TRANSFORMING CRITICAL COMMUNICATIONS NETWORKS FOR SUBSTATION AUTOMATION

COMMUNICATIONS NETWORK INFRASTRUCTURE REQUIREMENTS AND ARCHITECTURES

TECHNOLOGY WHITE PAPER

With a range of compelling market drivers, power utilities are transforming the way they operate and how they deliver electricity to customers. One of the principal changes is the technological development of substation automation to improve smart grid performance and efficiency and to simplify substations. Substation automation calls for extensive real-time operational information exchange and alarm status monitoring by deploying next-generation IP- and Ethernet-based intelligent electronic devices (IEDs).

To handle this IP and Ethernet traffic, a new communications network infrastructure is required inside the substation and in the WAN connecting the substations and control center. This paper describes the requirements and outlines the architectures and Alcatel-Lucent IP/MPLS solutions for smart grid infrastructures that enable substation automation, within and between substations and in the WAN. The paper also provides information about the current Smart Substation project in France, in which Alcatel-Lucent is playing a key role in implementing digital smart substations for significant electrical grid performance improvements and cost reduction.

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ORIGINS AND DRIVERS OF SUBSTATION AUTOMATION

Electric utilities are transforming the way they operate and how they deliver electricity to customers. The market is driving a range of changes:

- Increased power grid reliability and avoidance of blackouts
- Introduction of renewable energy, which causes energy generation to become distributed and irregular
- Emergence of electric vehicles and the associated mobility
- Improvement of power quality by eliminating voltage surges and brownouts
- Decreased transmission and distribution energy loss

One of the principal changes is the technological development of substation automation to improve grid performance and efficiency and simplify substation operation. Substation automation calls for extensive real-time operational information exchange and alarm status monitoring by deploying next-generation IP- and Ethernet-based intelligent electronic devices (IEDs). This information must be exchanged with other IEDs in the same or neighboring substations, or in control-center supervisory equipment for control, protection, wide-area situational awareness, fault and outage prevention management, and operational optimization of the grid.

To meet these challenges and to handle new IP and Ethernet traffic, a new communications network infrastructure is required inside the substation and in the WAN connecting the substations and control center. This paper identifies the requirements and outlines the architectures and solutions for the infrastructure that enables substation automation.

Substation automation and IEDs

The substation automation initiative originated in electronics and computer technology advances that triggered the evolution of substation equipment from electromechanical devices to microprocessor-based next-generation IEDs such as digital protection relays, digital transducers, recloser controls and programmable logic controllers. These smart digital IEDs perform traditional functions such as protection, remote monitoring and control at a lower cost and with less physical space compared to their electromechanical precursors.

To address the previously listed market-driven changes, utility companies are also deploying new IED-based grid applications, such as wide area measurement (WAM), volt-VAR optimization (VVO), and fault detection, isolation and recovery (FDIR), also known as fault location, isolation and service restoration (FLISR).

The next-generation IEDs are IP- and Ethernet-based. Depending on the application, IEDs can frequently transmit and receive control and data information to and from other devices inside substations, at neighboring substations, and control-center master equipment. For example, digitized measurement readings carried in the Sampled Value (SV) protocol can be above 10 Mb/s per SV source with a high sampling rate.[1]

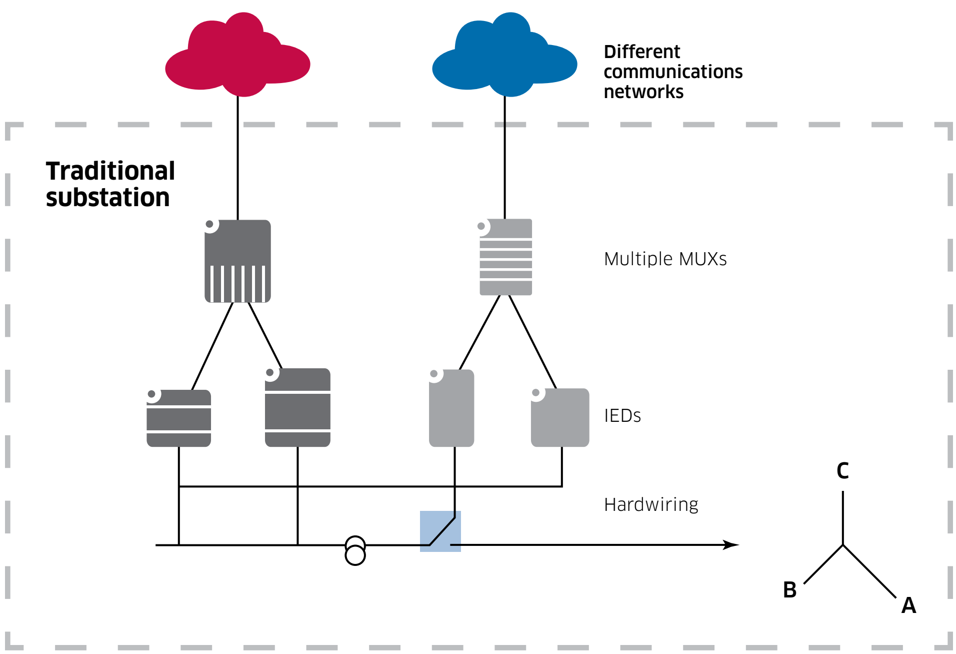
1 According to IEC/TR 61850-90-4, section 4.2.5, an SV message of typical size of 160 octets can be transmitted as frequently as every 250 µs in a 50 Hz grid or 208.3 µs in a 60 Hz grid. This amounts to 10.2 Mb/s or 12.3 Mb/s respectively.

ENABLING SUBSTATION AUTOMATION IN COMMUNICATIONS NETWORKS

Building a best-in-class communications network is indispensable when implementing substation automation. Today, substation equipment vendors use proprietary communication protocols, with a lack of interoperability. The physical partitioning of communications networks causes multiple network silos, with rigid hardwiring between devices inside substations. In addition, fixed TDM and multiple physical circuits in the WAN form multiple networks overlaying the same physical network infrastructure.

Figure 1 shows the high-level architecture of a traditional substation.

Figure 1. Traditional substation architecture



IEC 61850 and communications network standardization

Capitalizing on the evolution of substation automation and the trend toward open interoperability in the communications industry, IEC Technical Committee 57 has standardized the substation automation communications network in IEC 61850. The IEC 61850 suite defines both the communications network architecture and communication protocols. With the adoption of IEC 61850, power utilities can benefit from:

