



Creation of a **Metropolitan Broadband Network** by a **Publicly-Owned Utilities System:** **Overview and Architecture Design**

Written By:
Clyde Dardar, Principal Consultant, Global Data Systems
Mona Simon, Engineer III, Lafayette Utilities System
Heather Albritton, Performance Analyst, Lafayette Utilities System

LUS Powered Network
Lafayette Utilities System
1314 Walker Road
Lafayette, LA 70506
USA
www.LUSnet.net
info@lusnet.net
Tel: (337) 291-8930
Fax: (337) 291-5995

Table of Contents

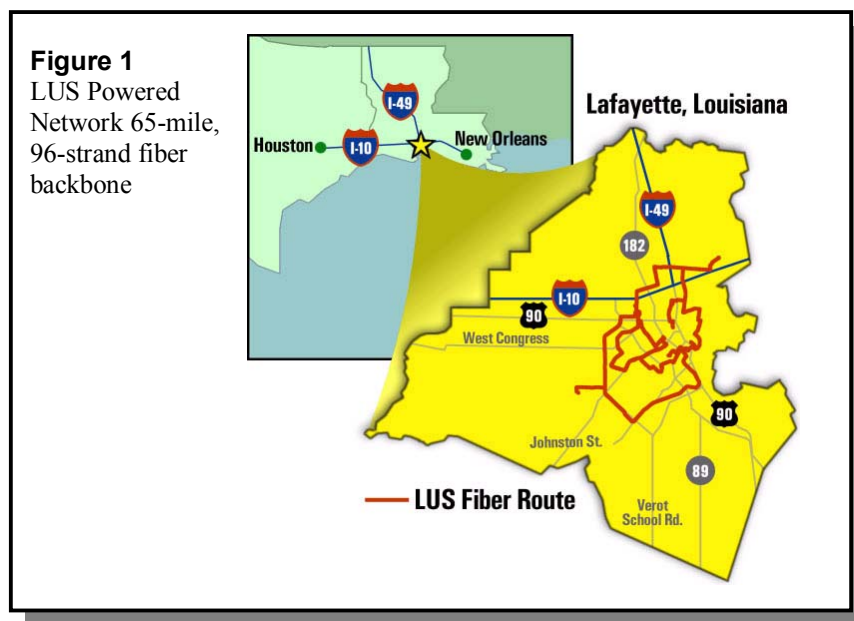
TABLE OF CONTENTS.....	2
LAFAYETTE UTILITIES SYSTEM – COMPANY OVERVIEW	3
<i>LUS Powered Network (Broadband)</i>	3
<i>Utilities</i>	4
LAFAYETTE UTILITIES SYSTEM TELECOMMUNICATIONS NETWORK - MARKET OVERVIEW	5
<i>LUS Powered Network Lafayette, LA Market Focus</i>	5
<i>LUS Powered Network Services</i>	6
Broadband Service	6
OCX SONET Ring Service	6
Last Mile Service	7
CPE Service.....	7
Direct Internet Access Service.....	7
Packet Services	8
Tower Lease Package.....	8
<i>Network Architecture Diagram</i>	10
<i>SONET Transport-Time Division Multiplex</i>	11
TDM Protection Methodology.....	11
<i>Internet Protocol Connectivity</i>	12
Overview	12
Contract Speed Regulation	12
Transparent LAN - Packet Ring Services	12
NETWORK COMPONENTS	13
<i>Layer 1: Fiber</i>	13
<i>Layer 1/2: Next Generation Optical Add Drop Multiplexors</i>	14
TDM Summary.....	14
Ethernet Summary.....	14
<i>Layer 2/3: Core Ethernet Switches and Routers</i>	16
Switching Fabric Redundancy	16
<i>Layer 3: Core Internet Routers</i>	17
Performance Summary.....	17
<i>Layer 4-7: Network Management Systems</i>	18
Network Management System	18
Network Node Manager	18
TECHNICAL SUMMARY	19



Lafayette Utilities System – Company Overview

LUS Powered Network (Broadband)

In 1998, the Lafayette Utilities System, located in Lafayette, Louisiana and owned by the Lafayette Consolidated Government, began expanding its infrastructure beyond traditional utilities by constructing a 65-mile, 96-strand SONET-based telecommunications system (LUS Powered Network). Completed in May 2000, the network reaches within one mile of most business and residential customers in Lafayette, Louisiana including major areas of development and primary traffic routes. LUS retained 12 fibers from the network for its communications needs including those of the electric transmission and distribution system. The remaining fibers are available to facilitate broadband and high-speed Internet access to wholesale customers including CLECs, ISPs, and CAPs.



LUS Powered Network History

1Q 1998

- LUS fiber installation began

4Q 1999

- Completed installation of 65 miles of fiber

3Q 2000

- Completed installation of the electronic equipment

3Q 2001

- Telecommunications Rate Ordinance, including authorization to enter into service level agreements approved by the Lafayette City-Parish Council

- Obtained CLEC (Competitive Local Exchange Carrier) certification from the Louisiana Public Service Commission

4Q 2001

- Major Internet service agreements and long-haul carrier collocation agreements executed
- Entered into an agreement with the University of Louisiana at Lafayette to provide fiber connectivity from the main campus to the University Research Park

1Q 2002

- Network Management System installed
- Internet and TDM services available for customers
- First customer announced to public

Utilities

For over 100 years, the Lafayette Utilities System has provided essential services to the community. In 1896, the citizens of Lafayette, Louisiana had the foresight to establish an entity to supply electricity and water to the community. This organization has developed into what is today the publicly owned LUS serving over 55,000 electric customers, 44,000 water customers, 35,000 wastewater customers and offering wholesale telecommunications services within the City of Lafayette and portions of Lafayette Parish (County). LUS employs over 400 people who ensure that LUS continues to provide customers with competitive rates and highly reliable services. LUS holds memberships in a variety of professional organizations including the American Public Power Association and the American Water Works Association. LUS is a registered Competitive Local Exchange Carrier (CLEC) with the Louisiana Public Service Commission.

