Hybrid Ethernet/SDH Transport Networks

A multiservice solution for IP/Ethernet Transport Services

A solution for service providers to leverage their installed based of SDH equipment to build service-rich networks

This white paper addresses:

- Incorporating next generation services in a multiservice environment
- Achieving network convergence
- Building a converged metro network architecture
- Supporting network convergence with Lucent Technologies platforms

Lucent Technologies
Bell Labs Innovations

Table of Contents

Abstract

The next generation of Lucent Technologies transport solutions for access, metro, and backbone networks offer a full, multiservice portfolio. They can allow circuit or voice transport to be freely mixed with flexible data transport. These types of networks are easier and less expensive to manage than alternative solutions, such as separate fiber networks using different pieces of equipment in the access and metro networks. Furthermore, these solutions can facilitate a smooth migration to future converged networks; they are designed to maintain the advantages and investments in today's circuit networks, while allowing for more advanced data services.

To accommodate the demand for these data services, equipment vendors are incorporating Ethernet technology into transport network systems. Ethernet is the enterprise network standard, and when added to a transport network, it allows for flexible and high-capacity bandwidth services that are easy to provision and maintain.

Almost all IP equipment has low-cost Ethernet interfaces. Therefore, Ethernet interfaces help provide a cost savings to the service provider and the end-user. The service provider may also benefit from Ethernet interfaces because Ethernet transport provides bandwidth flexibility and service differentiation allowing them to introduce new Ethernet services. Ethernet packets can be transported in numerous ways. For example, Lucent Technologies implements various standards, such as virtual concatenation and Link Capacity Adjustment Scheme (LCAS), in a broad range of products for different types of services and different types of network architectures. These products help form solutions with the reliability, interoperability, and manageability that can typically only be found in today's voice networks.

"To accommodate the demand for these data services, more and more equipment vendors are incorporating Ethernet technology into transport network systems."

Introduction

Service Convergence; Drivers for Hybrid Transport

Telecommunications service providers are moving toward a new generation of packet-based optical networks. Because of the constantly accelerating demand for bandwidth, connectivity, and new applications — broadband data services have become a major part of the networking business. As new packet-based optical networks are built, and services such as voice, video, and guaranteed performance Virtual Private Networks (VPNs) move onto these networks, a grand service convergence can occur.

The increased multiservice nature of converged networks requires efficient handling of voice and data, wideband and broadband, electrical and optical interfaces. Furthermore, an enduring network infrastructure must offer affordable evolution despite unpredictable demand growth. To support the convergence, one can switch to totally data (Ethernet) oriented networks, where each network element does packet switching. However, pure data (Ethernet) networks are typically not as robust in availability, reliability, pro-active and active maintenance, scalability and transparency. The other option is to extend the current transport network architecture into a new generation transport architecture optimized for both circuit transport and data traffic growth.

Ethernet has become the dominant technology for enterprise networking in LANs. In data centers and ISP offices, the application of Ethernet is increasing. Ethernet today is the most simple and low cost technology for short distance data connections. Compared to the Packet over SDH (POS) router interfaces, Ethernet interfaces are generally priced much lower. Also, when we examine how LANs are interconnected via the public transport network, the required POS long distance router interfaces are priced higher than Ethernet interfaces.

Networks built on SDH and WDM are ideal for offering reliable, cost-effective transport for voice and private line services – services that continue to dominate access network revenues today. However, pure SDH and WDM networks are not optimal for all services. For example, existing circuit solutions do not have the bandwidth scalability and granularity that high-speed data connections require. These shortcomings related to data transport are addressed with the next generation transport networks.

One of the next generation network components is the integration of Ethernet technology. Support for standard Ethernet interfaces directly on network elements, such as SDH Add/Drop Multiplexers (ADM) and DWDM Optical Line Systems (OLS), will offer the required optimizations for data services. This solution helps to enable low-cost data interconnectivity with customer and ISP equipment while maintaining the reliable and manageable data transport that is required in large networks. It allows Service Providers with large embedded SDH networks to leverage their investment in staff, operational practices, management systems and equipment to provide new Ethernet Services quickly from any location in the network at marginal cost. Lucent Technologies refers to this concept as "hybrid transport."

There are a number of new services that can enhance the operator's revenue and are made possible by the hybrid transport technology. These Ethernet services and the Ethernet solutions that Lucent Technologies can offer are presented in this white paper.

Hybrid Ethernet Transport Services

Lucent Technologies has identified three major Hybrid Ethernet transport services:

- Inter-POP services
- Corporate LAN interconnect services
- Managed IP services (i.e. IP-VPN, Internet Access, Hosting, VoIP etc.)

Each service has its own network requirement and therefore leads to different network architectures.

Inter-POP Connections

ISPs need flexible, high-bandwidth connections between their IP routers and their bandwidth wholesaler. The bandwidth demands could be anywhere between 100Mbps and 1Gbps. Inside a Point of Presence (intra-POP), the router connections are increasingly made by high speed Ethernet links. For connections between routers on different locations (inter-POP), a wide range of technologies is used. Some of these router interfaces like POS are expensive compared to Ethernet interfaces, driving costs up for both service providers and their customers.

Direct paths between the main routing locations in the form of dedicated SDH or WDM signals are more effective than networks where routing is performed at each and every node. If a router (or Ethernet switch) is used at an intermediate node, most data traffic that flows from the transport layer towards the router will return immediately to follow its way in the transport layer (pass-through traffic). In other words, in an intermediate node it is inefficient and expensive to add routing functionality. Furthermore, the amount of electronics needed in a router is much higher for comparable switching capacity. In particular, for high-speed connections where the components work near the limits of electronic processing, routing comes at a premium.

Hybrid Transport based on SDH can provide high-speed and simple leased line Ethernet connections over large distances (see Figure 1). These point-to-point services are flexible in bandwidth by the use of virtual concatenation and LCAS[1]. Ethernet interfaces support frame transfer rates of 0bit/s up to their designated interface rate of 100Mbps or 1Gbps. This combination allows for the provisioning of a wide range of bandwidth. A customer can slowly increase the bandwidth of its service connection, or can change the bandwidth frequently, depending on demand. These changes are quickly done through provisioning, without the need to change or update equipment.

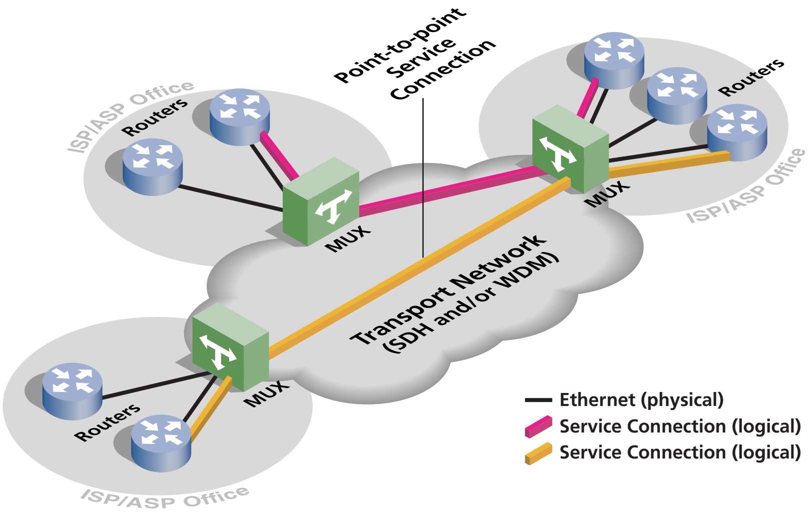

Figure 1: High-speed point-to-point Ethernet services as inter-POP connections

Another option is to transport Gigabit Ethernet (GbE) with hybrid transport based on WDM solutions. When the full bandwidth of a 10GbE service is needed, it is transported best with WDM technology, or when enough fibers are available, directly on a fiber.

