all applications while maintaining QoS for each type of application. This mission-critical design is ideal for the railway environment because it is capable of coping with thousands of video streams, voice traffic, and various data services simultaneously.

Even as Ethernet has emerged as the de facto standard for LANs, Ethernet has also become a standard offering in WAN applications. Ethernet provides scalable bandwidth in flexible increments. It is a cost-effective technology and is well understood. Railway operators benefit from cost savings in equipment, facilities, provisioning and maintenance, translating to CAPEX and OPEX reductions.

Table 1 illustrates the typical applications and the corresponding physical interfaces and IP/MPLS services used to support the applications.

Table 1. Typical applications and corresponding inte	rfaces and services
--	---------------------

APPLICATION	INTERFACE	IP/MPLS SERVICE
Signaling, interlocking, SCADA	Ethernet or TDM (E1/T1, E&M, serial)	VPLS, CES
GSM-R, TETRA, P25	TDM (E1/T1, E&M) or Ethernet	VPLS, CES
Ticketing, data	Ethernet	IP VPN
CCTV, digital signage	Ethernet	IP VPN and VPLS (multicast optimized)
Alarms	Dry contact	Dry contact port to SNMP alarm

### CAPITALIZING ON IP/MPLS NETWORK CAPABILITIES

Convergence of application traffic on a single network creates a need for high-capacity networks that support high bandwidth and flexible multipoint communications. Many railway operators have deployed their own IP/MPLS networks. IP/MPLS brings the advantages of a circuit-based network to an IP network, and enables network convergence, virtualization and resiliency.

#### **CAPEX/OPEX** and scalability

To meet railway operators' growing requirements for service deployment and bandwidth, the Alcatel-Lucent IP/MPLS network is extremely scalable, according to changing requirements. The IP/MPLS network can accommodate a growing number of applications and services. Minimal CAPEX requirements to deploy and scale this infrastructure are the result of the granularity in bandwidth, scaling options, and statistical multiplexing. The converged architecture and the ease of network management allow for optimized OPEX. A converged network also reduces the number of network elements required, thus also reducing costs.

#### **Multiservice support**

The Alcatel-Lucent IP/MPLS network offers a flexible network and service environment that enables the continuing support of existing TDM services while incorporating new IP and Ethernet applications. These packet applications are typically more efficient in bandwidth usage when deployed over an IP/MPLS network. All services converge at the access of the network, where the required packet handling, such as encapsulation and QoS capabilities, is executed. Different applications are transported through dedicated VPNs in a point-to-point, point-to-multipoint, or multipoint-to-multipoint manner.

#### High availability through IP/MPLS

High availability is essential to a railway operator's communications network, which carries mission-critical voice, video and data information. With the Alcatel-Lucent IP/MPLS network, railway operators have the necessary reliability level to maintain uninterrupted operations. The MPLS FRR feature enables the network to reroute connections around a failure. Because the network is service aware, FRR can distinguish and prioritize traffic redirection according to priority. To protect the network against node or interconnection failures, end-to-end standby MPLS paths can also be provisioned.

The Alcatel-Lucent IP/MPLS implementation includes the unique additional high availability features of non-stop routing and non-stop services. 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 VPN services are not affected when there is a control fabric module switchover.

Other resiliency features such as pseudowire redundancy, multi-chassis link aggregation group (LAG), multi-chassis automatic protection switching (APS), and synchronization redundancy can also be implemented to maximize network resiliency.

#### Quality of service and traffic management

In a railway communications environment where multiple services converge over a common infrastructure, QoS is essential. The Alcatel-Lucent IP/MPLS network can discriminate among various types of traffic, based on a rich set of classification attributes at Layer 1, Layer 2, Layer 2.5, or Layer 3, and prioritize transmission of higher priority traffic over lower priority. It utilizes extensive traffic management using an advanced scheduling mechanism to implement service hierarchies. These hierarchies provide maximum isolation and fairness across different traffic while optimizing uplink utilization. With multiple levels and instances of shaping, queuing and priority scheduling, the Alcatel-Lucent IP/MPLS network can manage traffic flows to ensure that performance parameters (such as bandwidth, delay and jitter) for each application are met.

