Alcatel·Lucent

APPLICATION NOTE

Next-Generation Utility Networking

Building a Better Network with IP/MPLS

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Overview

Utility companies rely heavily on their communications infrastructures to ensure the flawless delivery of critical services. As the Utilities Telecom Council's May 2007 research[1] indicates, information management technologies are being integrated with grid operations, to deploy new types of services, including automation systems, metering infrastructures, and control applications to improve customer service and power reliability. Increasingly, the utility network infrastructure must deliver integrated voice, data and video communications to ensure a non-disruptive information flow among all utility personnel and customers. While traditional communications systems have been effective, these newer services can be more effectively delivered alongside the utility's legacy services, in a converged next-generation network.

Alcatel-Lucent has a solution that will enable the utility to maximize the cost-effectiveness and efficiency of its network. The Alcatel-Lucent Next-Generation IP/MPLS Utility Network solution ensures that the utility can continue to operate legacy applications, while adding extensive support for packet-based applications. This application note illustrates the advantage of using IP/MPLS at the core of the network while leveraging microwave wireless and/or fiber optics where appropriate, all within an integrated and end-to-end communications infrastructure.

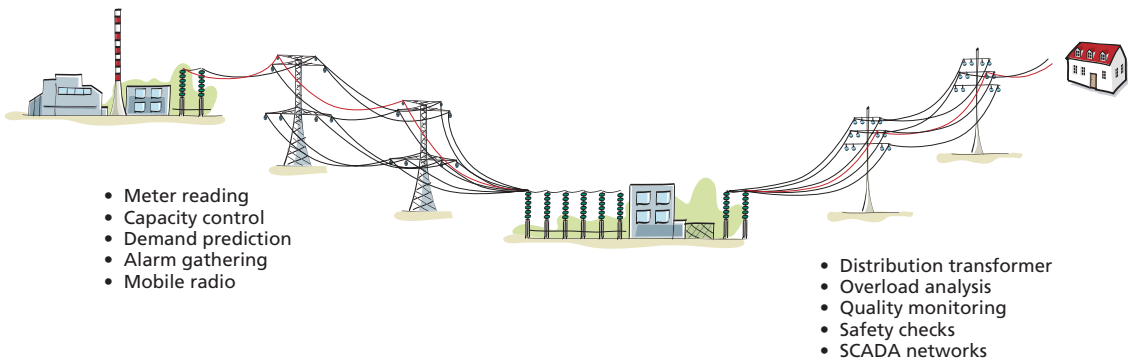
The Traditional Utility Networking Infrastructure

Utilities require critical communications solutions to:

- Ensure flawless operational control of service delivery
- Provide accurate billing for revenue collection
- Maintain a safe environment for employees and the general public
- Offer voice and data applications to improve efficiency and productivity
- Secure operation of electric grids, natural gas pipelines and water supplies

Utility networks are traditionally built to carry information between the utility headquarters and all remote sites — information that is used to manage capacity, monitor and control the system, bill customers and provide mobile radio communication. Traffic is typically carried over time division multiplexing (TDM) based circuits like RS232, V.35, and E&M. Traditional utility applications are shown in Figure 1.

Figure 1. Traditional Utility Operations



[1] *Next Steps to the Next-Generation Utility: An Assessment of Information and Communications Technologies Aiding Migration to Next-Generation Critical Utility Infrastructures.* The Shpigler Group Strategy Management Consulting Services for the Utilities Telecom Council. May 2007.