As with the lower-rate Ethernet interfaces, it is also possible to use a 10GbE interface while only a part of the bandwidth is available in the SDH transport layer. This gives more bandwidth flexibility between 1GbE and 10GbE. It should become more economical when the prices of 10GbE interfaces have dropped considerably, and the line rate of SDH systems has increased to 40Gbps.

[1] See Appendix A for an explanation of virtual concatenation and LCAS.

Corporate LAN Interconnections

With the growing need to communicate across long distances, many enterprises find themselves faced with the problem of having Ethernet available in each of their geographically distant offices LANs, but without a standard way to connect them. Often, LANs are connected via a dedicated private line circuit (e.g., n × 64 kbit/s, E1, DS3) or packet technologies like X.25, Frame Relay, and ATM. Both types of solutions require additional boxes at the customer's site, which makes these solutions costly. To solve this problem, it is better to have an Ethernet interface directly integrated on the network transport equipment.

Although optimized for IP, Ethernet is transparent for all Layer 3 protocols. This means it can also carry the still important but older protocols such as IPX, DECnet and EtherTalk. With an Ethernet connection over the public transport network (often referred to as WAN) the enterprise can truly work on each location as if it is using a single LAN (see Figure 2). Because each customer's traffic is isolated from other customers, there is no need to deploy security measures such as firewalls.

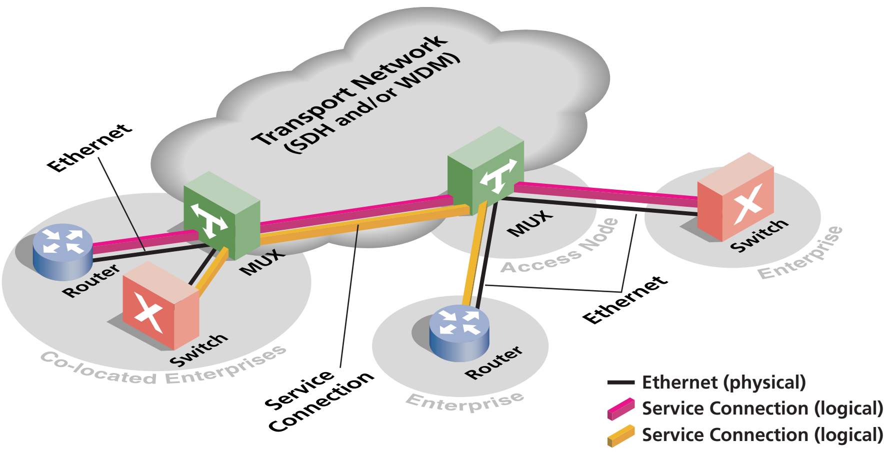

Figure 2: Point-to-point Ethernet services. (Enterprises can deploy both routers and Ethernet switches.)

At the access node it is possible to introduce more advanced features with an internal Ethernet switch. For example, multi-point connections that connect multiple sites with a single Ethernet cable on each site (see Figure 3).

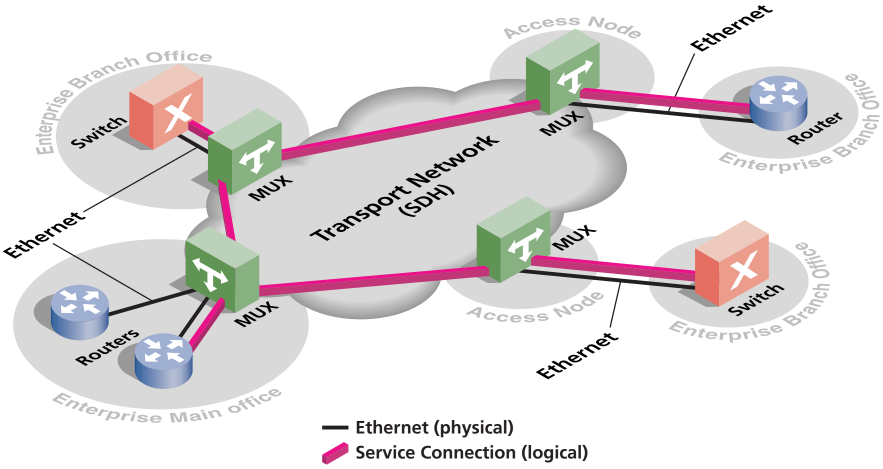

Figure 3: Multi-point Ethernet services and ISP access services

To allow a gradual increase of bandwidth usage from an enterprise customer, the bandwidth used in the SDH transport network is scaled with virtual concatenation (same as for inter-POP connections). This helps meet today's requirement of 2Mbps up to 1000Mbps. Another opportunity in the Ethernet service market is the area of service rates below 2Mbps and the area of bandwidth sharing. These connections can be aggregated/shared with statistical multiplexing to help provide cost-effective, access services with throughput rates of 150Kbps up to the full 1Gbps. Customer isolation is maintained with a user-tagging scheme, based on standard simple IEEE802.1Q or double-VLAN tagging scheme.

Very bandwidth hungry enterprises can be served with 1GbE interfaces. The requirements and solutions are similar to ISP inter-POP services in the previous section.

Managed IP services (i.e. IP-VPN, Internet Access, Hosting, VoIP etc.)

An ISP office has connections to many customers. When this is implemented with a point-to-point connection for each customer, many cable connections are required between the SDH multiplexer(s) at the ISP office and the ISP's router(s). To limit the number of cables and ports on the router, it is necessary to aggregate the data traffic from customers before that traffic is handed off to the router (see Figure 4). Routers can typically only deal with statistically multiplexed data. Therefore, an Ethernet switch is needed inside the SDH multiplexer to aggregate the different data streams into a single, statistically-multiplexed Ethernet stream for the router.

The result is that only a single Ethernet link is needed to connect the ISP router to the transport network, which is called a "VLAN trunk". A VLAN trunk lowers the number of interfaces on the router and SDH multiplexer. Furthermore, the reduced amount of cabling helps save installation and maintenance costs.

VLAN tagging, a standard way to mark Ethernet packets, is used to identify each customer's packet stream on the VLAN trunk. With VLAN tagging, strict security is maintained without the need for encryption. Conceptually this approach is identical to FR and ATM and offers the same statistical multiplexing advantage, but with higher speeds at lower costs without the need for separate, dedicated FR/ATM equipment.