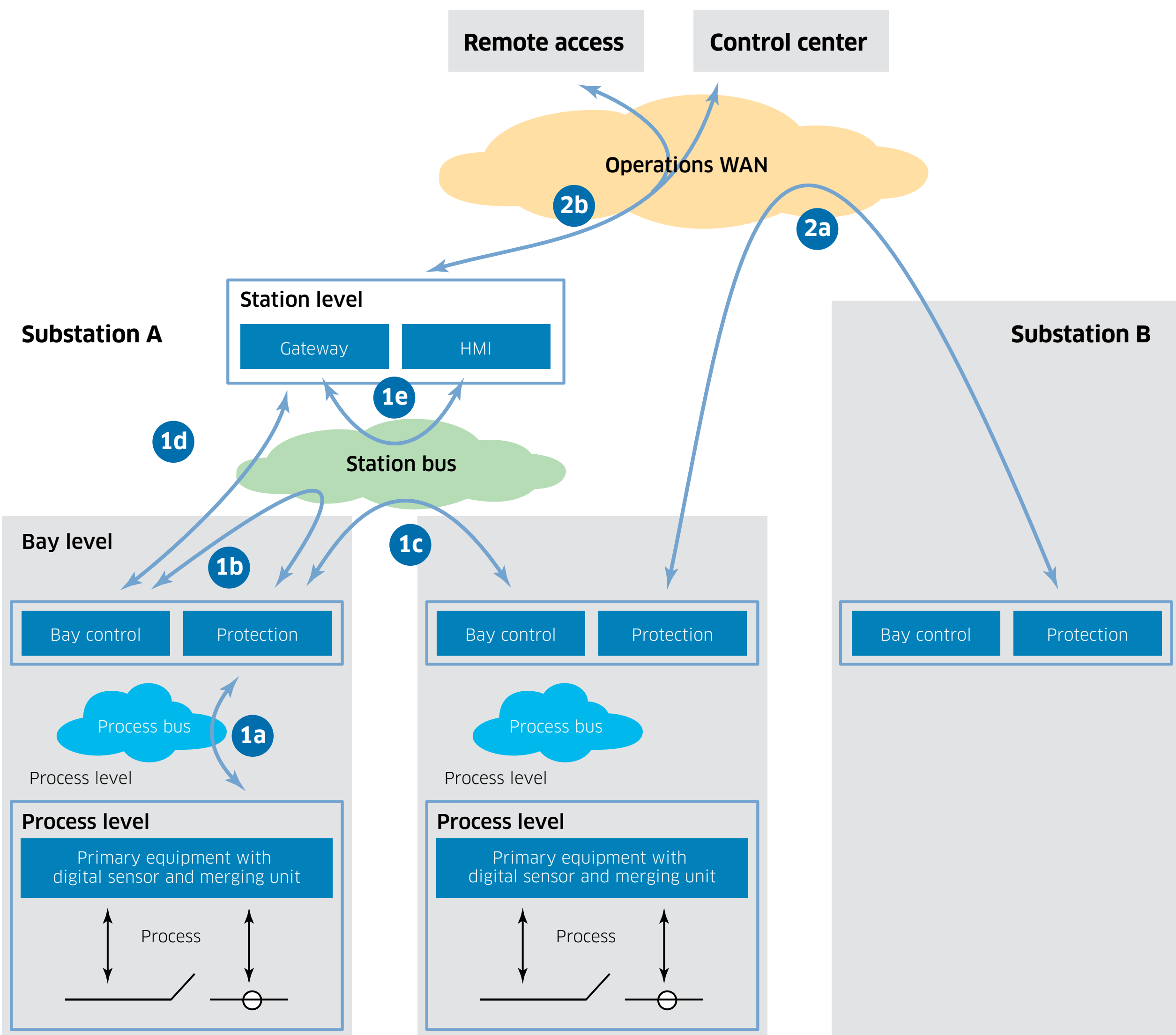
- Interoperability among substation equipment vendors, enabling multivendor application environments
- Deployment of cost-effective, fiber-based optical Ethernet LANs instead of hardwiring at the process level, for significant material and installation cost savings
- Consolidation of multiple network overlays into one converged next-generation communications network

IEC 61850 identifies two types of traffic flow in communications networks, as shown in Figure 2:

- Flow type 1 (Figure 2, 1a to 1e) for traffic flow within the substation (intra-substation)
- Flow type 2 (Figure 2, 2a and 2b) for traffic flow outside the substation over the WAN to another substation (inter-substation) or to the control center

The next sections provide descriptions of these traffic types.

Figure 2. IEC 61850 communications network architecture



IEC 61850 defines two types of protocol stack, as shown in Figure 3:

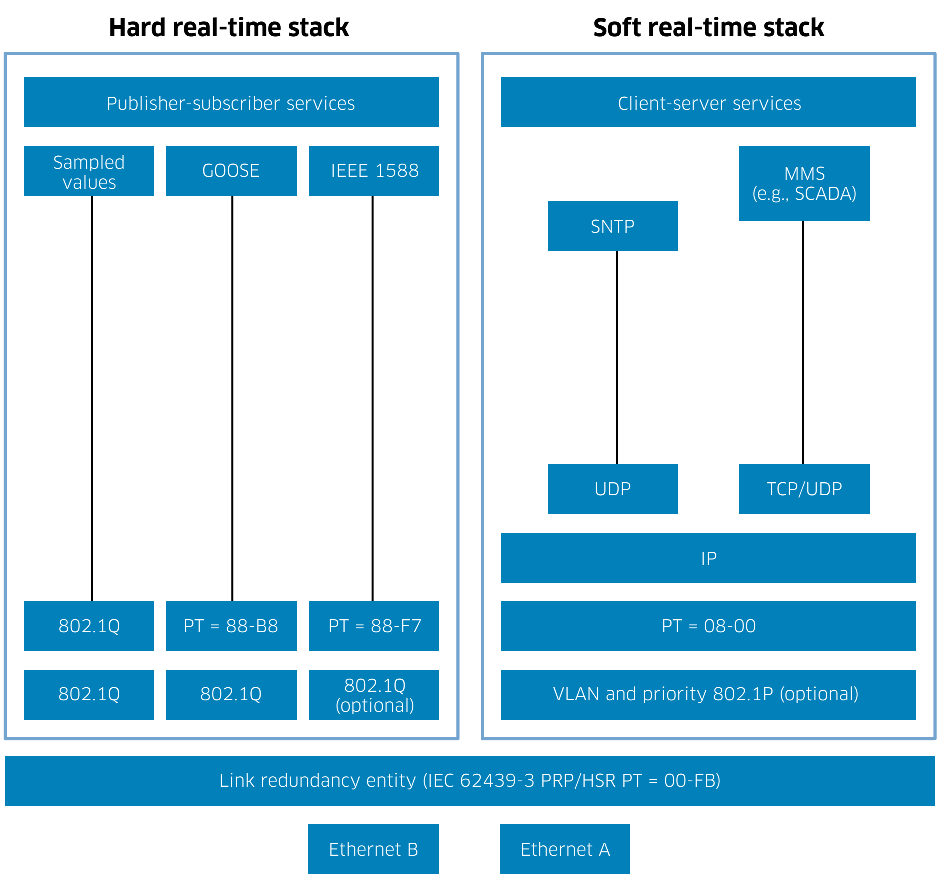
- **Hard real-time stack:** Contains delay-sensitive traffic and requires real-time processing by such applications as SV, carrying digitized current and voltage measurements and Generic Object Oriented Substation Events (GOOSE) for teleprotection.

  To speed application processing, the communication protocol stack is reduced to the minimum of Ethernet only.

- **Soft real-time stack:** Contains traffic that requires reliable delivery but is not as delay-sensitive.

  Examples of traffic types are Manufacturing Message Specification (MMS)-based applications such as supervisory control and data acquisition (SCADA) with Distributed Network Protocol version 3 (DNP3) or IEC 60870-5-104 and WAM/synchrophasor.