#### Network synchronization and timing

Accurate synchronization and microsecond timing is critical in communication networks to maintain network operational integrity. In most TDM networks, synchronization is distributed within the network using the SDH/SONET mechanisms built into the physical layer definition or by distributed global positioning system (GPS) clocks. To deliver the TDM service through a packet network, the same synchronization accuracy or better must be achieved.

To enable rapid and smooth migration of these networks, the Alcatel-Lucent IP/MPLS products support a wide range of synchronization and timing options to ensure that the network is properly synchronized and to allow for deployment of new timing technologies such as Synchronous Ethernet (SyncE) and IEEE 1588v2 Precision Timing Protocol (PTP). The following features are supported:

- External reference timing
- Line timing
- Adaptive clock recovery (ACR) timing
- Synchronous Ethernet
- IEEE 1588v2 PTP

The Alcatel-Lucent implementation of high performance timing for packet solutions are accomplished by a combination of built-in architectural features, efficiently tuned algorithms, and powerful QoS mechanisms to minimize the delay experienced by synchronization traffic.

#### Effective management for easier day-to-day operations

A key element of reliable and flexible IP/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 includes OAM tools that simplify the deployment and day-to-day operation of a railway communications network. For example, service, interface, and tunnel tests allow for rapid troubleshooting and enable proactive awareness of the state of traffic flows to help minimize service downtime.

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 IP/MPLS network, driving network operations to a new level of efficiency. It also provides simplified diagnosis and intuitive visualization of the relationship between services, the MPLS infrastructure and the routing plane. It enables railway operators to overlay Layer 2 and Layer 3 services, MPLS tunnels, and various OAM traces on the control plane map. This application simplifies problem resolution, reduces control plane configuration errors, and reduces troubleshooting time.

#### Support for key applications

The Alcatel-Lucent IP/MPLS network has proven to be highly successful in supporting innovative applications.

#### Synchronization for GSM-R base stations

To deliver the TDM service through a packet network, the same or better synchronization must be achieved. Some TDM applications require stratum-level clocking and distribution of information with very stringent accuracy. Synchronous Ethernet is an easy way to achieve (frequency) synchronization and to allow the benefits of an Ethernet network infrastructure to be realized without any change to the existing TDM network applications. The concept behind SyncE is similar to SDH/SONET system timing capabilities.

With SyncE, the network elements derive the physical layer transmitter clock from a high-quality frequency reference using the physical Ethernet interfaces. The Alcatel-Lucent IP/MPLS products support SyncE, which has proven to out-perform the standards requirements used by SDH/SONET, allowing migration from SDH/SONET to a full IP/MPLS network as desired.

One application where Synchronous Ethernet has proven effective in allowing railway operators to migrate their network to IP/MPLS and save costs is in the deployment of GSM-R over a single, unified network. Traditionally supported on SDH networks, GSM-R is a secure platform for voice and data communication between railway operational staff. GSM-R base stations need to be fed with synchronization of E1 circuits. The Alcatel-Lucent IP/MPLS network is able to comply with stringent ITU-T specifications including G.8261/8262 and G.823/824/825. SyncE is used to distribute synchronization to GSM-R base stations, as depicted in Figure 6.



#### Figure 6. Synchronous Ethernet for GSM-R base stations

Mission-critical Communications Networks for Railway Operators ALCATEL-LUCENT APPLICATION NOTE

#### Video surveillance

The railway communications network must be able to capably handle the massive amounts of video traffic generated by the CCTVs at each station. Maintaining the flow of this video traffic from each station toward the regional and central operation centers is key to the safe and efficient operation of the railway system. For example, Alcatel-Lucent developed a fully IP/MPLS-based solution to support train dispatch by the driver using CCTV. Video cameras on the platform transfer images directly to a monitor in the driver's cab and to the control center. The system not only speeds up operations, but also enhances safety. Additionally, economic benefits are realized with a reduction in the personnel required for dispatching the trains, especially when the number of trains is high.

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 railway operators 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. The Alcatel-Lucent IP/MPLS network can address the video surveillance requirements for guaranteed delivery of mission-critical CCTV video traffic and concurrent support of other critical data and voice traffic on a single converged network. The network is capable of handling current video traffic levels and future growth, including significant increases in bandwidth.

