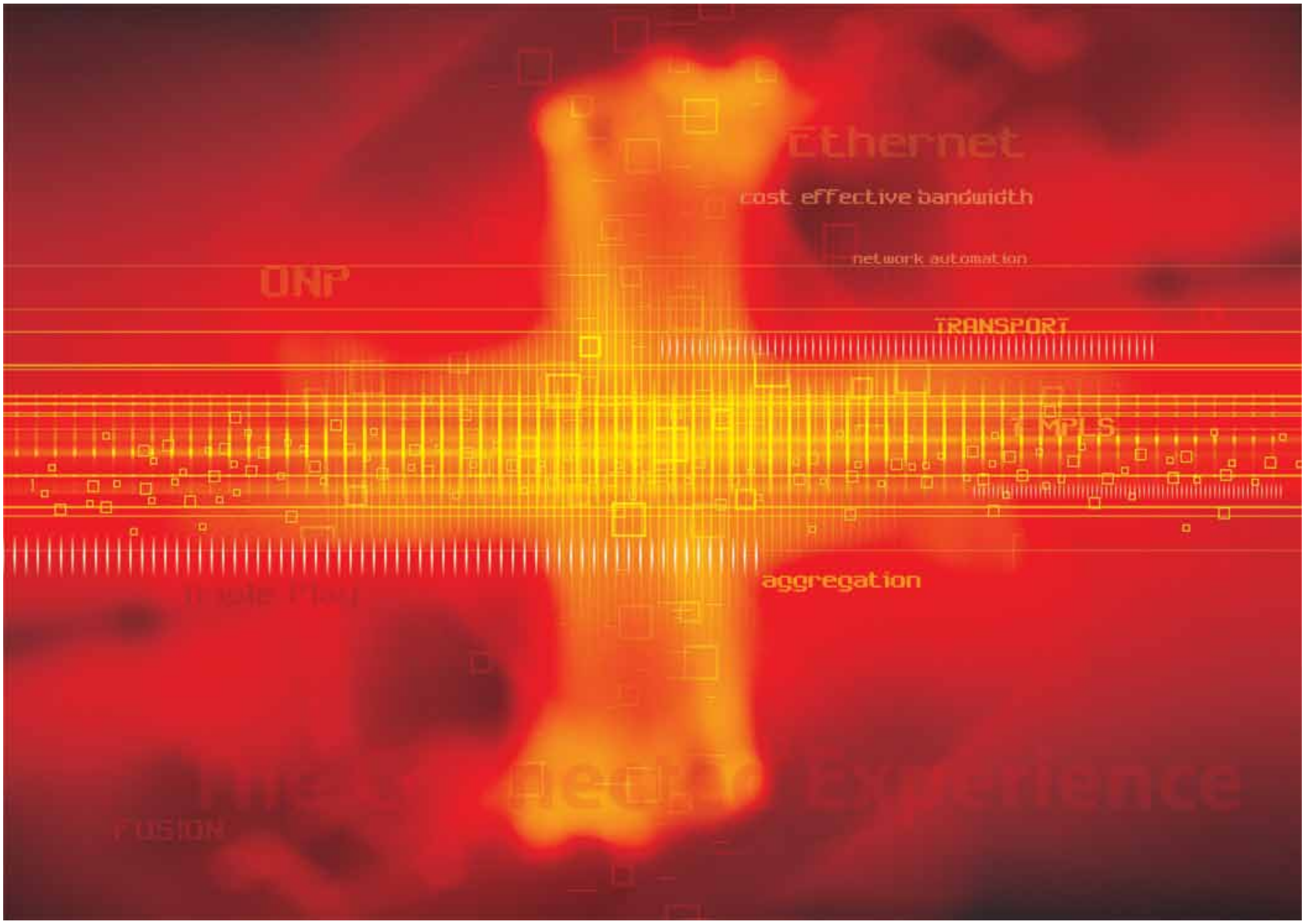
Packet Optical Networking Platforms

Delivering the Connected Experience



Introduction

If you are not already producing or using large amounts of online data, you soon will be. Rich media file sharing, social networking, online collaboration, and "triple-play" network services are fueling a groundswell of demand in the workplace, in the home, and on the road. This emerging wave of bandwidth-hungry anytime, anywhere services defines the Connected Experience. It is rewriting the requirements for delivering broadband across the board.