Electric

LUS owns and operates the Louis “Doc” Bonin generating plant located in Lafayette, Louisiana. Doc Bonin is comprised of three natural gas fired steam turbine electric generating units with a total capacity of 300 megawatts. The LUS electrical system consists of 230kV, 138kV, and 69kV transmission voltages. The system operates one distribution voltage of 13.8kV. LUS operates 14 electrical substations and maintains over 800 miles of primary electric distribution line. Ten microwave towers ranging from 97 to 180 feet in height that were once used for the power distribution communication systems are now available to wholesale telecommunications customers for wireless applications. The power distribution communication systems are now transmitted on the LUS Powered Network allowing the towers to become vertical real estate.

Water

LUS provides quality water to citizens through the ownership of two water production facilities with a production capacity of 18.5 million gallons per day. The LUS water source is the Chicot Aquifer, a large, natural underground “lake” in southwest Louisiana. There are five water towers (heights ranging from 165.7 to 178 feet) located strategically throughout Lafayette. These towers are also available to wholesale telecommunications customers for wireless applications. The water system also includes over 900 miles of water distribution pipe.

Wastewater

LUS owns and operates four wastewater treatment facilities with a capacity of 46.5 million gallons per day. The wastewater collection system is comprised of over 650 miles of pipe and 120 lift stations.

Lafayette Utilities System Telecommunications Network - Market Overview

LUS Powered Network Lafayette, LA Market Focus

LUS Powered Network service offerings focus on the Lafayette Metropolitan area, providing multiservice private network solutions between end user locations and complementary service providers. LUS feels that a multiservice networking approach provides the greatest flexibility to address the connectivity challenges that wholesale service providers are faced with today. Wide Area and Metropolitan Area Network infrastructures have begun a massive technology shift from circuit switching to IP dominance. Since LUS will be offering parallel services for wholesale customers, the network is designed to support both infrastructures. The ultimate goal of the LUS Powered Network is to provide fiber to the premises in order to deliver tailored communications solutions for access and bandwidth. During this shift, real world legacy applications must be accommodated while at the same time positioning for the shift to IP. LUS has chosen three technologies to address these trends and provide the foundation of the primary LUS service offerings: SONET, LAN Switching and Dense Wave Division Multiplexing.

Primary Service Scenarios (See Figure 2A-B):

- Service Provider to Service Provider
- Building to Service Provider
- Building to Internet
- Building to Building
- Lafayette Government MAN