Distributed video surveillance offers many advantages, including support for real-time video streaming in 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 IGMP to register these devices in 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. Convergence of data, voice and video traffic on a single network creates a need for high-capacity networks that support high bandwidth and flexible multipoint communications. An IP/MPLS network is capable of connecting several thousand CCTV cameras.

#### Support for LTE

Many mobile operators worldwide have deployed the Alcatel-Lucent IP/MPLS network for LTE backhaul. The same IP/MPLS network that a railway operator can deploy to support all the communications requirements today is also ready to effectively support future LTE backhaul deployment when the industry adopts the technology.

### CONCLUSION

Railway operators should ensure that their communications network transformation includes an IP/MPLS network, as only IP/MPLS can provide the reliability that is needed for mission-critical services. The Alcatel-Lucent IP/MPLS communications network can help a railway operator extend and enhance its network with new technologies

like IP, MPLS, and Ethernet while fully supporting existing TDM applications. These new technologies will enable the railway operator to optimize its network flexibility and management in order to reduce both CAPEX and OPEX without jeopardizing safety, security or reliability. A service-aware IP/MPLS network provides the benefit of supporting converged voice, data and video applications that can be managed through configurable QoS levels. The Alcatel-Lucent IP/MPLS product portfolio leads the industry in reliability and OAM tools, key enablers for meeting the "always-on" requirement for mission-critical railway operations. The Alcatel-Lucent IP/MPLS network can help address railway communications challenges with:

- High network availability
- Network virtualization
- QoS guaranteed for priority traffic
- Support for existing mission-critical TDM services and new IP and Ethernet applications
- Flexible synchronization options
- Reduced operating and maintenance costs
- Improved passenger safety through effective, always-on communications
- Readiness for LTE deployment

# ACRONYMS

ACR	adaptive clock recovery	MAC	media access control
APS	automatic protection switching	MPLS	Multiprotocol Label Switching
BTS	base transceiver station	MPR	Microwave Packet Radio
CAPEX	capital expenditure	OAM	operations, administration, and maintenance
CBTC	Communication-Based Train Control	ODU	outdoor unit
CCTV	closed-circuit television	OPEX	operating expense
CES	Circuit Emulation Service	P25	Project 25
CES IWF	Circuit Emulation Service interworking function	PDH	Plesiochronous Digital Hierarchy
CESoPSN	Circuit Emulation Service over Packet Switched	PE	provider edge
	Network	PSS	Photonic Service Switch
CODEC	coder/decoder	PTC	Positive Train Control
CWDM	coarse wavelength division multiplexing	PTP	Precision Timing Protocol
DWDM	dense wavelength division multiplexing	QoS	quality of service
E&M	Ear and Mouth	SAM	Service Aware Manager
ERPS	Ethernet Ring Protection Switching	SAR	Service Aggregation Router
ERTMS	European Rail Traffic Management System	SAS	Service Access Switch
ESS	Ethernet Service Switch	SAToP	Structure Agnostic TDM over Packet
FR	frame relay	SCADA	Supervisory Control and Data Acquisition
FRR	Fast Reroute	SDH	Synchronous Digital Hierarchy
FXO	Foreign eXchange Office	SLA	service level agreement
FXS	Foreign eXchange Subscriber	SNMP	Simple Network Management Protocol
GigE	Gigabit Ethernet	SONET	Synchronous Optical Network
GPS	Global Positioning System	SR	Service Router
GSM-R	Global System for Mobile Communications – Railway	SyncE	Synchronous Ethernet
ICT	information communications technology	TDM	time division multiplexing
IGMP	Internet Group Management Protocol	TETRA	Terrestrial Truck Radio
IP	Internet Protocol	VLAN	virtual local area network
ITU-T	International Telecommunication Union-	VPLS	virtual private LAN service
	Telecommunication Standardization Sector	VPN	virtual private network
LACP	Link Aggregation Control Protocol	VPRN	virtual private routed network
LAG	link aggregation group	VRF	virtual routing and forwarding
LAN	local area network	WAN	wide area network
LDP	Label Distribution Protocol	WLAN	wireless local area network
LSP	label switched path		

LTE Long Term Evolution