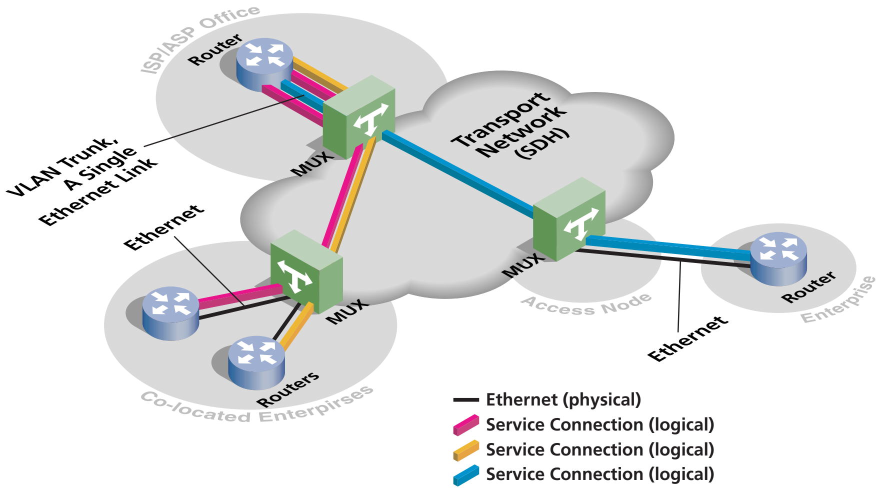

Figure 4: Managed IP services

Relevant bit rates for Enterprise Internet access services are up to 10Mbps at the enterprise access, with a 100Mbps VLAN trunk at the ISP, or a combination of services between 10Mbps and 100Mbps at the enterprise access, with a 1Gbps VLAN trunk at the ISP.

The advantage of using an SDH network is that regular services, such as E1 for voice telephony, can be transported over the same network. This is very useful for enterprises that want to keep their traditional PBX for telephony, and at the same time grow their data connections. Another market where the combination makes a perfect match is the xDSL network business. The current DSLAMs typically can be equipped with 100MbE or 1GbE data interfaces that need to be connected to the ISP office.

When an SDH network does not have enough capacity for a Metro region, Passive WDM (PWDM) is an option that can be weighed against new fiber installation. PWDM technology chooses lower-cost WDM technology over more expensive and more capable DWDM technology. PWDM makes it possible to cope with fiber scarceness in metro regions.

Lucent Technologies Ethernet Solutions

Lucent Technologies acknowledged the importance of Ethernet support at an early point in time. As a result, the ability to efficiently transport Ethernet-based clients is widely implemented in the Lucent Technologies optical networking portfolio.

When equipped with WaveStar® TransLAN™ Cards, Lucent Technologies SDH multiplexers can offer transport of both IP data and voice over SDH. In addition, the core networking products that Lucent offers are designed to efficiently support Gigabit Ethernet and 10 Gigabit Ethernet interfaces on DWDM systems.

This portfolio-wide implementation helps provide cost-effective solutions for a broad variety of applications and network segments. With the rapid growth of demand for (gigabit) Ethernet services, Lucent Technologies Ethernet solutions form a sound starting point to helping build a competitive edge in this promising market.

Together with the suite of management software and the field proven track record of network deployment around the globe, Lucent Technologies offers:

- tailored and cost-effective transport solutions for multiservice networks
- highly-efficient Ethernet transport capabilities
- efficient and integrated network operations
- professional network deployment

Lucent Technologies Solutions

Lucent Technologies offers solutions for the hybrid transport services that were defined in the previous sections. This section elaborates on how these solutions and services work with available Lucent Technologies products.

Table 1 provides an overview of the services and in which network segment they will most likely be used. Three areas are identified: the Access part of Metro networks; the Inter-Office part of the Metro network (IOF); and the Backbone. The lower portion of the table shows which products can be used to provide Ethernet services for a certain network segment.

Network Segment: / Services:	Metro-Access	Metro-IOF	Backbone
Inter POP Connections	X	X	(X)
Internet Access	(X)	X	
Corporate LAN Interconnection	X	(X)	
Products:	WaveStar® AM 1 Plus WaveStar® ADM 16/1 WaveStar® ADM 16/1 Compact	WaveStar® TDM10G LambdaUnite™ MSS Metropolis® EON	WaveStar® TDM10G LambdaUnite™ MSS LambdaXtreme™ Transport

Table 1: Relation between services, their network segments and suitable products.

The Managed IP Services and Corporate LAN interconnection services are not noted in the backbone column. These services are certainly capable of using the transport facilities of the backbone network, however, no special backbone equipment is needed for these services.

The following sections illustrate solutions in more detail. (These solutions are encircled in Table 1.)

Lucent Technologies Service Intelligent™ Architecture

Lucent's unique vision for Service Intelligent™ Architecture helps service providers optimize existing networks by reusing their embedded infrastructure and selectively adding systems when and where they're needed to offer new services. This approach helps generate profitable, new revenues in a measured fashion. At the same time, it helps lower capital and operational expenses and simplifies network operations.

While Lucent's vision of Service Intelligent™ Architecture is one of an integrated, flexible, service-rich network, it is also a deployable strategy for carriers to manage and evolve their networks, in order to flexibly and profitably deliver new services. It is a holistic approach that encompasses a service provider's entire network and focuses on the key elements essential for intelligent network planning and management.

SDH-based Solutions for Managed IP Services

Lucent Technologies SDH solutions offer bandwidth flexibility and high fiber utilization. This is important in many access networks where fiber is still scarce. Investments in installed TDM gear are protected because WaveStar® TransLAN™ Cards can be added to existing SDH systems. This helps service providers to offer Ethernet services in addition to the existing circuit-based services at interface rates up to 10Mbps, 100Mbps, and 1Gbps. And, virtual concatenation can make finer granular steps in between 10Mbps and 1Gbps possible.

The SDH metro/access products that help enable Ethernet transport are the WaveStar® AM 1 Plus, WaveStar® ADM 16/1, and WaveStar® ADM 16/1 Compact. The WaveStar® AM 1 Plus is a small sized (438mm x 293mm x 85mm) SDH multiplexer that is designed to be easily installed at the customer's premises. The WaveStar® ADM 16/1 and/or WaveStar® ADM 16/1 Compact can be placed at large customer sites, at intermediate nodes, and in the Central Office.