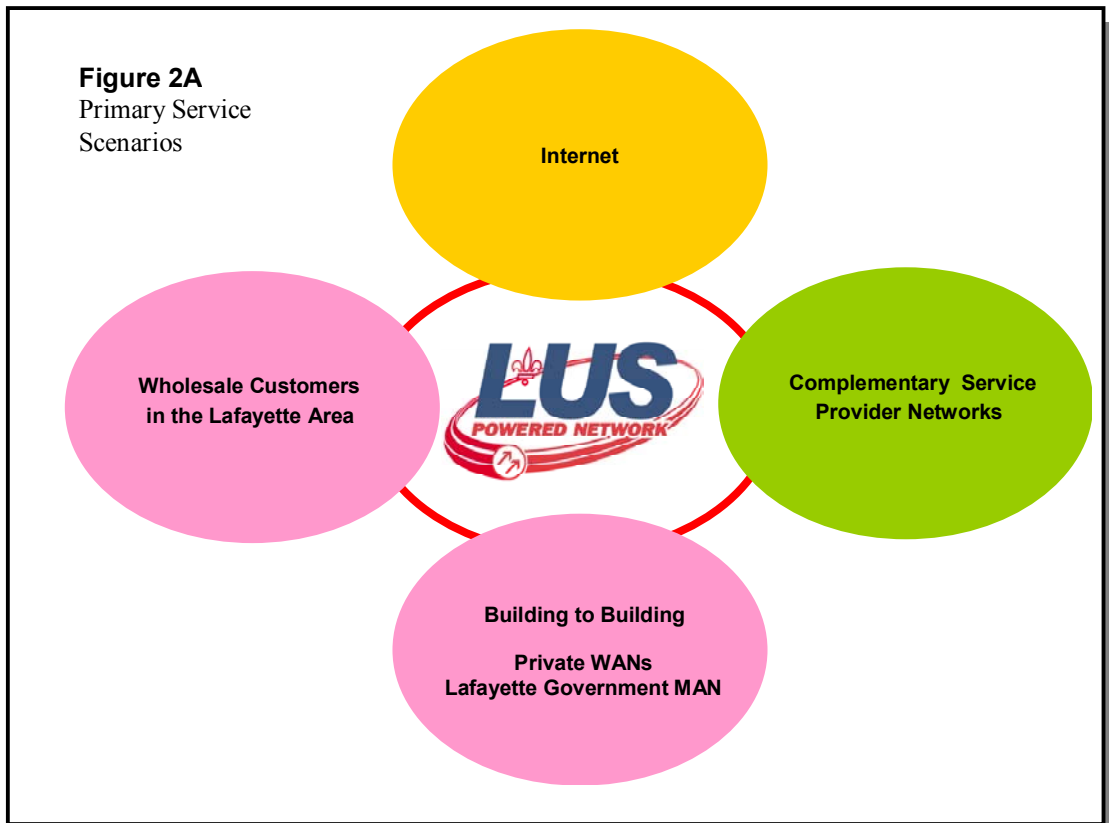
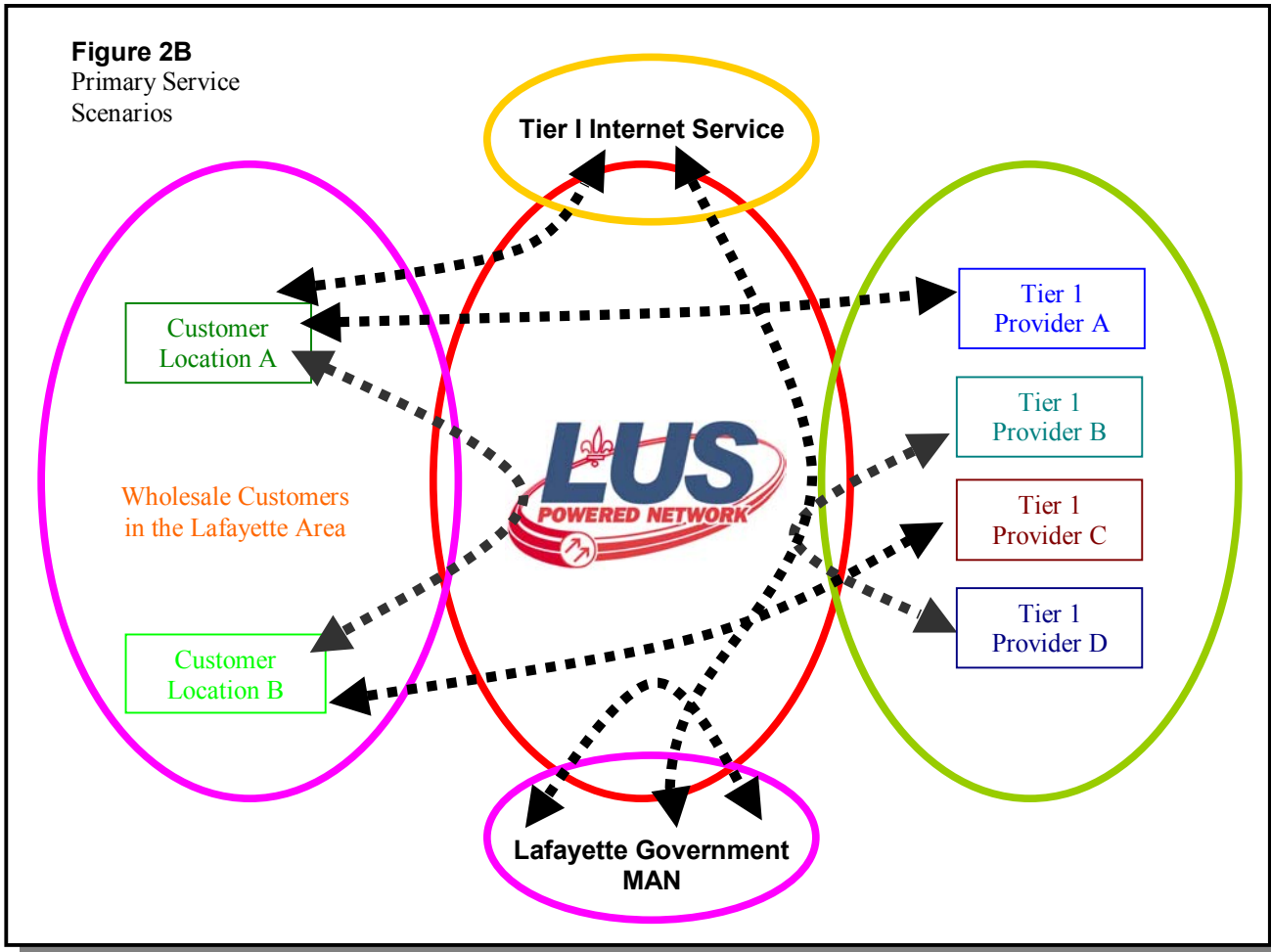


Figure 2B
Primary Service
Scenarios



LUS Powered Network Services

Broadband Service

The Broadband Service consists of bandwidth on the LUS SONET Network for a Time Division Multiplex circuit. The service may pass through multiple nodes/rings before arriving at its destination node.

OCX SONET Ring Service

The OCX SONET Ring Service provides a dedicated, high capacity network between the customer designated locations (nodes) designed to increase reliability using SONET equipment configured in a ring topology. The system is specifically designed to survive in the event of a single catastrophic failure within the network by rerouting traffic over the protect path. An OCX SONET Ring Service will provide up to OCX capacity at each of the designated locations (nodes).

Last Mile Service

The Last Mile Service provides the last segment of the circuit from the nearest LUS Point of Presence to the customer premises for use in conjunction with other LUS services. The medium for the service is fiber, but LUS reserves the right to install the appropriate medium to meet customer requirements. LUS also reserves the right to leverage its access agreements to furnish last mile solutions through its preferred vendors when the geographical requirements dictate this option. Subject to availability, this LUS service also consists of agreements with major carriers, used in conjunction with the LUS Broadband Service, in order to furnish the last segment of the circuit through the LUS network.

This service can provide the last segment of fiber along with fiber transceivers for use in conjunction with the LUS Packet Services. An 802.3 Ethernet interface will be provided at the customer premises as the demarcation point for the Layer 3 (router) device(s) of the customer. LUS requires that all customers use only Layer 3 devices to connect to the 802.1q VLAN at any given demarcation point. TDMoIP gateways that enable E1/T1, ISDN-BRI/PRI, FXS and/or similar technologies with proprietary IP encapsulation communication over IP networks will not be allowed on the LUS Shared Packet Service.

CPE Service

The LUS CPE Service is used in conjunction with other LUS services.

In instances where the customer requires a certain increment of bandwidth of the LUS Direct Internet Access Service, LUS will provide a router to regulate the throughput to and from the customer premises. This equipment is owned, monitored and maintained by LUS. The requirements of the router will be determined by the application.

In instances where the customer is receiving an LUS service that utilizes the use of a transceiver, LUS will provide the appropriate transceiver to access such service. This equipment is owned, maintained and monitored by LUS. The requirements of the transceiver will be determined by the application.

Direct Internet Access Service

LUS Direct Internet Access Service is comprised of bandwidth directly into the Internet with LUS providing Internet addressing information and optional domain name support. This Internet bandwidth will be monitored to insure quality throughput and performance.