Bandwidth and Quality of Service

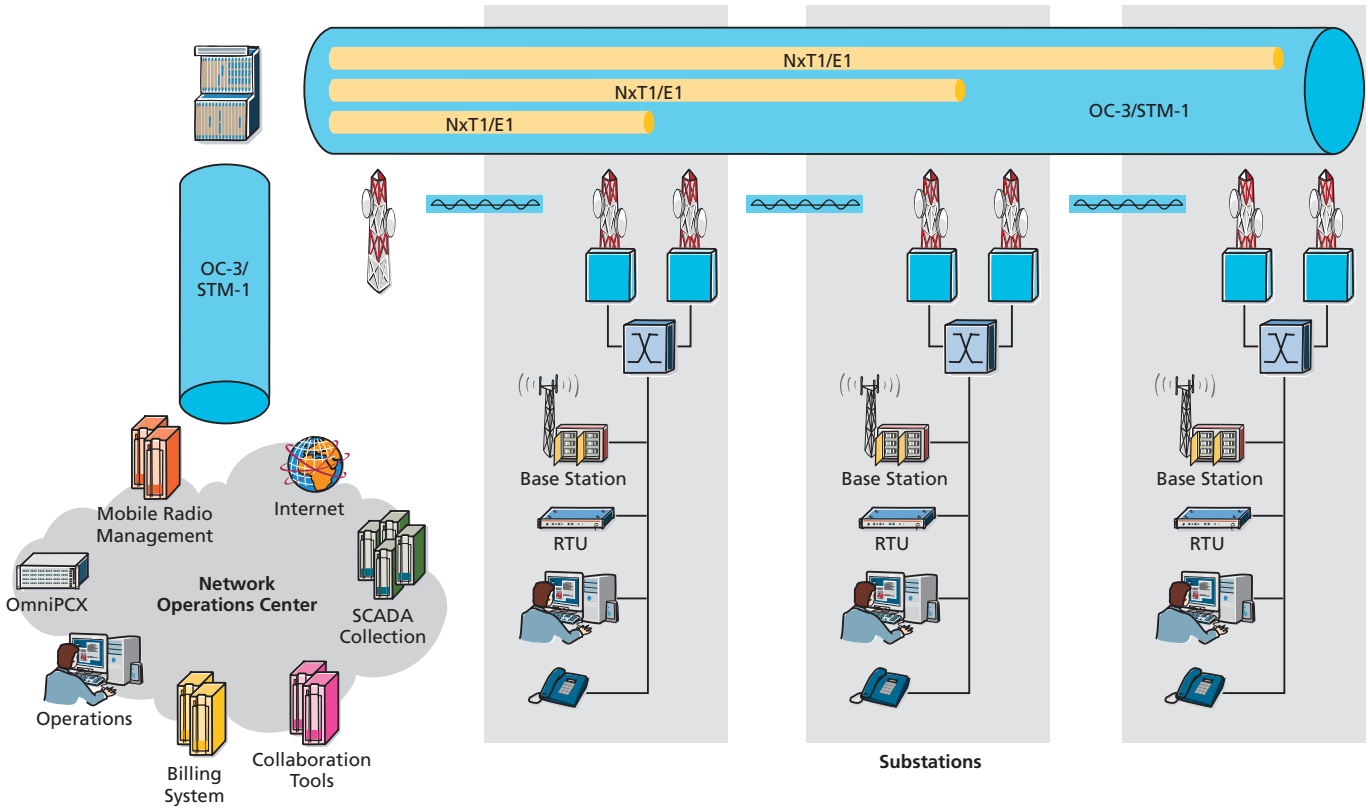
TDM systems traditionally support high reliability levels such as unidirectional path-switched ring (UPSR) when using SONET or SDH, which allows a utility to recover from a failure in less than 50 milliseconds.

To provide the required network protection, SONET/SDH has traditionally been used in a ring environment in which traffic is replicated and sent in both directions, effectively doubling bandwidth consumption. With SONET/SDH, the circuits are established in a static configuration, usually in increments of VT1.5 (1.5 Mb/s) or TU-12 (2 Mb/s). This approach works well and is deployed in many utility networks today, but it means that the bandwidth is reserved for a particular circuit whether it is used or not. Consequently, one application may have insufficient bandwidth while bandwidth that is reserved for an inactive application sits idle.

Because each circuit in a traditional TDM implementation is set with predefined bandwidth, quality of service (QoS) is inherent in the system; once the circuit is set, an application can only utilize the bandwidth assigned to it. When new packet-based services (primarily IP applications) are being integrated over a common infrastructure with TDM, the network needs to be able to discriminate between high priority critical traffic and lower priority traffic, while enforcing upper bounds on delay and jitter across the network.

Figure 2 shows a traditional utility SONET/SDH network. Typically, management and control functions are centralized at one location and linked via the ring to all substations. The network operations center (NOC) is connected to the ring at up to an OC-3/STM-1 rate, and the substations may be connected by fiber or through a wireless connection at NxT1/E1 rates.

Figure 2. Traditional SONET/SDH/TDM Implementation



CAPEX/OPEX and Scalability

In a SONET/SDH setting, the granularity of the bandwidth tends to be in the order of VT1.5 or TU-12, which is a 1.5 Mb/ s or 2 Mb/s increment respectively. As packet-based applications converge over SONET/SDH networks, bandwidth can quickly be exhausted. In a fixed wireless/ microwave environment, adding bandwidth may require significant hardware changes, including bigger antennas, more towers and the addition of new radios. Operational complexity also grows when running packet applications on top of a TDM infrastructure. Utilities must consider budget constraints when evaluating any new network or service. The utility must be able to add users and services without negatively impacting operating costs associated with equipment and maintenance, network carrier charges, and network administration.