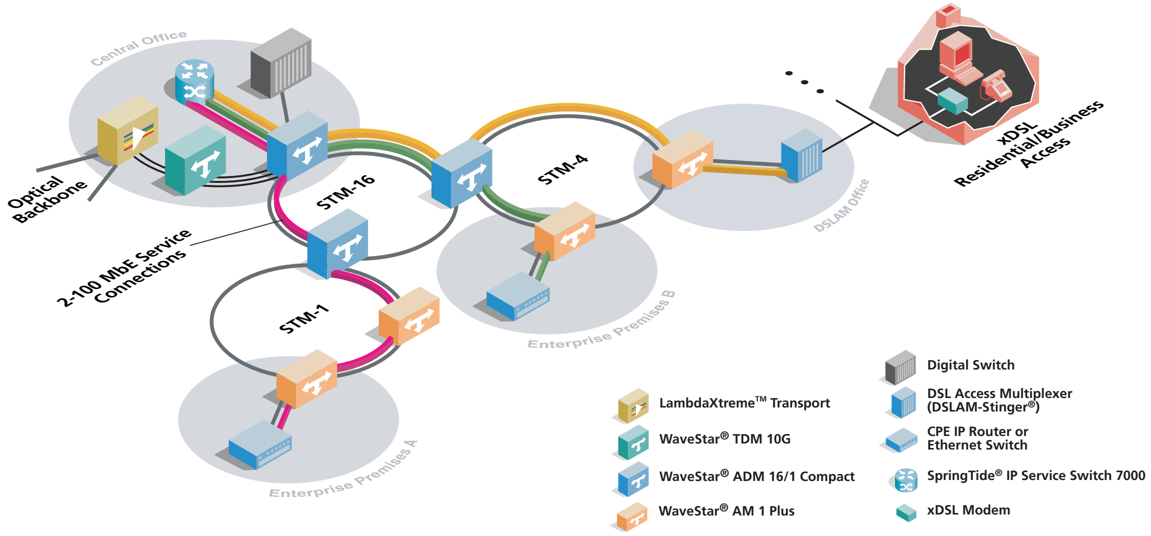

Figure 5: SDH-based network solution for Internet Access services

Figure 5 shows an example of a service provider network solution that offers Internet access to enterprise customers. These services are provided by connections from enterprise premises A and B to the Central Office/POP location. The WaveStar® AM 1 Plus on location A and B provide a 10BASE-T and 100BASE-T Ethernet interface to the customer's equipment. The Ethernet frames (traffic) tagged with an IEEE802.1Q VLAN tag is transported from the WaveStar® AM 1 Plus to the WaveStar® ADM 16/1 Compact in the Central Office with virtually concatenated VC-12 or VC-3, depending upon the offered service throughput. In the Central Office, the hand-off to the ISP router (for example, the SpringTide® 5000/7000) can be done with a 100BASE-T or 1000BASE-SX/LX VLAN trunk interface* on the WaveStar® ADM 16/1 Compact.

* Expected general availability 1Q03

The IEEE802.1Q VLAN trunk interface on the WaveStar® ADM 16/1 Compact aggregates the data streams from multiple customers into one fully utilized 100bit/s or 1Gbps* data stream. Statistically, multiplexing can be applied either in a central located WaveStar® ADM16/1 Compact or can be done in any of the intermediate nodes. This leads to a more bandwidth-efficient Ethernet transport in the Virtual Concatenated VC12 or VC3 signals that are connecting these central and intermediate nodes together.

Figure 5 shows how the DSLAM Office can be equipped with a WaveStar® AM 1 Plus to help provide Ethernet connectivity to the service node. This is an example of how a more sophisticated Service Intelligent™ Architecture could be built.

In addition to the transport of Ethernet over SDH, these systems can help provide the following Layer 2 switch capabilities:

- IEEE 802.1D MAC learning/filtering for point-to-point; and multi-point connections.
- IEEE802.1Q VLAN support; VLAN trunking;
- Layer 2 IEEE 802.1D Spanning Tree protocol, saving bandwidth over 1+1 SNC/P protection scheme. IEEE 802.1w Rapid Spanning Tree achieving restoration in order of 1s will be implemented (expected general availability 1Q03);
- GVRP for easy, consistent configuration of VLANs across the WAN with VLAN broadcast domain optimization offering both reduced operation costs and automatic network engineering;
- IEEE 802.1p/L2 DiffServ QoS architecture (including flow classification, policing (CIR, PIR), queuing, queue management, different scheduling disciplines) to transmit traffic in a predictable manner with prioritization for different levels of SLAs;
- Option to dedicate or share SDH paths among multiple customers

Note that the network architecture shown in Figure 5 supports other services mentioned in the previous section titled “Hybrid Ethernet Transport Services”.

Lucent Metro Network Solutions for Corporate LAN Interconnects

The Lucent portfolio allows service providers to offer LAN interconnection services to customers who need to connect their geographically dispersed offices. These services have throughput rates of sub-10Mbps up to 1Gbps. High-end service connections between 100MbE and 1GbE require a metro network with more capacity.

To help provide a 100MbE LAN interconnect service, the WaveStar® AM 1 Plus, WaveStar® ADM 16/1, and WaveStar® ADM 16/1 Compact can equipped with 10/100BASE-T interfaces. These products are designed to support point-to-point based (Ethernet Private Line-type) services, and multi-point LAN services with either dedicated bandwidth (Private LAN Services: PLS, aka PLAN) or shared bandwidth (Virtual Private LAN Services: VPLS, aka VPLAN).

* Expected general availability 1Q03

These services support transparency of customer's IEEE802.1Q VLANs. This transparency can be achieved with a double VLAN tagging scheme, a.k.a. VPN Customer tagging or transparent tagging. This tagging scheme is tagging customers Ethernet frames with an additional VPN tag based on the incoming port, and removing this tag at the network egress. The VPN tag is carrying a Customer ID (CID) and various QoS information helps enable statistical multiplexing via oversubscription. This operator-controlled tagging process is invisible to the customer. Next to IEEE802.1Q transparency, the VPN tagging also supports one spanning tree per VLAN for better traffic load equalization and bandwidth usage efficiency.

1GbE services in the metropolitan part of the network are possible with 1000BASE-SX/LX interfaces implemented on WaveStar® TDM 10G and the LambdaUnite™ MultiService Switch (MSS). It is also possible to provide 1GbE services in the metropolitan part of the network, with 1000BASE-SX/LX interfaces* implemented on WaveStar® ADM 16/1 and WaveStar® ADM16/1 Compact.

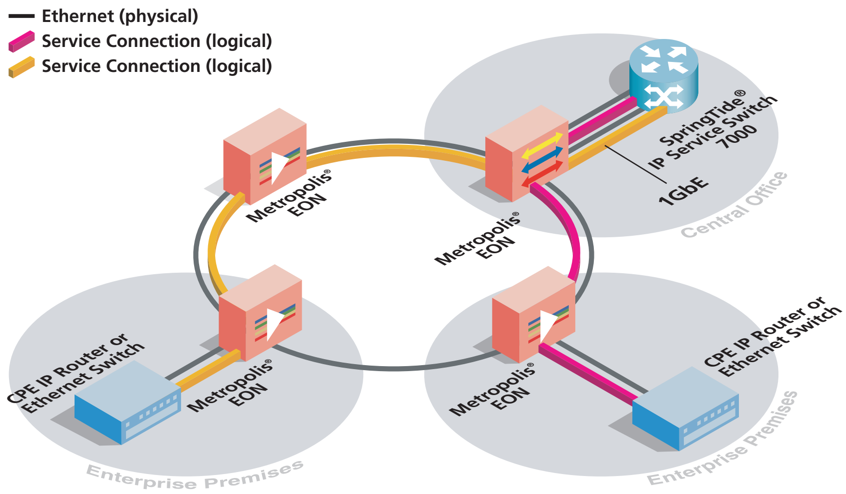

Figure 6: SDH based solution for Corporate LAN Interconnect

Figure 6 illustrates a 1GbE corporate LAN interconnect service between enterprise premises A and D. The WaveStar® ADM 16/1 and WaveStar® ADM 16/1 Compact offer a 1000BASE-SX/LX* interface to the customer, and both point-to-point and multi-point LAN connections are possible. The throughput of the link can be provisioned in steps of one VC-4 for providing scalability of services (150Mbps to 1000Mbps). The WaveStar® TDM 10G and LambdaUnite™ MSS help transparently transport the virtually concatenated SDH signals to the other locations of the enterprise. If the customer is close (< 2 km) to the WaveStar® TDM 10G or LambdaUnite™ MSS, another option is a direct Gigabit Ethernet link with the 1000BASE-LX interface.