The LUS Global IP Address Allocation Matrix (Figure 3) will be used as a guideline for issuing global IP addresses to customers. When a customer can display efficient use of 80% of the assigned address space, LUS will assign the appropriate global IP address space on an individual case basis.

Figure 3

LUS Global IP Address Space Matrix

Customer Bandwidth		Connection Type	MAN Mask	Serial Mask	Customer Mask	Customer IP Addresses
From	Up To					
0	3	TMD		252	27	30
3	10	TMD		252	26	62
10	45	TMD		252	24	254
<hr/>						
0	3	PR	27		27	30
3	10	PR	27		26	62
10	45	PR	27		24	254

Packet Services

Dedicated Packet Service

The Dedicated Packet Service provides the customer a specified amount of bandwidth around a designated portion of the LUS SONET ring. This bandwidth is reserved for the customer, on a private circuit configuration with an 802.1q VLAN assignment, by the use of separate cards and bandwidth. The customer has exclusive use of this bandwidth, port(s), and 802.1q VLAN for the transport of their 802.3 Ethernet information on the specified 802.1q VLAN at the Layer 3 level. 802.3 Ethernet interfaces will be provided at each drop for the Layer 3 (router) device(s) of the customer. LUS requires that all customers use only Layer 3 devices to connect to the 802.1q VLAN at any given demarcation point. The Dedicated Packet Service can be used in conjunction with LUS Internet service

Shared Packet Service

The Shared Packet Service provides the customer a specified amount of bandwidth around a designated portion of the LUS SONET ring. This bandwidth is reserved for a single customer by the use of 802.1q VLAN technologies. The individual LUS customer bandwidth assigned utilizes continual performance monitoring to allocate bandwidth resources. With the LUS Shared Packet Service, customers utilize leveraged 155 Mbps circuits across multiple nodes with the benefit of 802.1q VLANs for network isolation and security. The 155 Mbps customer transport system performance is monitored and regulated by the LUS Network Management Systems. The overall system bandwidth will be monitored to insure quality throughput and performance for all customers. 802.3 Ethernet interfaces will be provided at each drop for the Layer 3 (router) device(s) of the customer. LUS requires that all customers use only Layer 3 devices to connect to the 802.1q VLAN at any given demarcation point. When a customer requires multiple drops on a Packet Ring, LUS reserves the right to limit the access rate of the customer to the broadband bandwidth documented on the contract. TDMoIP gateways that enable E1/T1, ISDN-BRI/PRI, FXS and/or similar technologies with proprietary IP encapsulation communication over IP networks will not be allowed on the LUS Shared Packet Service. The Shared Packet Service can be used in conjunction with LUS Internet service offerings on a LUS 802.1q VLAN with a specified amount of regulated Internet content.

Tower Lease Package

The Tower Lease Package is bundled with other LUS services to provide an economical solution for wireless applications. The Tower Lease Package will provide tower space, collocation space, and an interface at each tower location as specified in the Service Order.

Lafayette Utilities System Broadband Network - Technical Overview

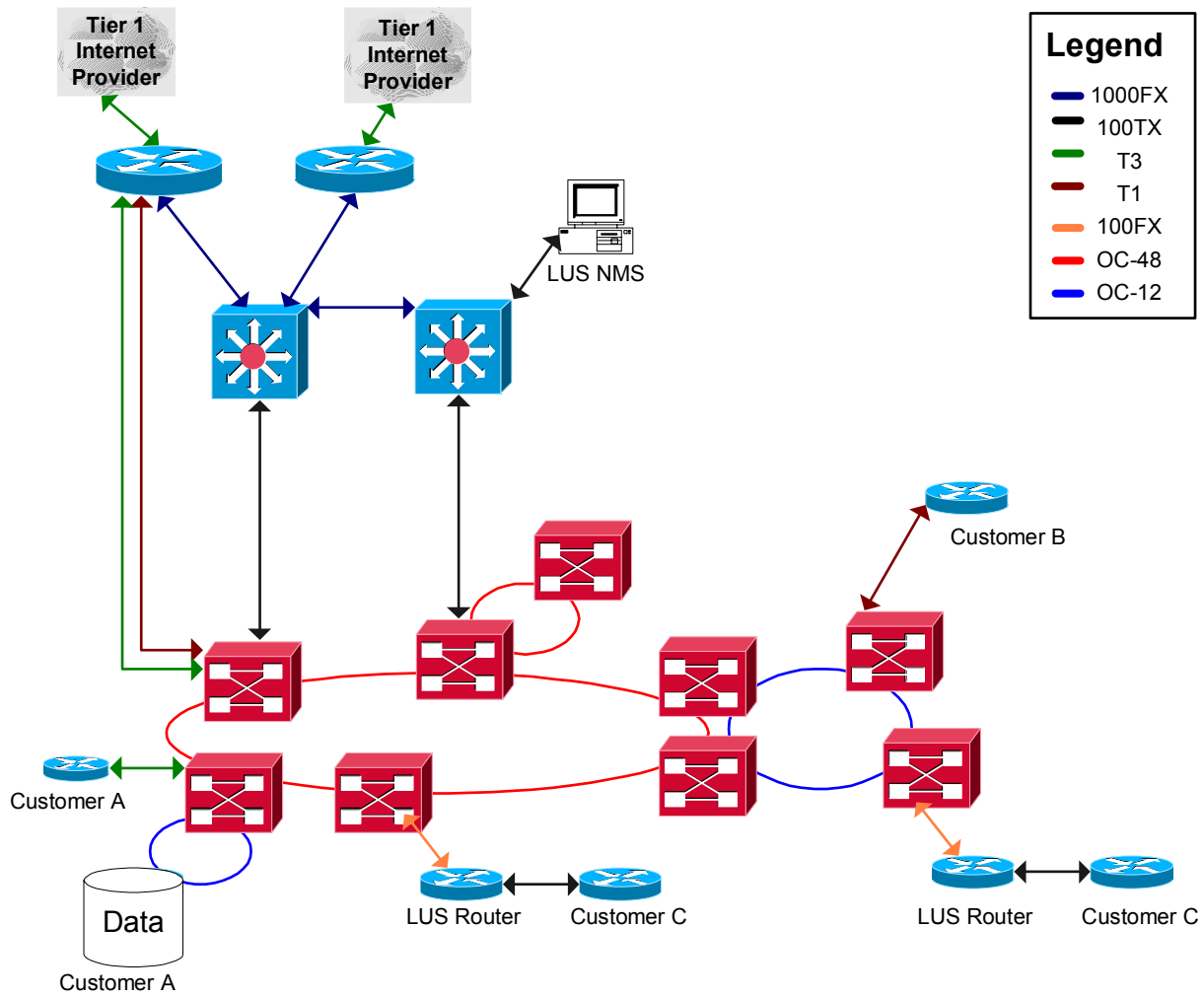
The LUS Powered Network consists of a Metropolitan Area Optical Network that can be used for Business Continuance, Storage Consolidation, and Multiservice Integration. IBM Main Frame, Geographical Information Network Management, SCADA, and SAP systems are currently operating successfully on the network. Lafayette Consolidated Government has plans for migrating voice, video and storage applications in Phase II of the implementation.