Next-Generation Utility Network Requirements

Today, utility companies are aggressively pursuing communications options that will result in improved operational efficiency and increased productivity, which means that many parameters must be kept in balance. First, the solution must be highly reliable: in a mission-critical environment, no compromise is acceptable. Second, capital expenditures (CAPEX) and operating expenditures (OPEX) must be minimized. Finally, the network should offer the opportunity to implement new services in a rapid and cost-effective manner. The ideal solution is one that offers the same level of reliability, QoS and security as that of traditional utility networks while supporting the full array of both TDM and packet services that are needed for core utility operations and administration.

New technologies provide utility companies with the opportunity to migrate traditional applications to more efficient IP and Ethernet technologies and to implement new IP-centric applications, such as:

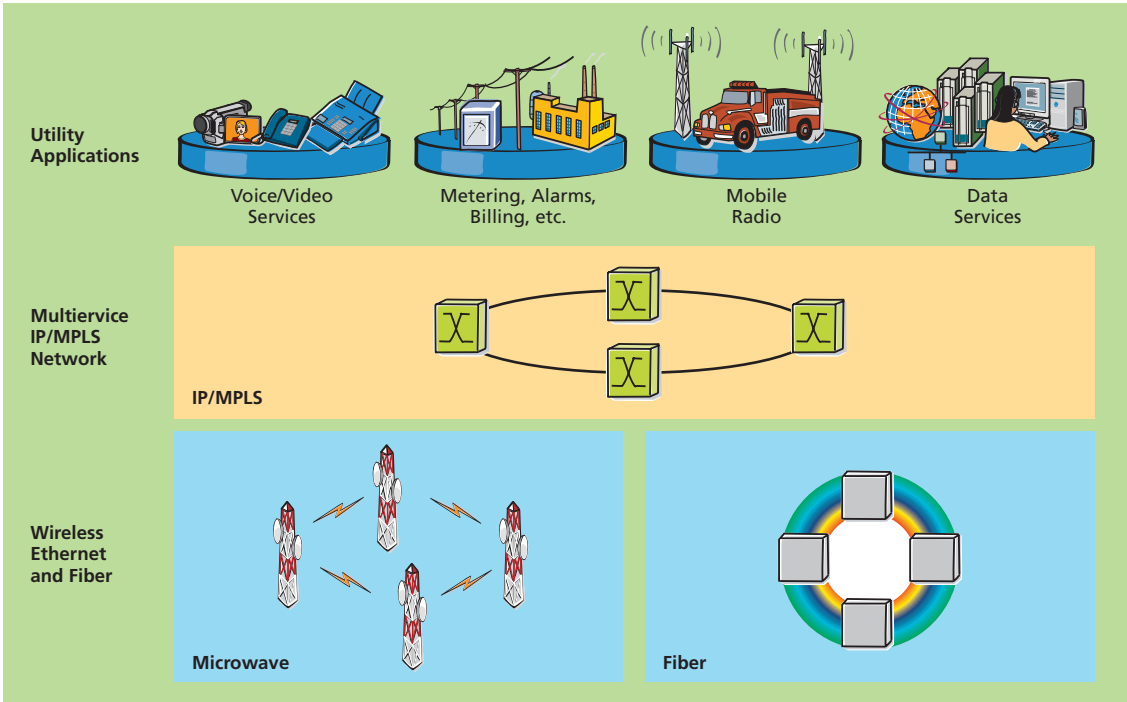
- IP-based mobile radio
- Ethernet supervisory control and data acquisition (SCADA)
- IP-based video surveillance
- Collaboration tools
- Voice over IP (VoIP)

IP technology can increase operational efficiency, supporting existing critical applications while providing the benefits of the new applications. There are several drivers behind this migration to IP:

- Traditional mobile radio systems tend to lack interoperability, which can put the utility in a propriety implementation situation and create isolated mobile radio islands. An IP-based mobile radio platform allows users to communicate among multiple mobile radio vendor systems.
- Legacy SCADA systems tend to be expensive, complex and difficult to commission and deploy. Ethernet SCADA allows for a simplified architecture, efficient bandwidth utilization, and decreased dependence on SCADA vendors while making available value-added IP applications such as trouble call management, load management and load forecast.

Figure 3 shows a high-level view of a typical utility IP/MPLS implementation. The physical layer can be either wireless or fiber and the multiservice IP/MPLS network supports a flexible array of utility applications.

Figure 3. IP/MPLS Utility Network



Bandwidth

The growth in IP applications drives the need for bandwidth and, more importantly, the need for bandwidth flexibility and efficiency. The new IP-centric applications tend to exhibit "bursty" traffic behavior: the application grabs a high level of bandwidth to send a large amount of traffic then, when the transmission ends, releases the bandwidth for other applications. With a traditional TDM core implementation, running multiple services becomes a challenge. The utility operator needs a service-aware network that can support IP and Ethernet applications without jeopardizing system availability.