The Connected Experience poses several key dilemmas for service providers as they evolve their networks to meet these new requirements. This white paper:

- Reviews the emerging services trends that characterize the Connected Experience
- Identifies the requirements they force onto metro aggregation and transport networks
- Discusses how optical networking technology components meet these requirements
- Introduces the next generation of optical networking technology: the Packet Optical Networking Platform

The Emerging Services Environment of the Connected Experience

There are already over 50 million residential broadband users in the United States and the rate of adoption continues to increase. Residential and enterprise users alike are not only using the Internet in greater numbers, they are using it differently, and with higher expectations than ever before.

User-generated content sites, and their heavy bandwidth demands, are among the most obvious examples of a changing Internet. According to a recent Nielsen poll, these sites account for five of the top ten fastest-growing Web brands, each of which is enjoying a 200 to 400% annual growth in traffic. These destinations feature abundant video and images: Heavy.com, Flickr, imageShack, and YouTube. Some of these sites are serving as many as 50 billion images every month.

Social networking sites, such as Zenga, MySpace, and Facebook, allow users to embed rich multimedia content—such as digital photos and homemade videos—onto personal Webpages, which they share with friends. In a recent BurstMedia survey [1] of 1800 adolescent Web users, almost 70% of respondents said that if they had no Internet access outside school, it would "ruin their day" or "make their day not as good."

The phenomenon of MMOG is also demanding more bandwidth from the Internet. Over 12 million users now have online gaming subscriptions. This number is increasing rapidly since the recent generation of Web-enabled console gaming systems entered the market. The ranks of online gamers are forecasted to swell to 30 million by 2009; some of the most popular games, such as Warcraft, often have over one million simultaneous users.

High-Definition Television service is here today and is another voracious bandwidth consumer. Several million U.S. homes already have HDTV sets. Adoption is expected to balloon to nearly 80 million households by 2010, with almost 90% receiving some form of HDTV service by that time. By delivering video using IP, the industry is shifting towards personalized, time-shifted, and on-demand content.

For your convenience, a list of acronyms can be found at the end of this document.

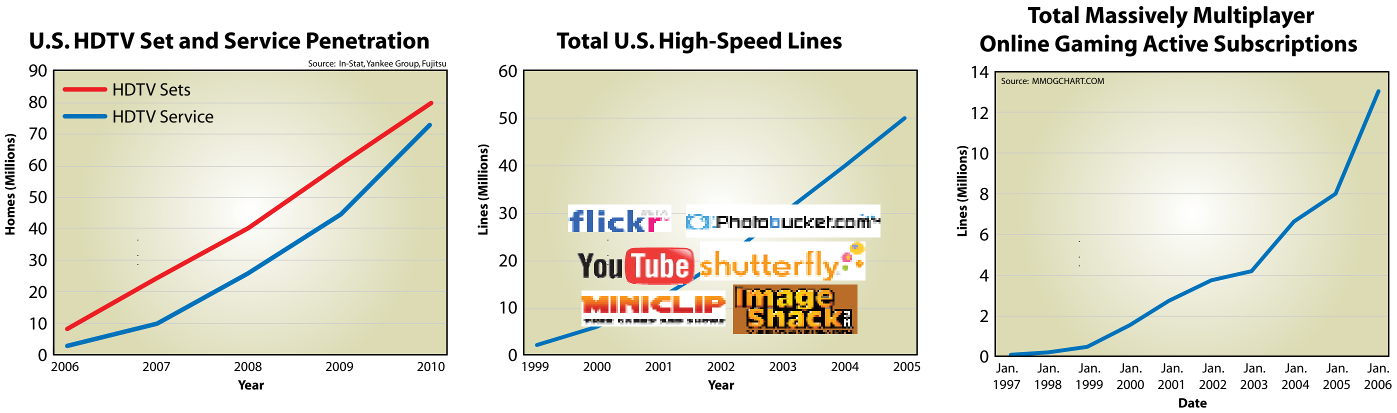


Figure 1: Residential Users Embrace Social Networking and Entertainment

Enterprise users are also seeking more from IP-based services. Enterprises are turning to applications that involve real-time multimedia connectivity—applications such as telepresence or remote collaboration, telemedicine, and online medical imaging, as well as distributed workforce innovation.