Figure 3. IEC 61850 protocol stack



INTRA-SUBSTATION COMMUNICATIONS FOR SUBSTATION AUTOMATION

Early substation architecture adopted a centralized concept because of limited processor power and communications technology. Defined in IEC 61850, the new processor-empowered IED-based architecture is distributed in three levels inside a substation, as shown in Figure 2:

- **Process level:** Bottom level, for instrumental transformers and switch equipment
- **Bay level:** Middle level, for the bay controller and IEDs for metering, disturbance recorder and protection
- **Station level:** Top level, for station computers and control

A process bus operates between the process and bay levels, and a station bus operates between the bay and station levels. "Bus" is a standard term for a broadcast domain, such as a LAN. The process bus and station bus enable communications among the three levels as shown in Figure 2, flow 1a to 1e.

Process bus traffic

The process bus connects plant equipment (intelligent switch equipment as well as current and voltage transformers) and IEDs. The traffic is typified by flow 1a for communication between plant equipment IEDs and mainly comprises SV, GOOSE and MMS protocol messages. The process bus must provide guaranteed Quality of Service (QoS) for real-time SV and GOOSE traffic and reliable delivery for MMS traffic.

Station bus traffic

The station bus interconnects the entire substation and provides connectivity between central management and the individual bays. The station bus also connects the devices within a bay and between different bays. This traffic is typified by:

- Flow 1b for data exchange within the bay level
- Flow 1c for direct data exchange between bays, especially for fast functions such as interlocking
- Flow 1d for the exchange of protection data and control data between the bay and station levels
- Flow 1e for data exchange within the station level, such as between the SCADA gateway and its human-machine interface (HMI) computer

The traffic is mainly GOOSE, MMS, Simple Network Management Protocol (SNMP) and File Transfer Protocol (FTP) messages as well as video and Voice over IP (VoIP). SV messages are also sometimes used in busbar protection applications.

Intra-substation communication requirements

Intra-substation communications involve a range of network requirements:

- Network virtualization
- Redundancy protection
- Advanced traffic management
- Operations, administration and maintenance (OAM) performance and fault management
- Security
- Synchronization

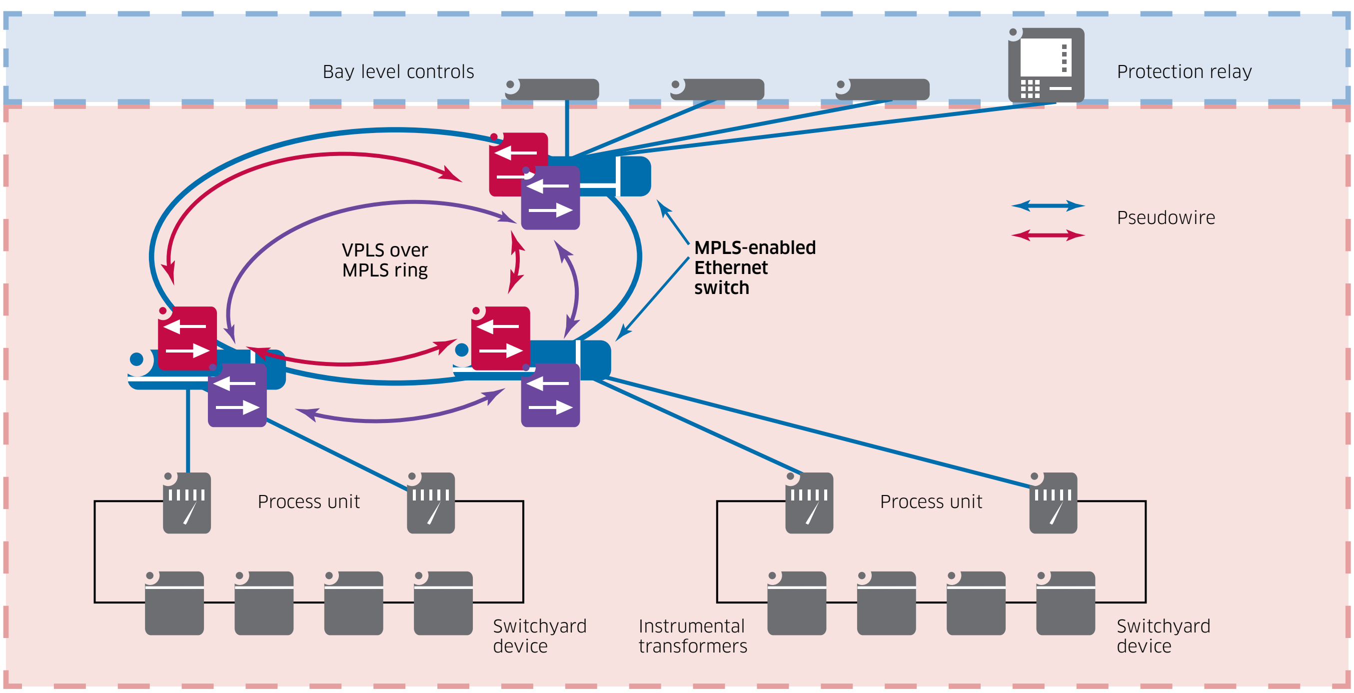
- **Network virtualization**

As previously described, traffic generated by multiple applications — for example, teleprotection, SCADA and SV — is carried over the substation communications infrastructure. To support a multiservice architecture, network virtualization with virtual LAN (VLAN) bridging is required to isolate each application. Each virtual bridge must have its own Media Access Control (MAC) forwarding table to process the traffic, QoS policy, and bandwidth partitions. There are two Ethernet networking options: Virtual Private LAN Service (VPLS) over Multiprotocol Label Switching (MPLS) ring or VLAN ring.

VPLS over MPLS ring

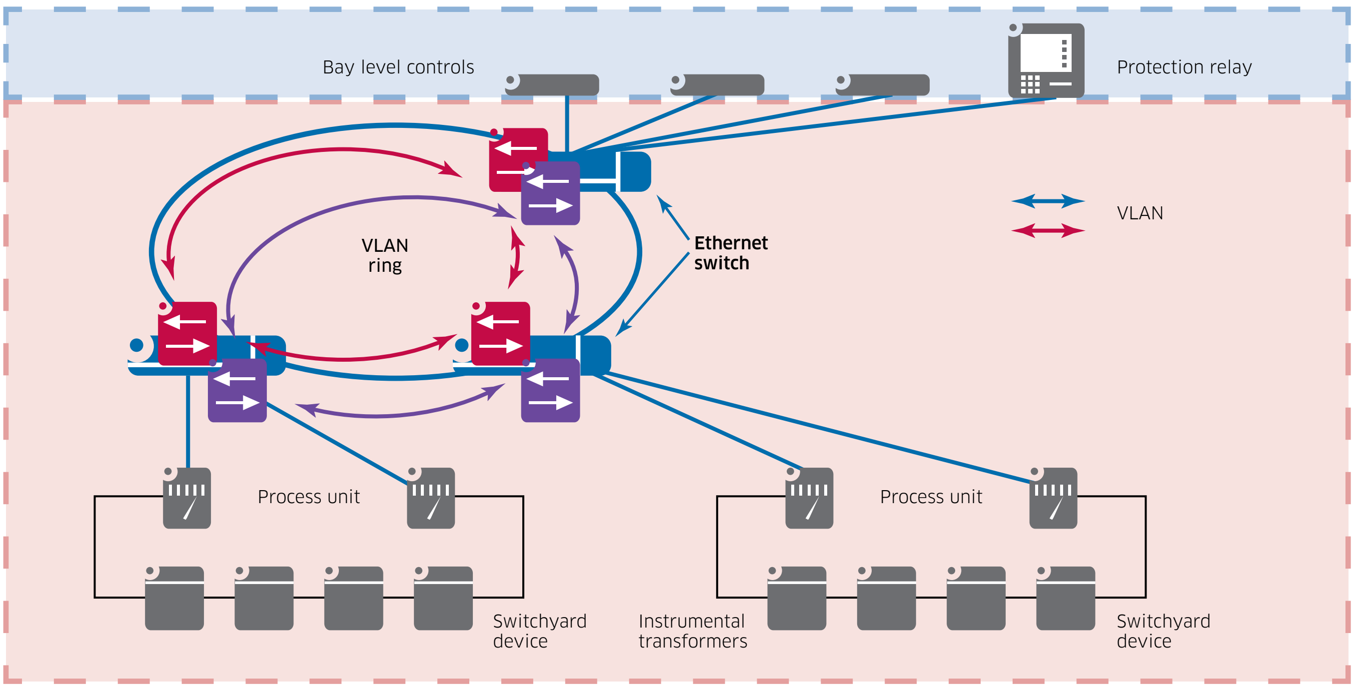
A VPLS creates a virtualized LAN connected by a pseudowire that runs over an MPLS tunnel between nodes. A VPLS is fully capable of learning and forwarding on Ethernet MAC addresses and is interoperable with E-LAN switches. Connected by a pseudowire over MPLS (see Figure 4), a VPLS can capitalize on MPLS in SDH/SONET-like ring recovery and a full OAM suite. Moreover, the same MPLS technology in the substation network and in the WAN enables synergy, with a common network design methodology and operation procedure design. The use of MPLS in the WAN is discussed later in this paper.