* Expected general availability 1Q03

Figure 6 also illustrates a multi-point corporate LAN interconnect service between enterprise premises A, B, and C. The throughput of this service is from 2Mbps up to 100Mbps. The Ethernet frames originating from location A and B are mapped in SDH (virtually concatenated VC-12s or VC-3s and consequently multiplexed into a VC-4). At the customer's headquarters (location C), a WaveStar® ADM 16/1 Compact is used to set up a multi-point LAN connection to locations A and B, to either another WaveStar® ADM 16/1 Compact or an WaveStar® ADM16/1. The Ethernet frames originating from location C signal are bridged and mapped in the two SDH paths. Because of the bridge inside the WaveStar® ADM 16/1 Compact, only one Ethernet cable is needed at the customer equipment sites.

Several other services are possible: for example, point-to-point corporate LAN interconnections and multi-point Corporate LAN connections. This network architecture can also be used to provide Internet Access services and inter-office connections.

Lucent Metro-Core Network Solutions for ISP Inter-office Connections

The Metropolis® Enhanced Optical Networking (EON) platform uses DWDM coupled with rate-adaptive OTUs, to help meet the challenge of providing a scalable solution for a variety of service-access transport needs while remaining cost-effective.

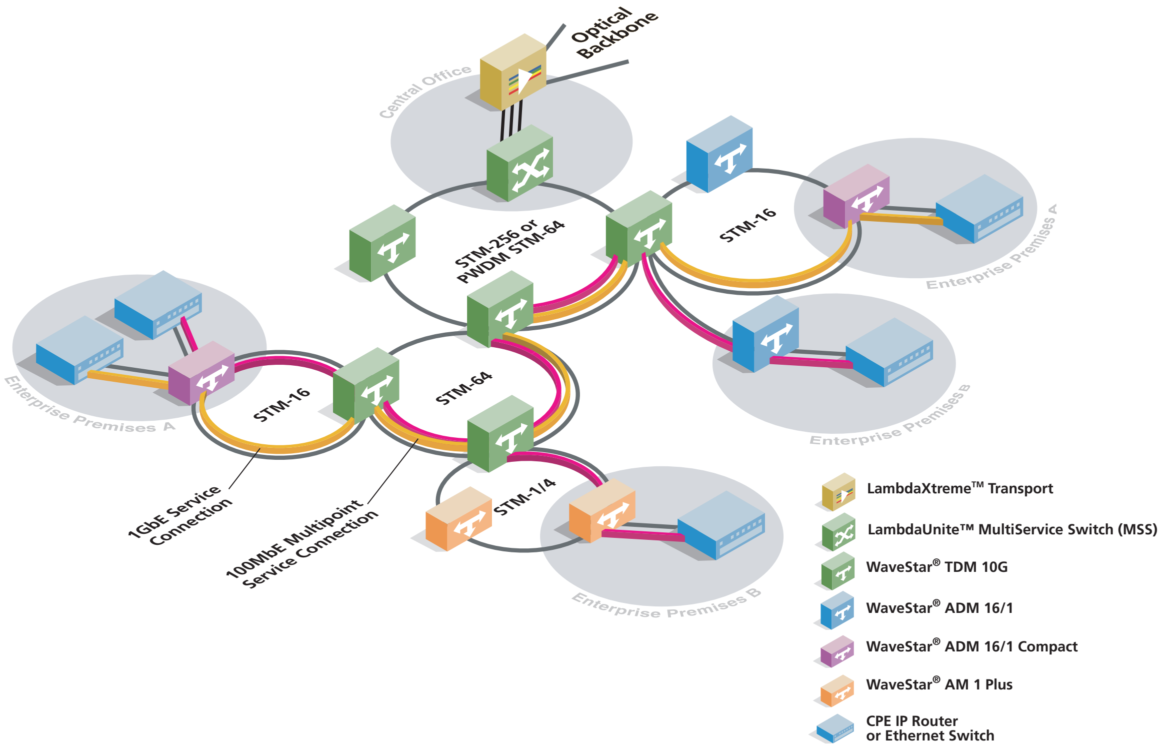

Figure 7: 1/10 GbE support over a Metropolis® EON metro-core network (ring architecture)

An application example for the Metropolis® EON is data center interconnectivity (ISP interoffice) in a metro-core network. Transport of a 1/10GbE provides 1/10Gbps of packet transport between router ports. This exceeds the capacity of a VC4-4c/VC4-16c payload by respectively 65 and 300 percent, while using lower-cost LAN interfaces on the data equipment instead of the more expensive TDM interfaces. For simple point-to-point connectivity between routers, the WDM layer OAM&P can suffice. Figure 7 shows how a 1GbE connection between a remote ISP router and a Long Haul Network is made over a Metropolis® EON. Additionally multiple 1/10GbE connection are shown between the data centers.

Lucent Backbone Network Solutions for ISP Inter-office Connections

For ISP inter-office connections over extended geographic areas, a fitting solution is a backbone network with Dense Wavelength Division Multiplexing (DWDM). Optical Line Systems (OLS) using DWDM technology help deliver huge transport capacity of more than 2Tbps over extended fiber facilities on high-speed optical channel rates of 2.5G, 10G and 40G. Although DWDM OLSs represent considerable investment, both in terms of equipment and facilities, for high traffic demands the costs may be justified by savings in the fiber installation.

Two options to help optimize the filling of DWDM wavelengths include:

- Map customer Ethernet signals directly in a wavelength with an HSBB OTU
- Map customer 10GbE signals directly in a wavelength with a 10GbE OTU or 4x10GbE multiplexing OTU.

The WaveStar® OLS 1.6T DWDM platform currently offers a rate-adaptive Optical Translation Unit (OTU) solution that helps support a 1000BASE-LX Ethernet interface. This OTU is called the High-Speed Broadband (HSBB) OTU. The HSBB OTU is designed to help carriers meet internal needs for transport of signals other than 2.5G and 10G optical channels. The WaveStar® OLS 1.6T DWDM platform also provides a 10GbE OTU that is designed to transport 10GBASE-EW Ethernet traffic.

In case of long haul applications (up to 4000km, up to 2.56Tbps capacity), the LambdaXtreme™ Transport DWDM platform offers a 10G and a 4x10G Optical Translation Unit, which supports the10GBASE-EW Ethernet interface.