Telepresence and remote collaboration applications aim to deliver dramatic improvements over conventional videoconferencing. By leveraging technologies such as HDTV, large screen displays, high-quality audio, and collaboration software, telepresence applications aim to create an environment whereby dispersed collaborators work together as effectively as if they were in the same physical room.

PACS-based medical imaging applications are becoming increasingly popular with healthcare facilities that derive a business benefit from digital image storage. These applications are enabling a revolution in telemedicine whereby highly detailed medical images—as large as 1 GByte—can be transmitted in real time across large distances for immediate or offline consultation. This has obvious benefits for understaffed facilities that share radiologists, for remote locations without specialized expertise, and for distributed campuses that need to share patient information rapidly.

> *"Enhanced social networking, broadband entertainment, and enterprise collaboration are among the many new applications that are driving service providers to seek equipment that delivers cost-effective bandwidth, stringent service requirements, management and operational efficiency, and multi-protocol access...."*
>
> **Erin Dunne**
> **Director of Research Services,**
> **Vertical Systems Group**

Beyond these examples, the future will extend networking toward an ever-increasing number of electronic devices—many of which are not networked today—allowing a future of distributed innovation. Early applications involve networking and IT systems integration, so that a distributed workforce can connect to headquarters and accomplish tasks with maximum efficiency. As more devices such as automobiles, machinery, home appliances, and RFID-enabled items become connected, the range of network applications and possibilities becomes nearly infinite.

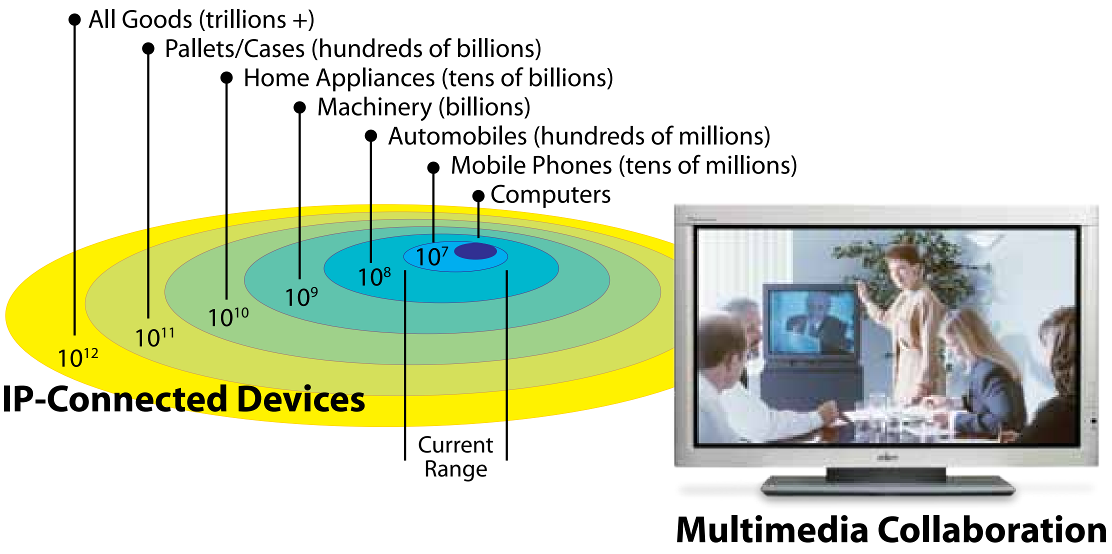


Figure 2: Enterprise Users Demand Collaboration and Distributed Innovation

The Technical Problem of Manageable Scalability

The emergence of the Connected Experience is forcing significant new requirements onto metro aggregation and transport networks—requirements for manageable scalability.

Manageable scalability comprises four dimensions:

- **Cost-effective bandwidth** – These applications all drive significant bandwidth requirements. HDTV, which can occupy 19 Mbps per stream, and VOD, are already driving dramatic increases in metro network bandwidth requirements. The desire for rich Internet content also requires a dramatic increase in Internet access bandwidth.

- **Stringent service requirements** – Loss and latency requirements are tightening. Packet loss for video can mean visible degradation of image quality. Latency requirements for mobile voice and collaboration also place new stress on packet networks.