Explosive growth of the Internet and enterprise business applications was placing a tremendous demand on the prior Frame Relay network, thus the mission-critical applications, such as e-business, voice, video, storage networking, and emerging applications such as streaming media were not possible. This new bandwidth demand was affecting access to metropolitan and wide-area networks of the Lafayette Consolidated Government and other industries such as financial services, healthcare, education and telecommunication service providers. As Information Technology services become increasingly critical to our daily lives, consumers expect instant, uninterrupted access to corporate systems and data. At the same time, unprecedented growth in storage requirements is forcing companies to reassess how and where they meet this steadily increasing demand.

LUS was able to foresee this network demand and responded to it with a carrier class deployment of a fiber-optic network to replace the aging microwave system that served the LUS power grid in the metro area. This fiber-optic network and the initial installation of surplus fiber strands laid the groundwork for dramatic high-bandwidth availability of multiservice network connections available in T-1, T-3, OCX, 10FX, 100FX, and Gigabit Ethernet for public entity and commercial business use. Presently, there are several key Lafayette governmental agencies connected to the City Metropolitan Area Network (MAN) that has been created for the purpose of interconnecting these and other Lafayette governmental agencies. The current network coupled with advances in optical technology, IP switching and access mediums such as dense wavelength-division multiplexing (DWDM), will lead the Lafayette region vigorously into the future.

Network Architecture Diagram

Figure 4
LUS Powered
Network Architecture



SONET Transport-Time Division Multiplex

LUS broadband Layer 2 TDM services are provided by high availability, SONET based, protected connectivity for existing voice, data, video, storage and service provider backbone applications. TDM provides high speed, dedicated, protocol independent bandwidth for any networking need. Interface choices include OCX, EC1, T3, and T1. (See Figure 4) Connectivity can be between two or more end user buildings, the Internet, or can connect end users to several complementary service providers which include local or long distance voice services, access to data service offerings including frame relay, VPN, ATM, DSL or long haul high speed private line services. Access to hosting facilities, storage providers, wireless access points and disaster recovery providers are also highly sought after connectivity requirements.

LUS utilizes optical transport platforms to provision Time Division Multiplex Services to customer premises locations. This TDM traffic may be building-to-building, building to POP or building to LUS core routers. Customers may utilize fiber transceivers as a transport mechanism until the bandwidth or port density requirements justify the installation of a SONET node depending on area customer trends at or near the node location. These circuits will be transported via STS payloads directly between the origination and destination locations. This dedicated bandwidth between sites will not be leveraged in any way. Dedicated TDM services may require additional hardware to accommodate the specific demand of the customer. This addition can be added to the existing SONET network by provisioning the appropriate amount of bandwidth from source to destination.

TDM Protection Methodology

Bi-directional Line Switched Rings

LUS utilizes Bi-directional Line Switched Rings (BLSRs) in the core and large access rings (where possible) for bandwidth reuse. BLSRs allocate half the available fiber bandwidth for protection. In an OC-48 BLSR, for example, STSs 1 – 24 are allocated to working traffic, and STSs 25 – 48 are allocated for protection. If a break occurs on one fiber, working traffic switches to the protection bandwidth (STSs 25 – 48) on the other fiber. Working traffic travels in one direction on STSs 1 – 24 on one fiber, and on STSs 1 – 24 in the opposite direction on the second fiber. Because the working and protection bandwidths must be equal, LUS can create only OC-12 and OC-48 BLSRs.

Unidirectional Path Switched Rings

A UPSR is a closed-loop, two-fiber transport architecture that survives cable cuts and equipment failure because it provides duplicate fiber paths for each service. LUS makes use of this technology for access rings needing connectivity back to the core ring. Nodes in the ring are connected using a single pair of optical fibers. Working traffic flows in one direction on the ring and the second fiber provides a protection path flowing in the opposite direction. If a problem occurs in the working traffic path, the receiving node switches to the path coming from the opposite direction. Services can originate and terminate on the same UPSR or can be passed to an adjacent access or interoffice ring for transport to the service-terminating location. Because each traffic path is transported around the entire ring, UPSRs are best suited for networks where traffic concentrates in one or two locations and is not widely distributed.

Internet Protocol Connectivity

Overview

LUS has agreements with multiple Tier I Internet Providers (See Figure 4) in order to provide a fully redundant Internet connection. Both Tier 1 provider POPs are located in Lafayette and within the range of the LUS network infrastructure. LUS has dual entrances into each Tier 1 POP. These Tier 1 provider networks are integrated into the LUS network at different SONET nodes within the system thus further enhancing the reliability of Internet service.