Reliability

The network must offer the necessary level of reliability to maintain uninterrupted operation for voice, data and video traffic. A single failure in the network should not be service-affecting. Service interruptions in utility environments can include consumers losing power, overload conditions, loss of communication over mobile radio, or the development of other potentially unsafe conditions. TDM systems traditionally support high levels of reliability such as UPSR when using SONET/SDH, allowing a utility to recover from a failure in less than 50 milliseconds. That level of service must be matched in a new IP-based network.

Mobility

Utility employees can be more productive if they can be mobile. Data and voice mobility allows users faster response times to expedite utility operations and improve customer satisfaction. Data mobility encompasses the ability to send and receive files such as work orders, schedules, manuals and procedures, and to monitor reports. Voice mobility allows users to roam across the utility network footprint, including WiFi access points, rather than being tethered to a physical location. For most efficient operations, mobility requires an IP core.

Manageability

The management of a utility network has a direct impact on the operational cost of maintaining and scaling the network. OPEX should not escalate exponentially as new services are added. Service-aware management software can simplify network operations while streamlining operational processes such as maintenance, troubleshooting, scaling and commissioning.

The Alcatel-Lucent Next-Generation Utility Network Solution

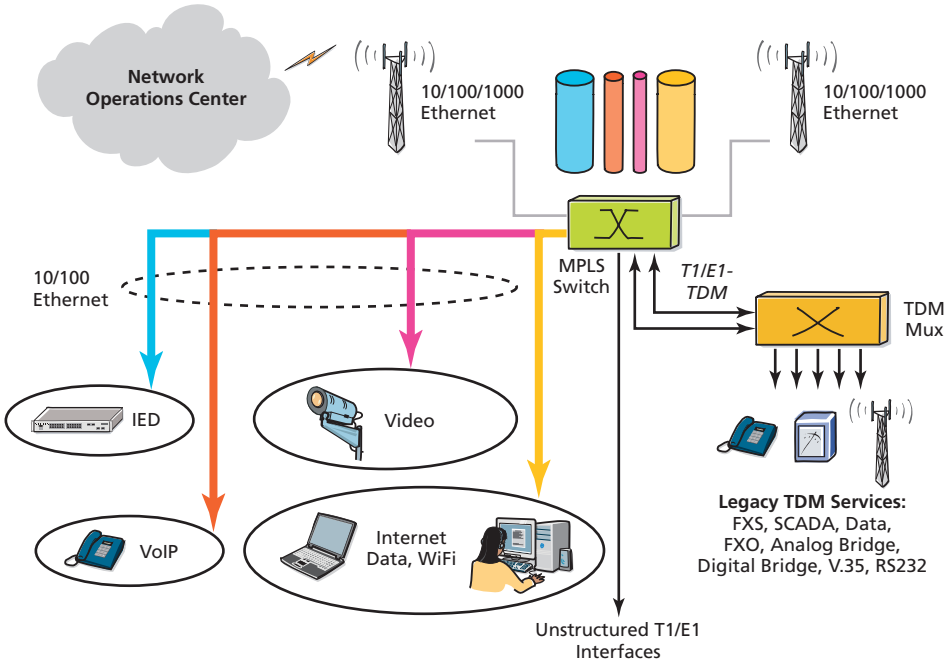
To reiterate, the utility communications network must be able to:

- Support critical existing utility TDM services
- Support new IP-based applications and services
- Minimize costs without compromising features, functionality and reliability
- Provide scalability, allowing the utility to increase services and grow the number of users
- Ensure network and operational system security
- Be highly survivable and resilient, with no single point of failure
- Enable scalable QoS to prioritize mission-critical applications over other traffic
- Provide reliable transmission over wireless microwave and fiber optic systems

Each utility may have a different approach or preference when implementing a communications network. The core of the operational network can be based on SONET/SDH, ATM, IP/MPLS and/or Ethernet. The Alcatel-Lucent solution portfolio includes a broad range of products to support the implementation of these different approaches. However, this application note looks specifically at the advantages to using IP/MPLS at the core of the network while leveraging microwave wireless and/or fiber optics where appropriate.

Figure 4 shows an overview of the Alcatel-Lucent solution for a next-generation utility IP/MPLS network. The network leverages MPLS to bring the advantages of a circuit-based network to an IP network, and to enable network convergence, virtualization and resiliency.