The WaveStar® OLS 1.6T can also provide cost-effective transport in backbone network applications when the GbE interfaces will be hosted on a WaveStar® TDM 10G or LambdaUnite™ MSS platform. The flexible virtual concatenation maps the GbE into STM-64 tributaries, which are then transported using the OLS product. This is shown in Figure 8.

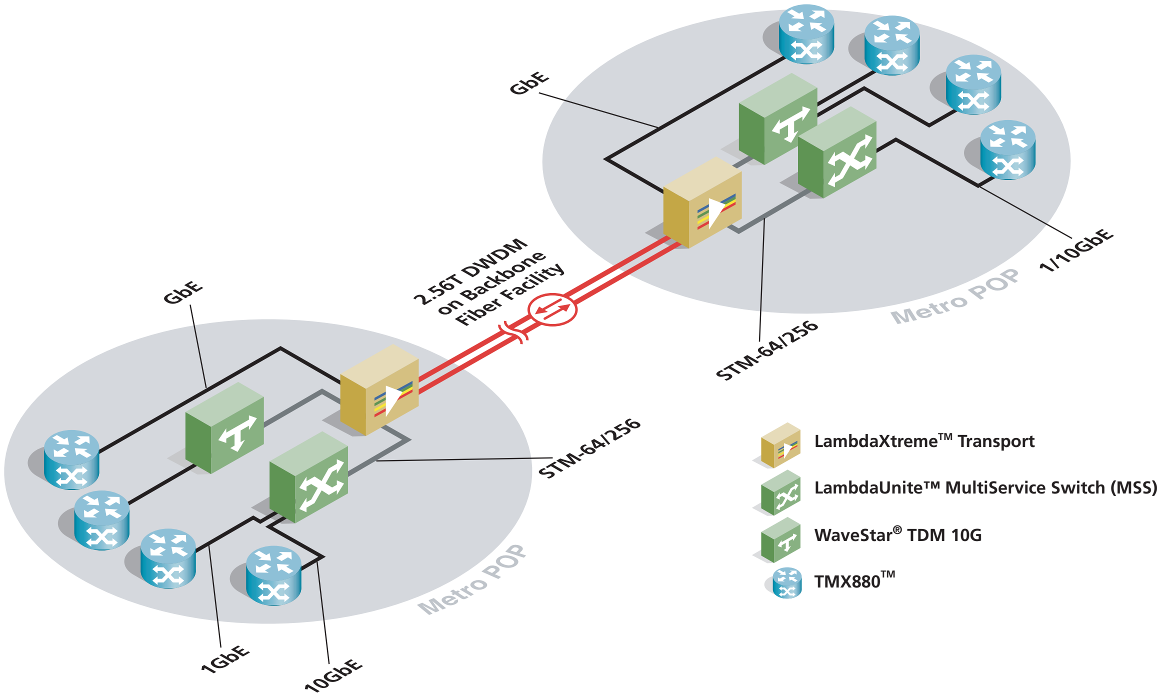

Figure 8: 1GbE and 10GbE transport via LambdaUnite™ MSS, WaveStar® TDM 10G, and WaveStar® OLS 1.6T

LambdaUnite™ MSS and WaveStar® OLS1.6T can allow the transport of 10GbE services. The ISP router can be connected to the LambdaUnite™ MSS using the WAN variant of the 10GbE IEEE 802.3ae standard. In addition to the Ethernet services, native voice service (e.g. STM-N services) can be offered with this network architecture.

Operations

Lucent Technologies solutions are delivered with operations and maintenance systems software, and the Ethernet solutions described in previous paragraphs can be managed by one integrated management platform.

Figure 9 illustrates the management architecture. Navis™ Optical Network Management System (NMS) is a single-seated, all-purpose solution for managing multi-vendor transport networks.

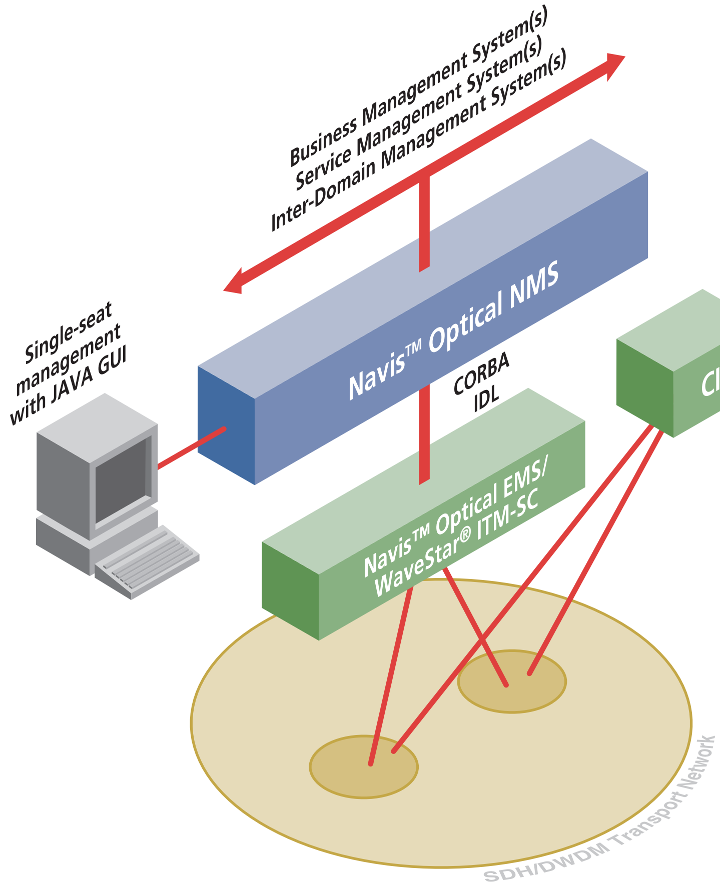

Figure 9: Overview of the management architecture

The operations required to set up an Ethernet connection are two-fold. First, an end-to-end transport connection is provisioned between the different Network Elements involved. Second, the Layer 2 switching relations are set up between WAN and Ethernet ports on the SDH/DWDM systems.

Setting up VC-12/3/4/DWDM transmission paths through the network is done on a point-and-click basis. For changing customer bandwidth needs, the management solution offers the means to add or remove bandwidth gradually, starting with 2Mbps granularity. Aside from provisioning, the Navis™ Optical NMS helps deliver a wide variety of processes to ensure QoS in a network, e.g. setting up SDH/DWDM protection schemes, performance monitoring capabilities, and LAN failure supervision.

Conclusion

Lucent Technologies supports Ethernet in its optical product portfolio. The capability of transporting Ethernet over SDH and DWDM is accomplished using the WaveStar® TransLAN™ Card.

The Lucent Technologies Ethernet solution can help operators provide a differentiated service mix of:

- Inter-POP connections
- Corporate LAN interconnection
- Managed IP services (i.e. IP-VPN, Internet Access, Hosting, VoIP etc.)

Ethernet services deployed with Lucent Technologies equipment can be provided, regardless of the network segment in which the equipment is installed. These services are designed to offer reliability, interoperability, and manageability that can typically only be found in today's voice networks.