Figure 4. VPLS over MPLS ring



VLAN ring
VLAN bridging is used to virtualize the Ethernet ring by connecting the Ethernet switches with the VLAN trunk in the ring (see Figure 5). ITU-T G.8032 or Rapid Spanning Tree Protocol (RSTP) can be used to prevent loop formation in the ring.

Figure 5. VLAN ring

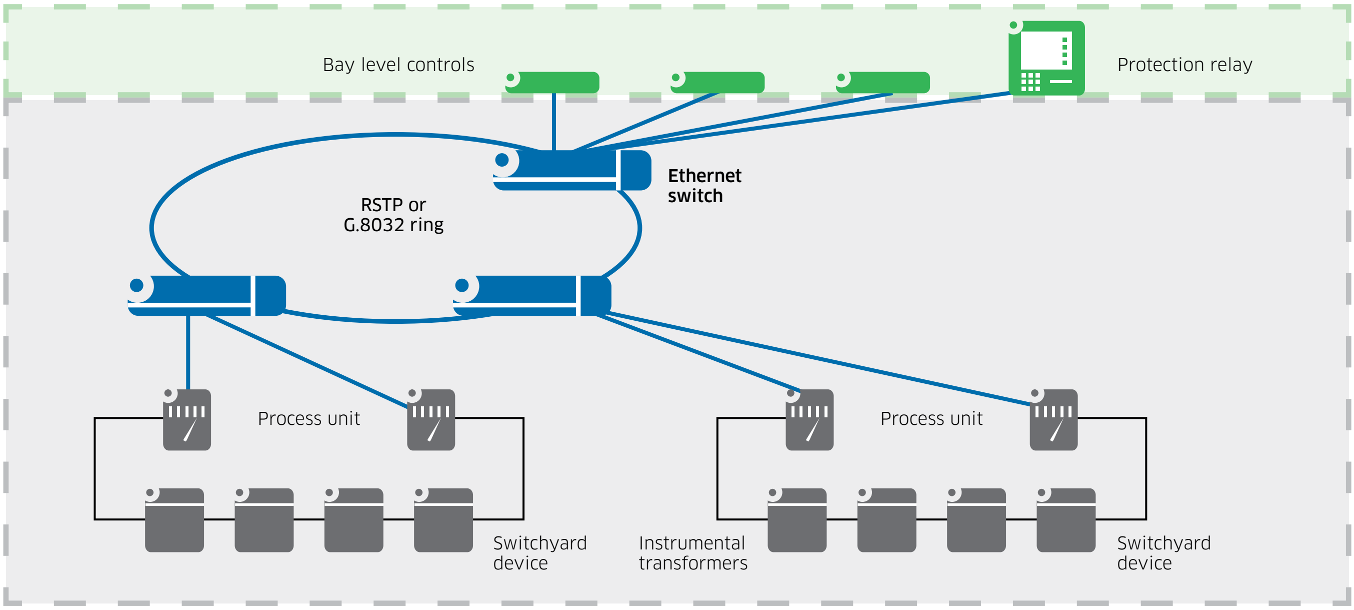


- **Redundancy protection**

Redundancy protection is essential when carrying critical industrial applications. As shown in Figure 6, a ring topology is optimal for providing network redundancy. In case of a link failure in the network, RSTP or Ethernet Ring Protection Switching (ITU-T G.8032) can be used for network recovery. Because ITU-T G.8032 uses ITU-T Y.1731 OAM for quick fault detection and is optimized for ring protection, it can provide SDH/SONET-like speed for switching protection.

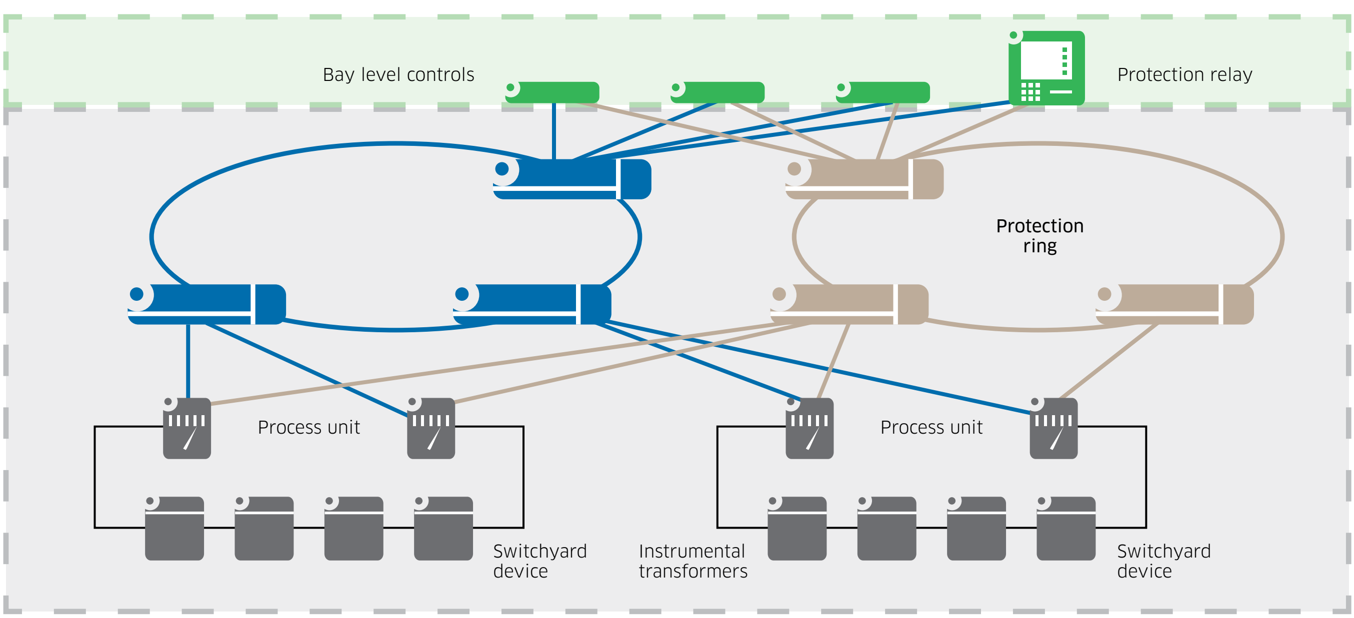
However, the Ethernet links between process units and the Ethernet switch remain a point of failure. In addition, the SV protocol requires seamless redundancy protection with zero failover time, which goes beyond what a communications network can support. IEC 61850 therefore standardizes application-level protection schemes that ride transparently over the E-LAN: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR).