Figure 4. Alcatel-Lucent Next-Generation Utility IP/MPLS Network



Alcatel-Lucent IP/MPLS Solution Building Blocks

The Alcatel-Lucent IP/MPLS solution leverages multiple state-of-the-art technologies to enable a utility network to continue supporting existing TDM-based applications while providing a smooth migration path to IP services. The service-aware infrastructure efficiently supports the full range of IP applications, ensuring each application can be allocated the resources it needs in terms bandwidth, QoS level, security, etc. Furthermore, hierarchical QoS (H-QoS) ensures that no bandwidth is wasted when an application is idle.

The components of the IP/MPLS solution include the Alcatel-Lucent 7750 Service Router (SR) product family and the Alcatel-Lucent 7450 Ethernet Service Switch (ESS). The Alcatel-Lucent 7750 SR and 7450 ESS products support IP routing and switching, complete with multiservice capabilities. They enable the utility operator to distribute real-time applications to the remotest network edges and their non-stop service functionality provides unparalleled reliability.

The administration of the Alcatel-Lucent IP/MPLS solution is handled by the Alcatel-Lucent 5620 Service Aware Manager (SAM), which automates routine tasks while facilitating the introduction and administration of new services.

The services enabled by the next-generation IP/MPLS infrastructure include but are not limited to:

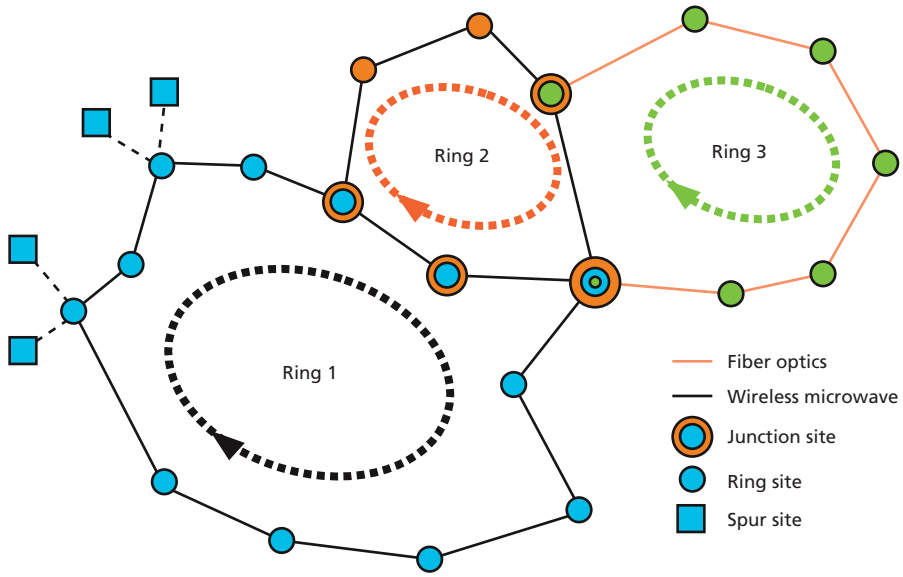
- Critical Traditional and Ethernet SCADA traffic
- Automated meter reading
- Mobile radio for internal operations
- IP telephony and collaboration
- Traditional voice services (digital and analog)
- Wireless IP data access points for workforce mobility
- Alarm circuits for all remote sites
- TDM digital/analog bridging
- Virtual private networks (VPNs)
- Customer relationship management
- IP-based video surveillance

The Network Topology

The network topology typically consists of one or more rings with spur sites on every ring. As shown in Figure 5, the topology consists of three adjacent rings.

A ring architecture provides a reliable environment because traffic can be rerouted to the other side of the ring, should a failure occur. In a SONET/SDH application, every node is always transmitting on both sides, effectively duplicating all traffic on the ring. In the Alcatel-Lucent IP/MPLS solution, the network relies on the MPLS fast reroute (FRR) feature for resiliency, so it is not necessary to duplicate the traffic. All bandwidth can be fully utilized and FRR ensures the ring can reroute traffic in sub-50 milliseconds, preserving all services on top of the ring.

Figure 5. Typical Ring Architecture



CAPEX/OPEX and Scalability

To meet the utility's growing requirements, the Alcatel-Lucent network is extremely scalable, with the bandwidth in each ring able to scale up or down independently, according to changing requirements. For example, Rings 1 and 2 may need a ring bandwidth of 150 Mb/s over a physical Ethernet interface while Ring 3 needs 50 Mb/s of bandwidth. The system can also scale down to provide the right bandwidth offering for the spur sites. There are three typical site types (as shown in Figure 5):

- *Ring site* – a site sitting on the main ring responsible for relaying traffic arriving from neighboring sites, providing connectivity for branch sites and meeting local service requirements on that site. Ring site functionality is shown in Figure 6.
- *Junction site* – a site located at the junction of two rings. Must be scalable to terminate multiple MPLS rings and act as a pivotal point to provide Layer 3 services. Junction site functionality is shown in Figure 7.
- *Spur site* – a spur off the main ring that will aggregate all the voice and data services on the spur site and forward to the ring site. To optimize efficiency and cost, the spur site should be scaled down in bandwidth to 12 Mb/s while continuing to provide all required services.