WaveStar® TransLAN™ Cards offer Ethernet interfaces with rates of 10/100MbE, 1GbE up to 10GbE. The data throughput of these interfaces can be provisioned from sub-10Mbps up to 10Gbps, depending on the interface and product.

Lucent Technologies SDH and DWDM equipment, including WaveStar® TransLAN™ Cards, can be managed centrally with Navis™ Optical NMS. It offers a point-and-click solution for provisioning customer's bandwidth demands within minutes, and incorporates functionality to help meet service level agreements that are negotiated between service providers and customers.

Appendix A: Ethernet Transport-Enabling Technologies

Synchronous Digital Hierarchy (SDH) and Ethernet Transport

Virtual Concatenation

Until recently, SDH systems were optimized only for telephony signals that fit in a strict hierarchy of bit rates. More flexibility was needed, especially for data applications. This resulted in the specification of the Virtual Concatenation standard. Virtual Concatenation is an inverse multiplexing technology that combines multiple SDH client signals into a single bit-stream. An important aspect of Virtual Concatenation is that it only needs to be supported at the end nodes; the rest of the network simply transports the separate channels. Virtual concatenation is fully standardized in ITU-T G.707 and G.783 (since 2000 Edition).

With Virtual Concatenation, bandwidth can be allocated as needed. For example, an enterprise might need 300 Mbps for an office interconnect. This is possible by allocating 2 VC-4s and combining this into a VC-4-2v stream of 2 × 150 = 300Mbps. The connection at the enterprise locations is done with a GbE interface. When the demand goes up, more VC-4s can be assigned to the same connection until 1Gbps is reached in the GbE interface.

Bandwidth Requirement	SDH Payload Type	Tributary Interface
Up to 10Mbps	VC-12-xv, x = 1..5	10BASE-TX/100BASE-T
50 Mbps and 100 Mbps	VC-3 and VC-3-2v	100BASE-T
Up to 1 Gbps	VC-4-xv, x = 1..7	1000BASE-SX or LX

Table 2: SDH payload signals can be used for Ethernet transport.

LCAS and Data optimized protection options

Link Capacity Adjustment Scheme (LCAS) is an extension of Virtual Concatenation that allows dynamic changes in the number of SDH channels in a connection. When channels are added or removed by management actions, it can be accomplished without loosing any customer traffic. LCAS functionality is standardized in ITU-T G.7042.

LCAS allows a bandwidth service with higher throughput when there is no failure in the network. When there is a failure the bandwidth, throughput will be lower. This occurs because when some of the channels of the virtually concatenated connection fail, the remaining channels will continue carrying the customer traffic.

This is an advantage for IP networks. An IP router will recognize that less bandwidth is available on an LCAS link with a failure. However, the IP topology has not changed and IP packets still go through. Therefore, the IP routing protocols do not need to re-converge, and no traffic interruption will occur. Traditional protection schemes are of course also possible. These are implemented in the SDH or WDM layer.

Transporting packets in circuits

Ethernet packets are transported in frames by the ITU-T G.7041 standard Generic Framing Procedure (GFP). It is a very efficient encapsulation protocol because GFP has a fixed and small overhead per packet. Unlike most framing protocols, GFP scales to very high bandwidth and is now also used in ITU-T for pure optical transport.

Wavelength Division Multiplexing (WDM) and Ethernet Transport

Optical Line System (OLS) platforms are the gateway platforms of WDM transport. Transport over an OLS WDM interface requires adapting the client signal to an optical channel rate and format of the OLS and generating the optical signal compatible with the OLS' WDM interface. The OLS sub-system that adapts a client signal(s) to WDM optical channels is the Optical Translation Unit (OTU). The add OTU (OTU-A) maps a User Interface signal into the client payload and provides the WDM-compatible optical signal. The OLS terminal aggregates the OTU-A optical signals using optical multiplexing (OMUX) of all lambdas or Optical Add/Drop Multiplexing (OADM) of selected lambdas. The destination OLS terminal accesses the wavelength carrying the client(s) using optical demultiplexing (ODMUX) of all the lambdas or OADM of selected lambdas. The optical signal is routed to the drop OTU (OTU-D) for client signal recovery and is output on the OTU-D User Interface.

Two methods for adapting GbE clients to OLS optical channels are: Map the GbE signal to an optical channel dedicated to the GbE client; Map the GbE into a client signal that shares the optical channel among multiple clients.

Dedicated Optical Channel

When transport and management of an individual GbE signal is needed, then a dedicated optical channel provides a simple solution. One approach that an OLS can use is an OTU-A that adapts to the Optical User Interface input rate and supports GbE in the range of signal rates supported. Similarly, the OTU-D adapts to the optical channel rate being dropped. By supporting a wide range of client signal types on an OLS with rate adaptive OTU-A + OTU-D, the costs required to support a wide array of User Interface types is reduced. Dedicating an optical channel to the transport of a single GbE client who uses only a fraction of the payload is not desirable from the viewpoint of providing a cost-effective, scalable transport solution for GbE. Therefore, dedicating a 2.5G or 10G optical channel to a single GbE client is not advisable.

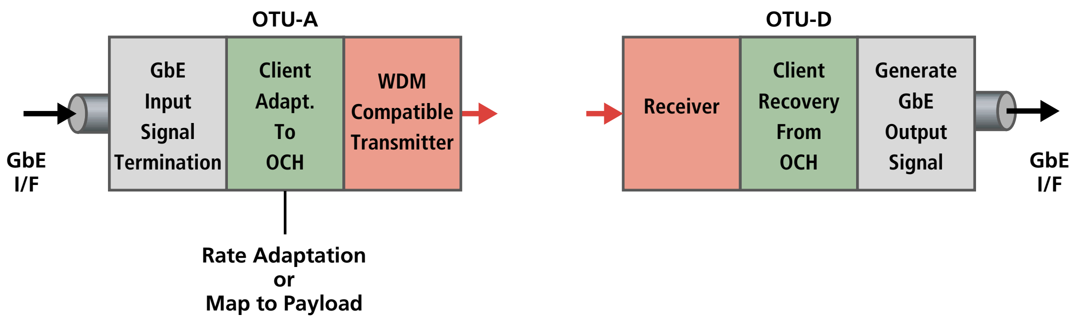

Figure 10: OTU-A + OTU-D for *dedicated* OCH

An advantage of the dedicated channel approach to GbE is that the optical channel path OAM&P provides path management for the GbE client over the OLS transport domain.

Figure 10 illustrates the concept of the OTU-A and OTU-D for dedicated optical channels.

Shared Optical Channel

When sharing a higher-speed optical channel payload with multiple GbEs, the complexity of client signal processing that can be supported on OTU-A + OTU-D functions is limited by necessity. The OTU-A and OTU-D designed to support multiple client inputs include Time Division Multiplexing (TDM) as part of the adaptation of the GbE clients to an optical channel payload. This Multiplexing OTU (MuxOTU) approach provides scalability for GbE transport using common OLS optical channel rates and formats and still permits flexible allocation of OLS resource on a per channel basis. Figure 11 illustrates OTU-A + OTU-D for shared optical channels. The optical channels and rates widely supported on OLS are 2.5G (STM-16) and 10G (STM-64) and the transport of 1.25Gbps clients requires that some signal overhead be pruned to achieve high utilization of 2 x GbE per 2.5G and 8 x GbE per 10G client payload.