In addition to the Internet Service Agreements, LUS also has Interconnection agreements with major carriers that use LUS Fiber facilities to integrate the network to the customer premises. The hardware consists of a SONET transport at Layer 2 into the core Layer 3 routers running BGP “dual-homed” into the providers. LUS configures TDM circuits on the SONET transport to the customer premises from the core routers as explained in the TDM Protection Methodology section.

Contract Speed Regulation

LUS regulates Internet bandwidth to and from the TDM circuit or 802.1q VLAN of the customer with the use of Committed Access Rate and/or Traffic Shaping on the interfaces of the Layer 3 components. This enables LUS to effectively regulate utilization of the bandwidth by rate limiting/shaping applications and hosts in order to adhere to the individual contract bandwidth of the customer. Committed access rate (CAR) and Generic Traffic Shaping are bandwidth management tools for controlling IP traffic transmission rates into the network. These features will enable LUS network managers to configure routers so they can control the maximum rate for IP traffic sent or received on an interface. An assignment of bandwidth to individual traffic flows at Layer 3 delivers a definable traffic rate that LUS can use for billing. This functionality will be configured on interfaces at the edge of the network to limit traffic into or out of the network as per the customer contract. This enables LUS to have subrate IP services to deliver a physical 100 MB to the customer, but offer a less-expensive subrate service (for example, 20 MB on a Physical 45MB connection or 20 MB on a 100TX connection). The customer pays only for the subrate Internet content bandwidth and the customer may be upgraded to additional access bandwidth upon request.

Transparent LAN - Packet Ring Services

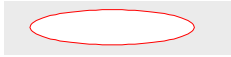
Transparent LAN Services addresses pure data applications where direct Ethernet connectivity is desired. TLS provides the most economical and technically homogeneous solution for providing transparent LAN connectivity. Private Virtual LAN networks can be built connecting building-to-building, building to Internet, and building to service provider, hosting, or storage providers. TLS connectivity is protected via Spanning Tree Protocol and by the underlying SONET transport. TLS provides an attractive access or interconnection service when interfacing with IP centric networks.

LUS utilizes core routers, switches, and optical transport platforms to provision Transparent LAN Services for Ethernet networks to customer premises locations. This TLS traffic may be building-to-building, building to service POP, building to Internet, or service provider to service provider. An Ethernet card is used to terminate these LUS circuits and provide the customer a point of demarcation for their router. LUS may utilize fiber transceivers as a transport mechanism until the bandwidth or port density requirements justify the installation of an Ethernet Layer 2 and/or Layer 3 switch or SONET node depending on area customer trends at or near the customer location. These circuits will be ported via STS payloads directly between the origination and destination locations in a VLAN along a leveraged STS-3 unless the customer requires dedicated bandwidth between sites. The standard interface for this type of connection between the Ethernet interface and the SONET transport complies with RFC 1619 PPP Over SONET (RFC 2615 obsoletes RFC 1619) and Telcordia GR-253 HDLC Over SONET. The Ethernet frame is encapsulated into a HDLC frame. The octet stream is then mapped into the SONET/SDH Synchronous Payload Envelope (SPE); with the octet boundaries aligned with the SPE octet boundaries. No scrambling is needed during insertion into the SPE. The Path Signal Label (C2) is intended to indicate the contents of the SPE. The Ethernet Spanning Tree Protocol algorithm terminates at the customer demarc to circumvent the possibility of STP loops or Root Bridge issues.

Network Components

The LUS network consists of the following major equipment types positioned at different layers in the OSI network model (See Figure 4): Single Mode Fiber, Optical Add Drop Multiplexors, Ethernet Switches, Routers and Network Management platforms. Each layer is owned, managed, monitored and maintained by LUS, which gives LUS the ability to offer telecommunications service providers the same high level of service that is provided to the LUS utility customer base.

Layer 1: Fiber



LUS has a total of 65 miles of Alcoa Fujikura All-Dielectric, Self-Supporting aerial fiber in the Lafayette region. The fiber paths are located in strategic areas for resiliency, redundancy, and market coverage. A central anti-buckling element made of reinforced plastic and eight tubes containing a water-blocking compound stranded around a central anti-buckling element make up the center of the cable. A layer of non-hygroscopic tape is applied around the stranded tubes with a polyethylene inner jacket over the cable core. The cable strength elements are comprised of two layers of torque-balanced aramid yarn applied helically over the inner jacket with a layer of non-hygroscopic tape covering them. The outer jacket is made of high modulus weather resistant polyethylene. Alcoa AGS cable suspension hardware, spiral vibration dampers and wire wrap dead end assemblies are used for cable supports along the fiber cable route.

Figure 5
Alcoa Fujikura
ADSS Optical Cable



Layer 1/2: Next Generation Optical Add Drop Multiplexors



The optical transport platform is a key building block of the LUS optical network due to its ability to offer next-generation transport performance and economics. It combines the best of traditional SONET TDM and statistical multiplexing in a single platform. This platform can aggregate traditional facilities such as DS1, DS3, STS1, EC1, OC3, OC12, and OC48 including multiwavelength DWDM optics. It is also designed to support data interfaces such as Ethernet, ATM, and video. This enables drastically improved efficiencies in the transport layer and breakthrough cost savings for initial and lifecycle deployment. Today, a single transport platform shelf can support combinations of OC3, OC12, OC48 and OC192.

TDM Summary

The optical transport platform supports multiple LUS service interfaces including TDM (DS1, DS3, DS3 transmux, EC1/STS-1), and optical (OC-3/OC-3c, OC-12/OC-12c, OC-48/OC-48c, OC-192). All optical bandwidth and optical services are deployed on demand by exchanging interface cards. This platform delivers metro optical transport solutions that meet these demanding network requirements. To deliver the LUS goal for fail-safe operations it has built-in redundant common equipment, stratum 3 internal timing, two BITS inputs, Synchronous Status Messaging (SSM), and dual power input feeds.