Scalability exists at the radio frequency (RF) level where the microwave system offers a scalable model of 12, 50 or 150 Mb/s of bandwidth, and at the network level where the MPLS core can accommodate a growing number of users and services. The Alcatel-Lucent IP/MPLS network has expanded media access control (MAC) entry support for up to tens of thousands of MAC addresses and up to several thousand label switched paths (LSPs) per uplink port. The granularity in MPLS bandwidth, scaling options at the RF level, and statistical multiplexing result in minimal CAPEX requirements to deploy and scale this solution. The converged architecture and the ease of Ethernet technology allow for optimized OPEX.

Figure 6. Ring Site

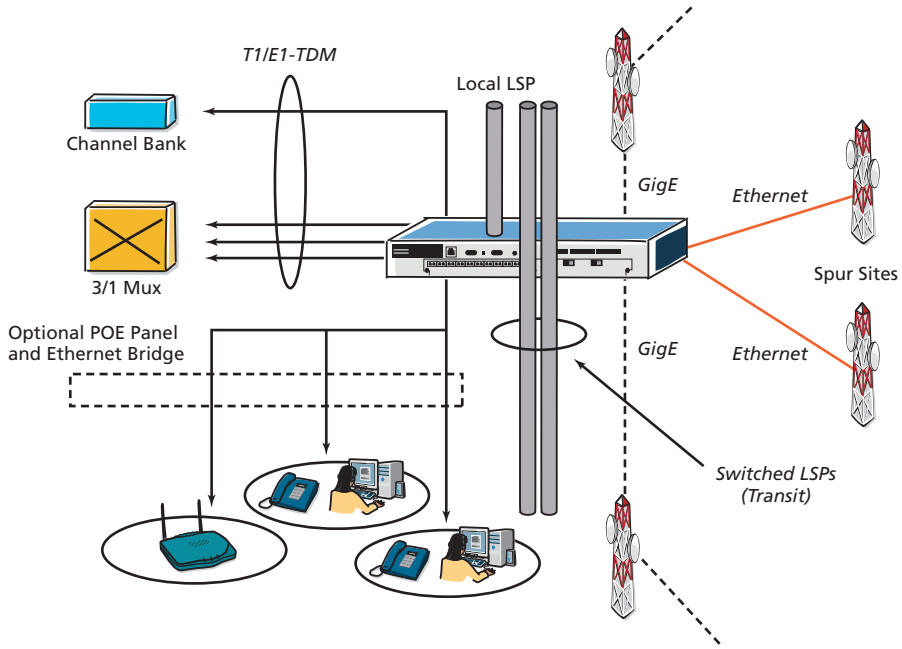
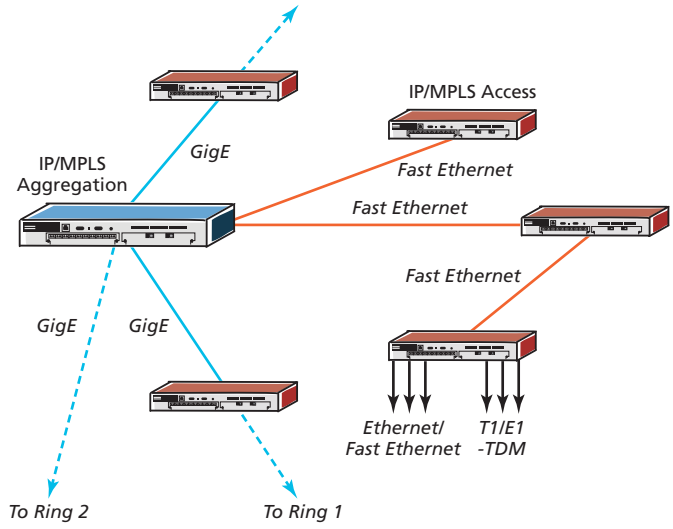


Figure 7. Junction Site



Multiservice Support

The Alcatel-Lucent next-generation IP/MPLS utility solution offers a flexible environment that enables the utility to continue supporting legacy services while gradually incorporating new IP applications, which will operate more efficiently. All services converge at the IP/MPLS layer with the necessary QoS capabilities. The network also allows the utility to migrate services from a TDM-based to an IP/MPLS-based operational environment. The solution supports both structured and unstructured T1/E1 services while providing a secure environment where different user groups can participate in different VPNs. MPLS also enables a scalable Ethernet-based virtual private LAN service, which can be used to provide different applications or user groups with a secure environment.