Figure 6. Ethernet ring in substation bus



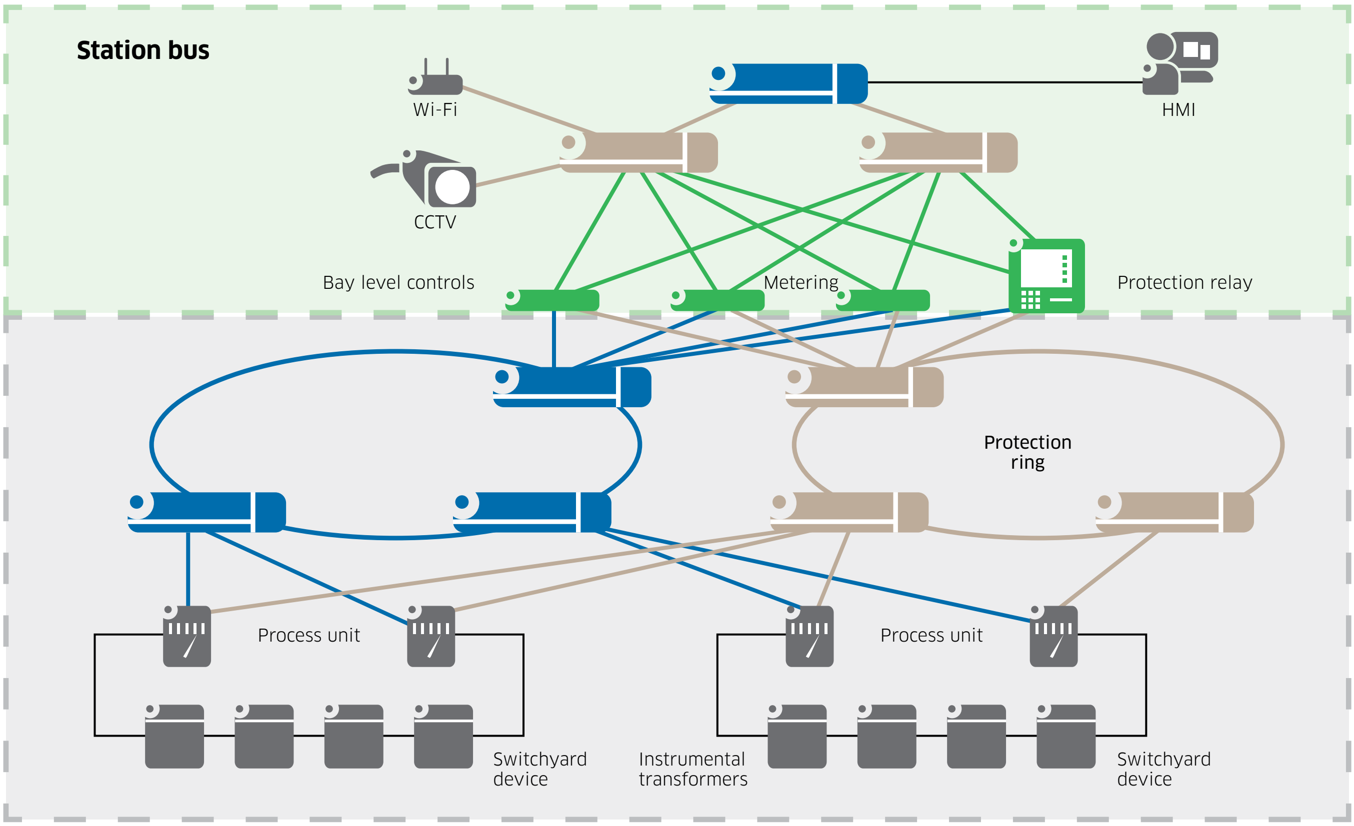
The PRP end device has two links that connect to two parallel LANs of any topology, including ring and star. Figure 7 shows a reference ring architecture. The process bus transmits and receives duplicated traffic in both networks and can filter on only one flow. In case of an end-link failure or multiple failures in the LAN, communications can continue using the second link and second ring without traffic loss.

Figure 7. Process bus with PRP



At the station bus, unless SV messages are also carried, a meshed or ring architecture can usually be used to provide redundancy, as shown in Figure 8.

Figure 8. Station bus architecture



HSR is another application-level scheme that works transparently with existing LANs. However, the underlying LAN is restricted to a ring architecture.

- **Advanced traffic management**

Because some applications are delay-sensitive and operate in real time, the network must be able to deliver this traffic with complete reliability. The network platform must, on a per-VLAN basis, perform hardware-based switching with low latency and advanced traffic classification, using a high-priority forwarding class without sacrificing forwarding performance.

Traffic queuing and scheduling on a per-application, per-class basis enable the appropriate sharing of Ethernet link bandwidth while managing application delivery. Combining traffic queuing and scheduling with hierarchical traffic rate limiting or shaping guarantees the proper bandwidth amount and priority for each application to run seamlessly.

- **OAM performance and fault management**

Delay is critical for some traffic flows, so it is important that network performance measurement — for example, delay, jitter and packet loss — can be continually verified at all substations. When the measurement threshold is reached or exceeded, a comprehensive suite of OAM tools should be available for troubleshooting at different locations for different layers. The OAM measurements can be orchestrated from the management platform using a lightweight portal that can also generate statistics reports.

- **Security**

As critical infrastructure, substation equipment must have strong protection. In North America, the Federal Energy Regulatory Commission (FERC) has adopted Critical Infrastructure Protection (CIP) Version 5, authored by the North American Electric Reliability Corporation (NERC), as the mandatory guidelines for power utilities to follow. Internationally, the IEC 62351 and ITU-T X.805 standards are the key recommendations.

Within the sheltered substation environment, security protection with authentication for access to the Ethernet switch is necessary for preventing unauthorized access, using a mechanism such as Terminal Access Concentrator Access Control Server Plus (TACACS+) or Remote Authentication Dial-In User Service (RADIUS). The Ethernet switch must also support mechanisms such as syslog and user activity accounting for security audits. Moreover, all Ethernet ports should be disabled by default to provide port security and to support IEEE 802.1X authentication. To detect physical intrusions, dry contacts on the Ethernet platform can be used to relay alarms from local facility surveillance systems.

- **Synchronization**

Time-of-day synchronization is becoming a critical requirement with the introduction of new applications — for example, SV and IED devices such as merging units. This type of IED can obtain synchronization using IEEE 1588v2 distribution of time-of-day information in addition to Inter-Range Instrumentation Group Format B (IRIG-B) interface. IRIG-B signal is carried in separate wiring and is more popularly supported today. However, the network must be built with IEEE 1588 readiness for future evolution.