Multiple protection mechanisms give service providers utilizing the LUS Network additional peace of mind. This platform supports UPSRs, 2 and 4 fiber BLSRs, unidirectional and bidirectional linear automatic protection switching (APS), and path protected mesh networking (PPMN).

With comprehensive Synchronous Transport Signal level 1 (STS-1) and Virtual Tributary level 1.5 (VT1.5) bandwidth management, packet and cell switching, and transmux functionality, the optical transport platform will also be utilized as a distributed bandwidth manager, reducing the need for legacy digital cross connects at every central office. The optical transport platform allows system operators to terminate multiple rings or linear systems on a single chassis and to mix and match service interfaces on that same chassis in order to enable a unified data, voice, and video network.

Standards Compliance

- NEBS Level 3
- GR-1089-CORE
- GR-63-CORE
- GR-253-CORE
- GR-1400-CORE
- IEEE 802.3, 802.1p, 802.1Q, 802.1D
- Rural Utility Service (RUS) approved

Ethernet Summary

To maximize Ethernet cost effectiveness, Ethernet access is integrated into the same SONET platform that transports data and voice traffic. The optical transport platform supports Layer 2 switching and the ability to classify Ethernet traffic as defined in IEEE 802.1 Q. Tagged traffic can be switched onto separate SONET STS channels to engineer bandwidth by traffic class. Ethernet over SONET lets service providers augment Time Division Multiplex (TDM) services with Ethernet and allows users to deliver data traffic over existing facilities. The ONS 15454 can also concentrate Ethernet ports into one or more STS-n circuits to use bandwidth more efficiently.

Standards Compliance

- IEEE 802.3 10/100 Mb Ethernet
- IEEE 802.3z Gigabit Ethernet; GBIC Support

- IEEE 802.3x Full Duplex Communication and Flow Control
- IEEE 802.1d Spanning Tree Protocol
- IEEE 802.1p Priority Tagging
- IEEE 802.1q VLAN Tagging
- RFC 1619 PPP Over SONET (RFC 2615 obsoletes RFC 1619)
- Telcordia GR-253 HDLC Over SONET

Ethernet Card Architecture

- Switch Fabric - Each Ethernet card is enabled with a 1.2 Gb switch capacity, which allows for frame switching between ports and for frame transport.
- Throughput - Throughput is the maximum rate at which none of the offered frames are dropped by a device. The throughput for both E100-12 and E1000-2 cards is > 1.1Mfps.
- Latency - Latency is the time interval from when the last bit of the input frame reaches the input port to when the first bit of the output frame is seen on the output port. The latency of E100T-12 card is <15 microseconds for front-switching, and <40 microseconds for STS switching. The latter is a function of the inherent latency of SONET.
- MAC Support- The MAC address forwarding table is a record of Layer 2 addresses. The Ethernet card is responsible for learning and maintaining its own forwarding table. The Ethernet cards share the forwarding table if the cards are in multi-card (stitched) mode. Each single-card (un-stitched) Ethernet card can store >8000 MAC addresses.
- VLAN Support - VLAN functionality allows for the logical segregation of traffic flows within a switch and across a network. It also allows for ingress and egress traffic policing on a per port basis. The ONS 15454 supports > 500 VLANs. The VLAN table of a node is stored on the TCC or TCC+ card.
- Ethernet Framing - The Ethernet cards support Ethernet frame sizes ranging from 46 bytes to 1518 bytes as specified in IEEE 802.3 for untagged ports. For tagged they accept up to 1522 byte frames and process them as expected.
- Spanning Tree – The optical transport platform runs native Ethernet and statistically shares/aggregates traffic at each node, the mechanism used to control bridge loops is IEEE 802.1D Spanning Tree Protocol (STP). Dynamically, STP will block a link to avoid looping traffic. If there is a link or node failure, SONET will reroute the traffic with its superior 50ms reroute capability. When the network is back to full operational status, SONET will heal the ring. If there are multiple failures, that isolate a node(s), SONET and STP will be used for reconvergence. STP convergence time is <30s, as dictated by the IEEE 802.1D standard.
- HDLC Encapsulation - The protocol used to encapsulate the Ethernet on SONET is a form of the RFC 1619 standard, which looks similar to HDLC. This section does not focus on the details of this HDLC encapsulation. The ONS 15454/15327 conforms to the general specifications of RFC 1619, in that the Sequence of Ethernet frame processing follows the steps generally defined in RFC 1619.

Layer 2/3: Core Ethernet Switches and Routers



The switches play a key role in the Layer 2 and Layer 3 areas of the LUS network. The switches deliver high-performance, multilayer switching solutions for enterprise and service provider networks. It is designed to address the increased requirements for gigabit scalability, high-availability, and multilayer switching in backbone/distribution and server-aggregation environments. These switches deliver exceptional scalability, price and performance and also support a wide range of interface densities, performance, and high-availability options. By combining superior control-plane and packet-forwarding scalability with a rich set of intelligent services, they deliver the foundation for new-world enterprise and service provider solutions such as converged voice/video/data and e-commerce services.

Switching Fabric Redundancy

Since its introduction, the core switches are on a single bus switching architecture, which provides the data path for all packets through the system. Included is a crossbar switching fabric (the SFM) as an alternative switching architecture for higher-bandwidth requirements. The SFM also provides another level of hardware redundancy to the system. This allows the system to use the switching fabric as the primary means of data transfer for fabric-enabled line cards. If the switch fabric fails, the system bus backplane will take over to ensure packet switching continues, albeit at 15 Mpps, and the network remains on line. Note that this change in switching performance is applicable only if the system is initially forwarding at greater than 15 Mpps. If a system is running at 15 Mpps or below, then the fabric-to-system bus fail-over does not affect performance. Active fabric-to-standby fabric and active fabric-to-32-Gbps backplane fail-overs recover to normal operation in less than three seconds.