- **Multi-protocol environment** – As networking moves toward packet-based IP and Ethernet, there is still inertia for TDM access circuits and TDM-based bulk bandwidth management. Since most of today's network is circuit-based, the network of the future must handle traffic in a multiprotocol reality. The challenge will be how to scale Ethernet alongside TDM requirements.

- **Management and operational efficiency** – Increasing bandwidth and service stringency force new efficiency requirements. These will result in a desire to reduce the number and types of network elements. Improvements in network automation and troubleshooting in a complex and service-rich environment are important.

Aggregation and Transport—Key to Delivering Manageable Scalability

The key to building a manageable, scalable metro network is a balanced architecture that includes both service and infrastructure elements. In the classic circuit-based environment, the service elements (ATM and frame relay switches, TDM voice switches, and Web routers) were:

- Service specific
- Higher cost
- Feature-rich
- Used for service provisioning
- Deployed in a targeted manner

The infrastructure elements (circuit-based optical networking gear comprised of MSPPs along with DWDM systems) were an excellent fit for addressing aggregation and transport infrastructure, because they were:

- General purpose supporting all services
- Low cost
- Simple to manage
- Optimized for aggregation and transport
- Deployed in a geographically distributed area

Thus, in classical metro networks, manageable scalability was achieved by deploying large numbers of low-cost, rock-solid aggregation and transport systems that interconnected the end user to service-rich, feature-rich service elements. This balanced architecture delivered benefits including efficient use of costly resources, providing service delivery over a broad footprint and simplifying service life cycle management.

For the new environment of the Connected Experience, characterized by high-quality, high-bandwidth packet services (TDM/Ethernet/wavelength access), the service elements are routers and packet switch elements. These systems have identical characteristics and network roles to their predecessors:

- Service-specific
- Higher cost
- Feature-rich
- Used for service provisioning
- Deployed in a targeted manner

The question now is how to provide high-quality packet-centric aggregation and transport infrastructure that delivers:

- Cost-effective bandwidth
- Stringent service requirements
- Private line equivalent QoS for Ethernet
- IP/PPP/TDM plus Ethernet
- Scalable management and operations
- Any and all services
- Compatibility with the current optical network

Optical Networking for Packets

Various optical networking technologies play important roles in accomplishing the four dimensions of manageable scalability:

1. Photonic technology to play a foundation role in cost-effective bandwidth, improved management, and operational simplicity.
2. Ethernet transport technology to deliver packet-based services with very stringent service requirements.
3. SONET technology to support the multiprotocol access network.
4. Automation and control technologies that accompany optical networking to enable management and operational simplicity.