Alcatel-Lucent networking solution for intra-substation communications

The Alcatel-Lucent 7210 Service Access Switch (SAS)-based Ethernet networking solution inside substations can help network operators to build a network that fulfills the requirements listed in Table 1.

Table 1. Fulfilling substation LAN communication requirements with the Alcatel-Lucent Ethernet solution

Substation LAN requirement	Alcatel-Lucent substation Ethernet networking solution features
Redundancy protection	• Application layer: PRP/HSR in IED • Ethernet layer: MPLS FRR, ITU-T G.8032, RSTP, LAG
Network virtualization	• VPLS or VLAN bridging
QoS	• Flexible and advanced hierarchical queuing and scheduling • VID, IEEE 802.1P, IP 5-tuples classification
OAM performance and fault management	• On-node service assurance agent directed by network manager with report generation
Security	• Strong authentication capability • Comprehensive syslog and user accounting for audit trail • IEEE 802.1X port authentication • Ethernet port down by default

Together with the service-aware Alcatel-Lucent 5620 Service Aware Manager (SAM) and Alcatel-Lucent Service Portal Express for Utilities, this solution brings a range of benefits to power utilities, including rapid provisioning and work order processing, scalable performance management, and report generation. Figure 9 shows the solution components.

Figure 9. Alcatel-Lucent intra-substation communications solution

Table 2 lists the Alcatel-Lucent solution highlights. For more information, see http://www.alcatel-lucent.com/power-utilities/critical-wide-area-network.

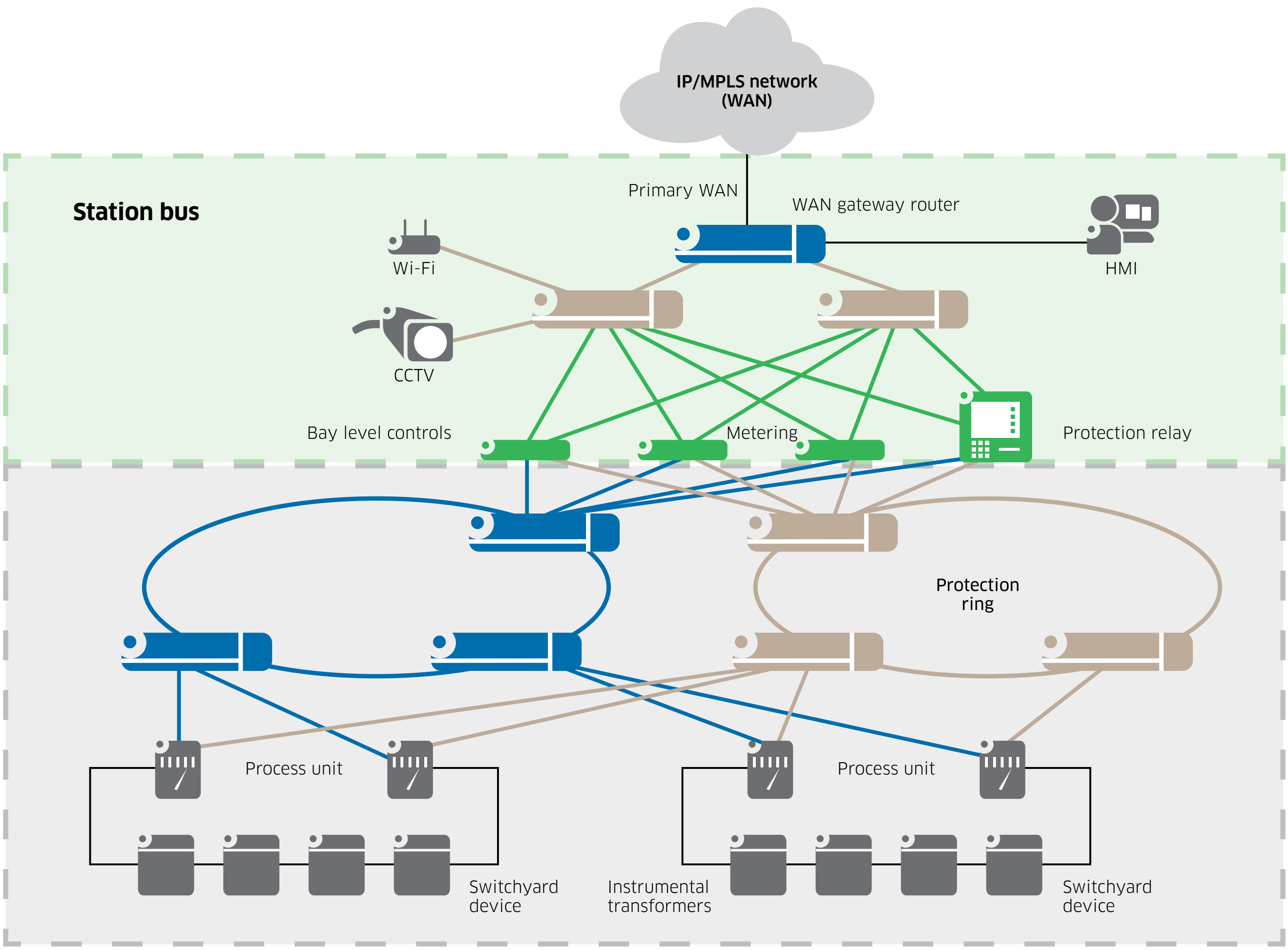
Table 2. Alcatel-Lucent intra-substation communications solution

7210 SAS	5620 SAM	Service Portal Express for Utilities
Flexible substation-grade Ethernet access and aggregation platform	End-to-end service-aware management platform	Agile web-based portal for utilities
• 10GE link support and up to 124 Gb/s half-duplex capacity • Optical integration with DWDM and CWDM • PoE/PoE+ capable	• Rapid provisioning • SLA monitoring with service assurance • Correlated multilayer troubleshooting • Simplified OSS integration	• Wider accessibility for top-level views and comprehensive report generation • Automated controlled work order processing • Proactive network and application assurance

WAN COMMUNICATIONS FOR SUBSTATION AUTOMATION

As previously described, traffic that travels out of a substation into the WAN is destined for another substation or control center. The traffic originates from devices at the process, bay or station level, then exits the substation through a WAN gateway router, as shown in Figure 10.

Figure 10. Substation with WAN gateway router



The WAN gateway functions as a demarcation point between the WAN and the intra-station LAN domains and also as an entry point to all circuits and services in the WAN for communications traffic.

Inter-substation communications

Inter-substation communications serve two main functions, as shown in Figure 2, flow 2a:

- Protection, including distance, differential and phase comparison protection
- Control, such as interlocking

Inter-substation traffic has the following characteristics:

- Delay-sensitive messages encoded directly in the Ethernet payload to minimize processing delays by end devices, as shown in the real-time stack in Figure 3
- Point-to-point between IEDs in two substations
- Evolution to any-to-any nature for future zone-based protection and control applications

TDM-based control and protection traffic from legacy devices will continue to be in use for the next five to ten years. Today, this traffic is typically carried over a TDM/SONET network or even dark fiber.