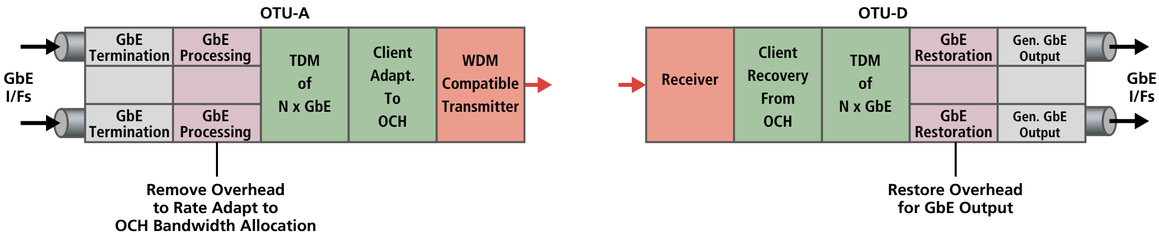

Figure 11: OTU-A + OTU-D for *shared* OCH

10 GbE Clients on OLS

In contrast to GbE, the 10GbE standards include a WAN interface (10GBASE-W, also known as WAN PHY) specification compatible with the framing and rate of an STM-64 signal. The STM-64 framing and rate means that supporting 10GbE on OLS has an obvious and direct solution. Use an OTU-A + OTU-D with 10GbE user interfaces on the OTUs to map the 10GbE signal into either a legacy SDH or a Rec. G.709 10G optical channel. When optical channels at 40G are available on OLS, a MuxOTU approach to 10GbE will also be possible.

Authors

Dirk C L M van Bree

Metro Optical Ethernet Network Architect & Senior Application Engineer

Mr. Van Bree joined Lucent Technologies in 1997 and has held several positions in Optical Networking Research & Development including: network testing, systems engineering and team leader for an interoperability test team.

Two years ago he moved to the Optical Networking Group-EMEA in an Application Engineering position responsible for Europe. His focus is on Ethernet and GbE applications — acting as a pre-sales engineering for customer teams for optical Ethernet, SDH and DWDM technologies, as well as optical portfolio/roadmap management.

Mr. van Bree holds a bachelor's degree in Electronic Engineering – Telecommunication Techniques from Utrecht University.

Stéphan Roullot

Metro Optical Ethernet Network Architect & Technical Marketing Systems Engineer

Mr. Roullot joined Lucent Technologies in 1998, and has held several positions in Optical Networking Research & Development, including system tester, system engineering technical manager on hybrid multiservice SDH multiplexers with PDH, Ethernet, ISDN interfaces.

Recently he moved to the European Technical Marketing organization where his current activities are architecture, product, and technology support to pre-sales customer teams for optical Ethernet, SDH and DWDM technologies, as well as optical portfolio/roadmap management.

During the last three years, Stéphan has been coordinating the international System Engineering activities for the implementation of Ethernet over SDH/DWDM solutions in the Optical Networking portfolio of Lucent.

Mr. Roullot holds a Master of Science degree in Electrical Engineering – Scientific and Technical engineering studies at INSA Lyon in France.

Appendix B: Glossary

Acronym	Meaning
ADM	Add/Drop Multiplexer. SDH equipment that can add or remove (drop) a customer signal from an SDH signal.
ASP	Application Service Provider. Company that provides remote access to software applications for other companies.
ATM	Asynchronous Transfer Mode. A form of packet switching in which the information is organized into cells.
Central Office	The building that houses the switching equipment where business and residential telephone circuits are connected; also called an "Exchange."
DS3	A PDH signal with a throughput of 45Mbps. Used for voice, video and data.
E1	A PDH signal, mostly used to carry voice. Throughput is 2Mbps.
Edge-Router	A router located at a POP. An edge router contains functions needed to provide Internet Access like authentication, access control lists, billing, etc.
Frame Relay	A form of packet switching, but using smaller packets and less error checking than traditional forms of packet switching (such as X.25). Now a new international standard for efficiently handling high-speed, bursty data over wide area networks.
GbE	Gigabit Ethernet
HSBB	High-Speed Broadband
ISP	Internet Service Provider. Company that provides Internet access to other companies and individuals.
LAN	Local Area Network. A network designed to move data between computers within a small geographical area.
LCAS	Link Capacity Adjustment Scheme. LCAS is an extension of Virtual Concatenation that allows hit-less growth and reduction of bandwidth. With correct provisioning it also increases availability.
MbE	Megabit Ethernet
MAC Address	An identifier for Ethernet interfaces
OLS	Optical Line System. A WDM terminal multiplexer
OTU	Optical Translation Unit. An OLS sub-system that adapts a client electronic signal(s) to WDM optical channels.
PBX	Private Branch Exchange. A private switching system, usually serving an organization, such as a business or a government agency, and usually located on the customer's premises.
POP	Point-Of-Presence. This is a location of an Internet service provider, used to facilitate remote users' access to the range of applications and IP addresses in the internetwork.
POS	Packet Over SDH. A way to encapsulate IP packets into a SDH signal.
QoS	Quality of Service. The ability to provide some level of assurance for consistent network data delivery.
SDH	Synchronous Digital Hierarchy. A transport technology based on TDM.
Statistical multiplexing	A multiplexing technology for packet traffic. Packets are allocated a time slot as they arrive. It is called statistical because the guarantee that a time slot can be allocated to a packet can only be expressed with statistics.
TDM	Time Division Multiplexing. A multiplexing technology where each information stream is allocated fixed guaranteed timeslots.
Transport Network	A network specially designed for long distance transport of digital information. Excels in reliability and scalability.
VC-4-4c	Four contiguous concatenated VC-4s. Throughput is 600Mbps.
Virtual Concatenation	An inverse multiplexing technology that combines multiple SDH client signals into a single bit-stream. For example 2 VC-4s can be combined to a single 300Mbps bit-stream.
VLAN	Virtual Local Area Network. An IEEE standard that defines how to add extra information (in the form of a tag) to each packet for identification purposes.
WAN	Wide Area Network. Public transport network. All connections that are not in the hands of an end-user can be considered part of the WAN.
X.25	A standard for packet-switched networks. It describes how data travels into and out of public data communications networks.

To learn more about our comprehensive portfolio and the new Lucent Technologies network solutions, please contact your Lucent Technologies Sales Representative or call +800 11223333 (Europe wide Freephone) or +32 70 22 20 52. Visit our web site at http://www.lucent.com.

This document is for planning purposes only, and is not intended to modify or supplement any Lucent Technologies specifications or warranties relating to these products or services. The publication of information in this document does not imply freedom from patent or other protective rights of Lucent Technologies or others.

WaveStar, Metropolis, and SpringTide are registered trademarks of Lucent Technologies Inc.

TransLAN and Navis are trademarks or service marks of Lucent Technologies Inc.

Copyright © 2001-2
Lucent Technologies Inc.
All rights reserved

ONG v4.1002

Lucent Technologies
Bell Labs Innovations