Reliability

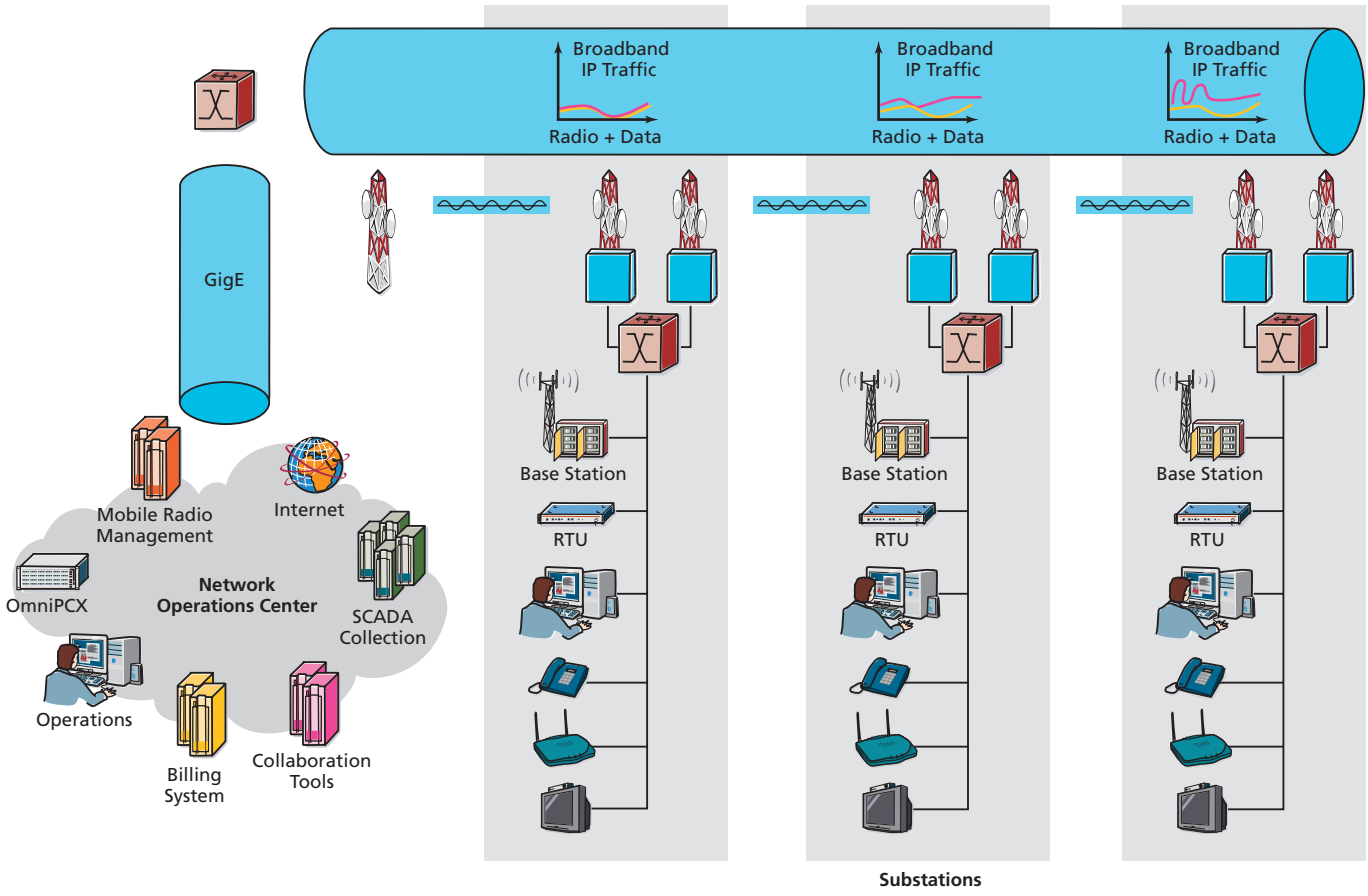
With the Alcatel-Lucent IP/MPLS solution, the utility has the necessary reliability level to maintain uninterrupted operations for both voice and data traffic. The network must be able to find an alternative route around a failure. The MPLS FRR feature enables the network to reroute connections around a failure in less than 50 milliseconds. Because the network is service-aware, FRR can distinguish and prioritize traffic redirection according to priority.

To ensure maximum end-to-end system availability when using microwave links, reliability should extend to the RF level as well. This Alcatel-Lucent solution assumes the use of licensed frequency throughout the microwave system to prevent interference. Spur sites should be configured as hot-standby in case of a failure at the RF level.