Substation-to-control center communications

Substation-to-control center communications (Figure 2, flow 2b) enable control center staff to monitor and control the grid at a regional or national level. These types of communications serve a wide range of applications, including:

- SCADA
- Synchrophasor
- Other dispatching applications

In addition to the above operational functions are non-operational applications, such as VoIP, Internet access and video surveillance.

Substation-to-control center traffic has the following characteristics:

- Non-delay-sensitive and encoded over Transmission Control Protocol (TCP)/User Datagram Protocol (UDP) over IP, as in the soft real-time stack in Figure 3
- Point-to-point and multipoint-to-point with traffic that is merged by routing toward a central device
- Delay- and jitter-sensitive traffic from VoIP and video applications

As with inter-substation communications, TDM-based control and protection traffic from legacy devices is expect.ed to be in use for the next five to ten years, carried over a TDM/SONET network

WAN communication requirements

WAN communications involve a range of network requirements:

- Network topology and medium versatility
- Network virtualization and service flexibility
- Redundancy protection
- Traffic engineering
- Advanced traffic management
- OAM performance and fault management
- Security
- Synchronization

- **Network topology and medium versatility**

While it is feasible to choose and build a topology with the optimal choice of fiber inside a substation, this is not always possible in the WAN. Power utilities must be resourceful, making use of whatever network assets are available, including microwave. Where fiber is available, Coarse Wavelength Division Multiplexing (CWDM) technology can be integrated in the network for future traffic growth. Where fiber is not available, an attractive option is next-generation packet microwave, which supports higher transmit power, MPLS-aware packet compression, and advanced microwave link types such as Cross Polarization Interference Cancellation (XPIC).

The WAN circuit or tunnel between any two locations must be built seamlessly and scalably end-to-end, independent of the network topology and network medium in between. The WAN gateway router, which integrates the microwave and CWDM add/drop multiplexer functions, can consolidate multiple layers of different transmission media to streamline the WAN design and operation.

- **Network virtualization and service flexibility**

As previously described, WAN traffic has diverse characteristics: it can ride over Ethernet or IP in real time or non-real time in a point-to-point or multipoint pattern, connecting to neighboring substations or to a control center. Point-to-point and multipoint bridging TDM traffic from current applications must still be transported in the future.

Table 3 lists some major applications and WAN traffic characteristics.

Table 3. WAN traffic characteristics and service types

Application	Interface	Service
Teleprotection	TDM (serial, E&M, ITU-T G.703), Ethernet	TDM circuit emulation, Ethernet
Telecontrol/SCADA	TDM (serial), IPoE	TDM circuit emulation/data bridging, IP/Ethernet
VoIP/CCTV/intranet/Internet	Ethernet/IP	IP routing or Ethernet VLL
IED management	IPoE	IP/Ethernet

The communications network must be virtualized to support each application with the correct type of virtual private network (VPN).

- **Redundancy protection**

High availability in the WAN is critical for reliable grid operation. The WAN must be able to recover at SDH/SONET speed in case of a network failure. In addition, the WAN must support physical-site diversity protection for the control center. In the case of primary control center damage, the substation WAN gateway router automatically switches to the standby control center, which could be far away. This kind of control-site redundancy support is essential for ensuring the continued operation of the grid in case of disaster.

- **Traffic engineering**

With a network topology such as ring or meshed, traffic engineering must be able to achieve network bandwidth and resource optimization, particularly when microwave links are in use. This capability helps operators to direct traffic depending on different criteria, including application type and class of service.

- **Advanced traffic management**

The network must be able to classify and prioritize a diverse mix of traffic according to its forwarding class so that high-priority TDM and real-time traffic is sent with the highest priority while the rest of the traffic is sent reliably across the network.

- **OAM performance and fault management**

Because delay is critical for some traffic flows, network performance — for example, delay, jitter and packet loss — must be continually verified at a wide network scale. When problems occur, a comprehensive suite of OAM tools should be available for troubleshooting different layers.

Performing these kinds of tasks using a traditional command-line interface is tedious and error-prone. A preferred approach is to automate tasks using a network manager so that measurement is scalable and efficient.

- **Security**

As critical infrastructure, the power grid must have strong protection. The WAN router in the network core as well as at the edge (the WAN gateway inside the substation) must provide fortified security protection to the network and to the substation equipment, playing the role of an electronic security perimeter in the routing, signaling and data planes. In North America, NERC CIP Version 5 has been adopted by the FERC as mandatory for power utilities. Internationally, the IEC 62351 and ITU-T X.805 standards are the key recommendations.

Comprehensive protection must occur at both the network infrastructure and service layers in all routing, signaling and data plane dimensions. Moreover, to relay alarms to the control center, the platform can provide dry contacts that connect to a local facility surveillance system.

- **Synchronization**

Synchronization is critical for ensuring that applications run smoothly. Legacy TDM-based applications such as teleprotection and SCADA require end-to-end frequency synchronization. Depending on the network topology and transmission medium, there are different frequency synchronization options. For example, line synchronization from Synchronous Ethernet, microwave link and SDH/SONET links is ideal for transporting frequency synchronization.

When line synchronization is not feasible, IEEE 1588v2 delivery over the WAN is possible if the network elements can provide IEEE 1588v2 hardware assist in the form of a boundary clock or transparent clock. The WAN gateway router, as an IEEE 1588v2 slave, can recover and distribute the frequency to other devices as required.

New IP/Ethernet-based applications, including SV and WAM, require time-of-day synchronization, almost always delivered by a local standalone global positioning system (GPS) receiver that is the time-of-day synchronization source for the entire substation. The WAN gateway router, with an integrated GPS receiver, can incorporate this role, thereby reducing equipment. Based on the synchronization information in the GPS signal, the WAN gateway router can act as the source for time-of-day synchronization using IEEE 1588v2 messages or IRIG-B.

With growing concern about the vulnerabilities of GPS to accidental or intentional interference, much consideration is being given to the use of network-wide time-of-day synchronization distribution, with IEEE1588v2 as a backup to local GPS reception. Therefore, the WAN network with IEEE 1588v2 hardware assist can also be a backup source.

Alcatel-Lucent networking solution for substation WAN communications

The Alcatel-Lucent IP/MPLS-based network solution can help network operators to build a network that fulfills the requirements listed in Table 4.

Table 4. Fulfilling WAN communication requirements with the Alcatel-Lucent IP/MPLS solution

WAN requirement	Alcatel-Lucent IP/MPLS solution features
Network topology and medium versatility	MPLS is topology- and medium-agnostic
Network virtualization and service flexibility	IP/MPLS-based VPN can be a L1, L2, L3 or integrated L2/L3 VPN for point-to-point and multipoint connectivity
Redundancy protection	Wide range of tools, including FRR, backup LSP, pseudowire redundancy combined with VRRP, LAG, and BFD
Traffic engineering	On-node CSPF with flexible constraint-based path calculation
Advanced traffic management	Hierarchical scheduling and QoS
OAM performance and fault management	On-node service assurance agent directed by network manager with report generation
Security	Rich set of control, data and management plane security-protection capabilities
Synchronization	Full IEEE 1588v2 support (master, boundary clock, transparent clock, slave) and integrated GPS receiver

The Alcatel-Lucent 7705 Service Aggregation Router (SAR) is a family of IP/MPLS service aggregation platforms for WAN substation automation deployment. Together with the service-aware 5620 SAM and Service Portal Express, the solution enables power utilities to benefit from rapid provisioning and work order processing, scalable performance management and documentation, and report generation. Figure 11 shows the solution components.