Layer 3: Core Internet Routers



The LUS high-performance routers provide advanced support for LAN/WAN services, redundancy, reliability, and performance. The distributed architecture using Versatile Interface Processors (VIPs) is the key to the scalability of the router. Each VIP has its own processor, which is capable of switching IP data packets and providing network services. This scenario allows the overall system performance of the routers to scale up when they need to handle more high-speed network connections and more data packets. Route Switch Processors (RSPs) run routing protocols with other routers in the network to gather switching intelligence, which is then downloaded to the VIPs so that each can switch IP packets on its own.

In addition to performing packet switching, the VIPs can provide a set of distributed IP network services including access control, QoS, and traffic accounting. With the VIPs off-loading these IP switching and service functions from the RSP, the RSP can devote all of its CPU cycles to handle other essential tasks. VIP distributed switching is the way to scale up system performance, and should be enabled where possible, to significantly reduce CPU utilization on the RSP.

The multiprotocol/multiple-media network capabilities of the router enable integration of multiple WAN technologies and provide the necessary bandwidth and service requirements unique to each remote site. The router integrates the richest set of Layer 3 services available including QoS, security, encryption, and traffic management. Advanced multichannel technology provides for a scalable and cost-effective WAN solution where high-density, leased-line services are required.

The Advanced Router System distributes services across multiple VIPs to provide the scalability necessary in today's fast-paced Internet environment. The VIP is based on a RISC engine optimized for input/output (I/O) functions. One or two port adapters or daughter boards (auxiliary cards) are attached to this engine. These port adapters provide the media-specific interfaces to the network.

Performance Summary

A distributed architecture ensures high packet throughput as network speeds and route complexities increase by moving the packet-forwarding decisions from the central routing engine out to the network line cards. The VIP provides this service by offloading all packet-forwarding decisions from the central processor.

Software services are distributed to each VIP in the system. This enables the deployment of large-scale e-business applications by spreading the service load across multiple independent processors. Advanced Router System (ARS) utilizes many technologies to accelerate data movement in VIPs and to scale the application of network services. ARS takes advantage of the distributed features within each VIP to accelerate a variety of network services such as QoS, security, data compression, and accounting. For example, each VIP can intelligently classify traffic flows at T3 rates (90 Mbps). Using two VIPs increases this capability to two T3s, three VIPs, three T3s, and so on. Each additional VIP linearly increases the ability of the router to provide services without adversely affecting the other VIPs already running in the system.

- *High-performance switching*—This feature delivers high performance for mission-critical applications by supporting high-speed media and high-density configurations. Using the processing capabilities of the Versatile Interface Processors (VIP) and express forwarding, the router system capacity can exceed two million packets per second.

- *Full support for software and enhancements for high-performance network services*—The router performs network services such as quality of service (QoS) and security at high speed. VIP technology extends the performance of these services through distributed IP services.
- *High port density*—Provides high port density and an extensive range of LAN and WAN media. This feature dramatically reduces the cost per port and allows a flexible configuration.
- *Unmatched interface flexibility*—Supports a broad selection of interface processors (IPs) and port adapters (PAs).
- *High Availability*—Enhanced HA features and capabilities include redundant route processors, power supplies, and software fault isolation and fail-over capabilities.

Layer 4-7: Network Management Systems



The LUS transport manager platform provides powerful features for the optical transport platform. The combination of these features with the open, standard interfaces provided by the transport manager allows it to serve as the foundation for the LUS Operations Support System. The transport manager is a carrier-class element management system that provides advanced capabilities in the functional management areas of configuration, faults, performance, and security for optical network elements, subnetworks, and networks. LUS backups, software upgrades, and other routine maintenance tasks are automated with client/server architecture. The transport manager is a key enabler for automation in the LUS Operations Support System.

Network Management System

With an easy-to-use Java-based, point-and-click craft graphical user interface (GUI), LUS engineers utilize the Transport Controller (TC), for the optical transport platform node configurations and monitoring. The TC allows LUS to design transport networks around subscriber needs by providing scalable bandwidths, easy switching and grooming, A to Z circuit provisioning, auto network element discover with network topology, and custom bandwidth management.

Network Node Manager

The LUS Network Node Manager (NNM) provides fault management for IP devices as well as comprehensive capabilities spanning performance, service, and customer management. Using the NNM, LUS engineers can ensure and document service availability and performance against service-level agreements.

Network Node Manager and Network Node Manager Extended Topology come together to make the most accurate, open, extensible, and easy-to-use network management solution in the industry.

The included capabilities let LUS know when there is a problem in the network so that it can be resolved before it escalates to a critical stage. At the same time, this solution helps to intelligently collect and report on key network information and plan for network improvements.

Features

- Manages Layer 2 environments as well as routed Layer 3 environments
- Provides an enhanced web user interface with dynamic views
- Shows a filtered view of the entire environment for management of large networks
- Supports heterogeneous switched network management (LAN and WAN)
- Launches targeted views from events for rapid problem resolution
- Provides views of protocols running on top of the network, for example, OSPF

Technical Summary

With the growing role of the Internet and of new applications, the pressure is on managers to provide high bandwidth, scalable, and reliable networks. LUS believes that a multiservice networking approach provides the greatest flexibility to address the connectivity challenges that wholesale service providers are faced with today. LUS has strategically positioned select equipment at the appropriate layer for the greatest amount of customer flexibility. This equipment is owned, managed, monitored and maintained by LUS, which gives LUS the ability to offer telecommunications service providers the same high level of service that is provided to the LUS utility customer base. LUS Powered Network is well positioned to offer services that focus on the Lafayette Metropolitan area, providing multiservice private network solutions between end user locations and their service providers.

It is clear that future data networks will use enhanced IP as the Layer 3 technology. Future networks will combine attributes from traditional data networks and voice networks that are in operation today. The requirements that are imposed on the nodes that comprise these new networks will use advance supporting tools, such as planning and management tools, since it is not only the network itself, but also the operation of the network, that will be changing. The current LUS network coupled with advances in optical technology, IP switching, network management and access mediums such as dense wavelength-division multiplexing (DWDM), will provide the thrust for the technology sector in the Lafayette region.