Bandwidth Efficiency

The Alcatel-Lucent IP/MPLS architecture provides a SONET/SDH-like reliability of sub-50 milliseconds recovery without duplicating the traffic. MPLS can deploy explicit route LSP capabilities to traffic engineer the network and optimize bandwidth utilization. MPLS is based on statistical multiplexing, so the utility operator can still configure circuits with very low granularity; moreover, when not in use these circuits can shrink to free up bandwidth for other "bursty" data applications. This concept is illustrated in Figure 8.

Figure 8. Efficient Bandwidth Management with an IP/MPLS Architecture



Quality of Service

In a utility environment where multiple services converge over a common infrastructure, QoS is essential. The service-aware Alcatel-Lucent IP/MPLS solution enables the network to discriminate among various types of traffic and advance higher priority traffic over lower priority. The H-QoS implementation also allows lower priority traffic to burst to fill available bandwidth when higher priority applications go idle. H-QoS uses 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 solution can manage traffic flows to ensure performance parameters (e.g., bandwidth, delay, jitter) for each application are met.

Mobility

The Alcatel-Lucent IP/MPLS solution offers a utility's mobile field workforce ubiquitous access to critical applications that improve productivity and efficiency. In the Alcatel-Lucent IP/MPLS network, mobility is achieved by deploying WiFi access points to allow the secure transmission and reception of data wirelessly. When within the coverage range of a wireless access point, users can send and receive vital data files regardless of location. The network also permits the partitioning of different application portfolios and access rights for different groups with defined privileges. All WiFi sites are networked over the IP/MPLS backbone. Since the WiFi network can enable both data applications and wireless VoIP services, the IP/MPLS network infrastructure prioritizes traffic types within the WiFi offering to enforce the necessary QoS policies.

Manageability

Effective network management allows the utility to maintain, manage and add new network services while minimizing operational risk and impact. The service-aware Alcatel-Lucent IP/MPLS network management system extends all features to all sites, end-to-end, including the ring, junction and spur. A powerful set of operations, administration and maintenance tools is available to assist the utility operator with the management of every aspect of the network. The utility operator can also oversee the entire network from a single, centralized, network management station.

Summary

Utility companies are experienced at building and operating reliable and effective networks to ensure the delivery of essential information and maintain flawless service delivery. The Alcatel-Lucent IP/MPLS solution can enable the utility operator to extend and enhance its network with new technologies like IP, Ethernet and MPLS. These new technologies will enable the utility to optimize its network to reduce both CAPEX and OPEX without jeopardizing reliability. Advanced technologies also allow the introduction of new applications that can improve operational and workflow efficiency within the utility. Alcatel-Lucent leverages cutting edge technologies along with the Company's broad and deep experience in the utility industry to help utility operators build better, next-generation networks with IP/MPLS.

The Alcatel-Lucent Advantage

Alcatel-Lucent has years of experience in the development of IP, MPLS and Ethernet technologies. The Alcatel-Lucent IP/MPLS solution offers utility operators the flexibility, scale and feature sets required for mission-critical operation. With the broadest portfolio of products and services in the telecommunications industry, Alcatel-Lucent has the unparalleled ability to design and deliver end-to-end solutions that drive next-generation communications networks.

Alcatel-Lucent is a leader in fixed, mobile and converged broadband networking, IP technologies, applications, and services. The Company's Professional Services Portfolio includes Service and Solution Consulting, Network Build Out, and Operations Support. Within the utility industry, Alcatel-Lucent has proven to be a reliable partner with an excellent record for cooperation and communications throughout a project's life cycle, high technical competence, consistently high-quality implementations, and solution-oriented project execution.

Acronyms

ATM	Asynchronous transfer mode
CAPEX	Capital expenditure
FRR	Fast reroute
FXO	Foreign exchange office
FXS	Foreign exchange subscriber
H-QoS	Hierarchical quality of service
IP	Internet protocol
IP/MPLS	IP/multiprotocol label switching
LSP	Label switched path
MAC	Media access control
MPLS	Multiprotocol label switching
NOC	Network operations center
OPEX	Operating expenditure
QoS	Quality of service
RF	Radio frequency
SCADA	Supervisory control and data acquisition
SDH	Synchronous digital hierarchy
SONET	Synchronous optical network
TCM	Three color marker (RFC 2697/2698)
TDM	Time division multiplexing
UPSR	Unidirectional path switched ring
VoIP	Voice over IP
VPN	Virtual private network
VT1.5	SONET/SDH equivalent of T1-1.5 Mb/s
WiFi	Wireless fidelity

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