Figure 11. Alcatel-Lucent WAN communications solution

Table 5 lists the Alcatel-Lucent solution highlights. For more information, see http://www.alcatel-lucent.com/power-utilities/critical-wide-area-network.

Table 5. Alcatel-Lucent WAN communications solution

7705 SAR	5620 SAM	Service Portal Express for Utilities
Flexible utility-grade IP/MPLS router	End-to-end service-aware management platform	Agile Web-based portal for utilities
• 10GE link with up to 60 Gb/s half-duplex capacity • Integration with packet microwave, CWDM and GPS • PoE/PoE+ capable	• Rapid provisioning • SLA monitoring with service assurance • Correlated multilayer troubleshooting • Simplified OSS integration	• Enables wider accessibility for top-level views and comprehensive report generation • Automates a controlled work order process • Proactive network and application assurance

CASE STUDY: *SMART SUBSTATION* PROJECT IN FRANCE

The digital control/command-based operations model in IEC 61850, as well as the critical need for the exchange of reliable real-time information between substations, is mandating a new way of building and operating communications networks.

The goal of the *Smart Substation* project is to devise an open, IP/MPLS-based communications solution that facilitates the secure, reliable and efficient delivery of all application data and results, with significant electrical grid performance improvement and cost reduction. The main project objectives are:

- Full digitization of all links between high-voltage equipment and IEDs
- Development of an open system architecture that supports a standard interface, with high-level functions such as local state estimation, local analysis and diagnosis of incidents, and auto-adaptive protection schemes
- Implementation of sensors and monitoring for system operations and maintenance
- Implementation of a digital interface between the transmission system operator and distribution system operator
- Full redundancy for relays and SCADA

Innovative solutions will be implemented and tested in real operating conditions with strong cybersecurity measures. The project will demonstrate the benefits of substation automation:

- Lower environmental impact
- Better integration of renewable energies
- Improved transmission capacities
- Optimal use of existing assets

The consortium that is executing the Smart Substation project comprises:

- Réseau de Transport d'Électricité (RTE) and Électricité Réseau Distribution France (ERDF), the two major transmission system and distribution system operators in France
- Four leading industrial companies: Alcatel-Lucent, Alstom Grid, Schneider Electric and Neelogy

The project consortium aims to complete the design, implementation and testing phases and start operating two fully digital smart substations as part of the transmission grid in 2015.The initial trial will start in early 2014 in the northern region of Somme, where wind-power production capacities are the highest in France.

Participation of Alcatel-Lucent

The Smart Substation project provides a forum for transmission and distribution system operators, electric system vendors and communications equipment vendors to work together to formulate a blueprint. The project also enables the consortium to fully demonstrate the seminal role that a digital smart substation can play in grid modernization to efficiently and reliably fulfill future electricity demands.

Alcatel-Lucent brings communications and security expertise to the Smart Substation project. With its world-class IP/MPLS solution, Alcatel-Lucent is uniquely positioned to help organizations design and deploy highly available and secure communications systems in mission-critical networks.

For decades, Alcatel-Lucent has partnered with power utilities worldwide and is now a full participant in their evolution toward a smart grid, in which substation automation is a major component. With these efforts, it is increasingly recognized that a communications network is the foundation of a smart grid. For the Smart Substation project, Alcatel-Lucent is identifying communications network requirements, network architecture design, and wide-scale network deployment and operations methodologies.

With its expertise in network defense and security best practices, Alcatel-Lucent is also leading the assessment and analysis of vulnerability risks and the formulation of security strategy and practice to withstand serious network threats and intrusions.

CONCLUSION

Today, power utilities are facing immense challenges:

- Relentless and increasing demand for more electricity
- Widely distributed and irregular energy generation with renewable sources
- Periodic surges of energy consumption by electric vehicles

To meet these demands, the electrical grid must incorporate more intelligence and become digital with substation automation technology.

With its best-in-class, end-to-end managed communications solution, Alcatel-Lucent is partnering with power utilities worldwide to modernize their communications networks and implement successful substation automation.

ACRONYMS

5620 SAM	Alcatel-Lucent 5620 Service Aware Manager
7210 SAS	Alcatel-Lucent 7210 Service Aware Switch
7210 SAS-M	Alcatel-Lucent 7210 SAS (MPLS-enabled utility-grade Ethernet platform)
7210 SAS-T	Alcatel-Lucent 7210 SAS (10GE or PoE/PoE+-capable utility-grade Ethernet platform)
7705 SAR	Alcatel-Lucent Service Aggregation Router
7705 SAR-8	Alcatel-Lucent SAR (fully redundant IP/MPLS router with eight slots)
7705 SAR-H	Alcatel-Lucent SAR (hardened IP/MPLS router)
7705 SAR-Hc	Alcatel-Lucent SAR (hardened compact IP/MPLS router)
BFD	Bidirectional Forwarding Detection
CCTV	closed-circuit television
CIP	critical infrastructure protection
CSPF	Constrained Shortest Path First
CWDM	Coarse Wavelength Division Multiplexing
DNP3	Distributed Network Protocol version 3
DWDM	Dense Wavelength Division Multiplexing
E-LAN	Ethernet LAN
ERDF	Électricité Réseau Distribution France
FDIR	fault detection, isolation and recovery
FERC	Federal Energy Regulatory Commission
FLISR	fault location, isolation and service restoration
FRR	Fast Reroute
FTP	File Transfer Protocol
GE	Gigabit Ethernet
GOOSE	Generic Object Oriented Substation Events
GPS	geo-positioning system
HMI	human-machine interface
HSR	High-availability Seamless Redundancy
IEC	International Electrotechnical Commission
IED	intelligent electronic device
IP	Internet Protocol
IPoE	IP over Ethernet
IRIG-B	Inter-Range Instrumentation Group format B
ITU-T	International Telecommunication Union – Telecommunication Standard
L1, L2, L3	Layer 1, Layer 2, Layer 3
LAG	Link Aggregation Group
LAN	local area network
LSP	Label Switched Path
MAC	Media Access Control
MMS	Manufacturing Message Specification
MPLS	Multiprotocol Label Switching
MUX	multiplexer
NERC	North American Electric Reliability Corporation
OAM	operations, administration and maintenance
OSS	Operations Support System
PoE	Power over Ethernet
PoE+	Enahnced IEEE 802.3at-2009 PoE standard
PRP	Parallel Redundancy Protocol
QoS	Quality of Service
RADIUS	Remote Authentication Dial-In User Service
RSTP	Rapid Spanning Tree
RTE	Réseau de Transport d'Électricité
SCADA	supervisory control and data acquisition
SDH	Synchronous Digital Hierarchy
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
SNTP	Simple Network Time Protocol
SONET	Synchronous Optical Network
SV	Sampled Values
TACACS+	Terminal Access Concentrator Access Control Server Plus
TCP	Transmission Control Protocol
TDM	Time Division Multiplexing
UDP	User Datagram Protocol
VAR	volt-ampere reactive
VID	VLAN ID
VLAN	virtual LAN
VLL	Virtual Leased Line
VoIP	Voice over IP
VPLS	Virtual Private LAN Service
VPN	virtual private network
VRPP	Virtual Router Redundancy Protocol
VVO	volt-VAR optimization
WAM	wide area measurement
WAN	wide area network
XPIC	Cross Polarization Interference Cancellation

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