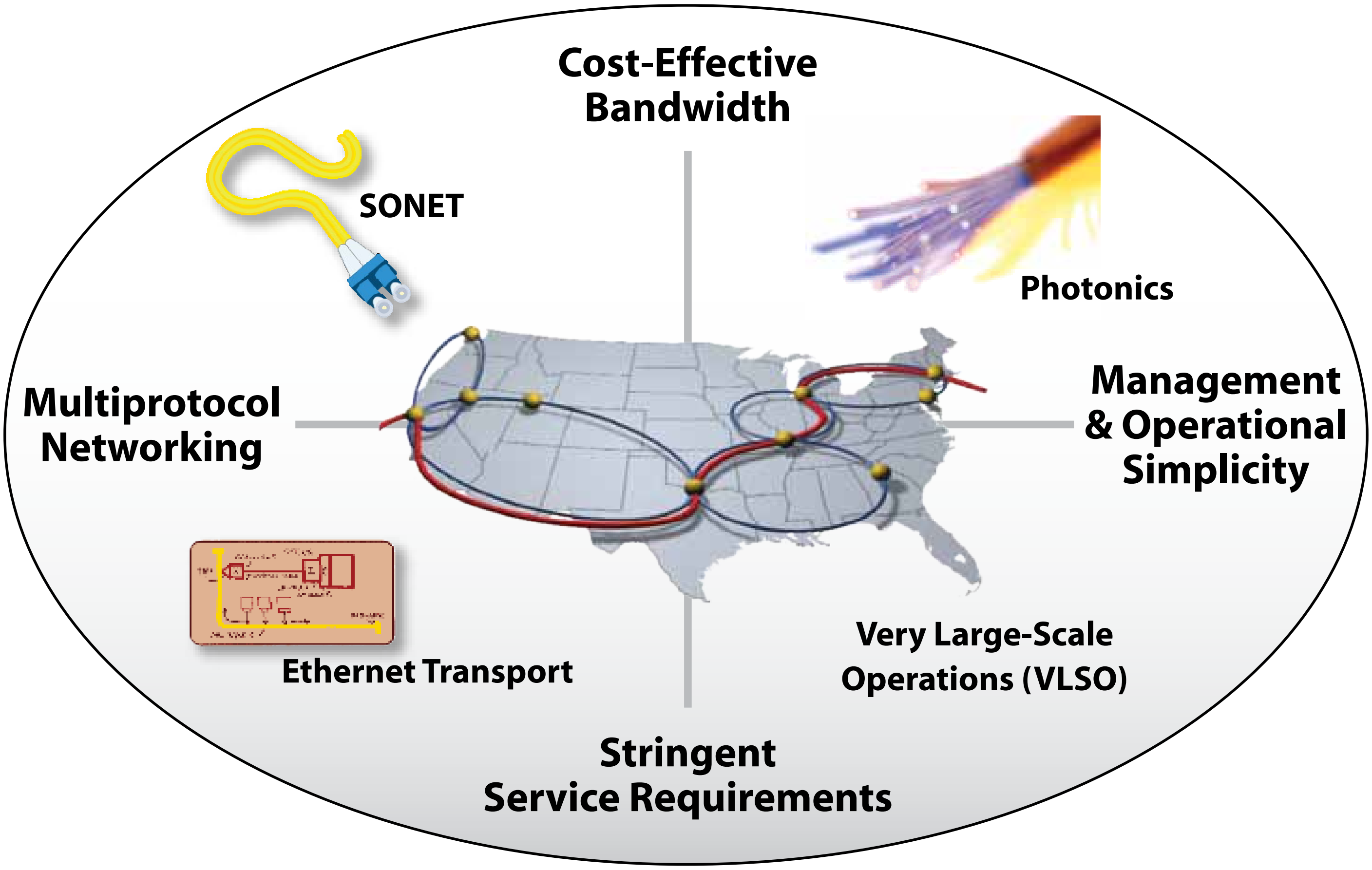


Figure 3: The Fusion of Optical Networking for the Packet Environment

Fundamental Optical Networking Technology #1—Photonic Networking

Photonic networking is the foundation for network scalability from a capital and operational cost point-of-view. Some believe network architectures should be router-centric, with a simple interconnection of those routers provided by classic DWDM or some other technology. However, router technology does not scale well from a capital cost point-of-view. As shown in a separate white paper [2], adding a flexible and reconfigurable photonic (ROADM) layer can justify the extra initial cost with as little as 2 GB of traffic per site, delivered in simple ring architecture. A ROADM provides the ability to bypass sites where traffic passes through at 10% the cost of what it takes to go through the site with a router.

On the operational side, with legacy photonic networking systems (first-generation DWDM systems), assigning a lightpath across a couple of rings often required visiting every site along those two rings to adjust power levels for each added wavelength, which is clearly not scalable. New photonic networking products make that process much simpler, with support for simple single rings, multiple rings, and elaborate mesh networks. To add a new wavelength across the entire network and perhaps a large number of nodes, it is only necessary to touch the endpoints when adding a card or port. All other requirements to activate service are set automatically at the intermediate points.

> *"We are seeing the emergence of a new category of optical product that combines photonics, Ethernet packets, and SONET in a single device. We see optical networking for packets as the biggest trend in optical networking in 2007, and this is likely the most significant development in optical since the advent of the multiservice provisioning platform (MSPP) back in 1999."*
>
> **Sterling Perrin**
> **Senior Analyst, Heavy Reading**

Fujitsu sees photonic technology heading toward a lambda-addressable network of multiple rings or a mesh topology, with SONET capabilities integrated into each ROADM to allow carriers to collapse their core network into fewer boxes. By distributing ROADM functionality to other network elements, the ROADM or photonic platform is no longer a separate element. The first step was the SONET integration; the second will be packet integration to package ROADM technology in smaller sizes so it can be moved toward customer locations. Eventually, ROADM/photonic technology will be purely dynamic, with complete access integration and optical regeneration over an arbitrary topology.

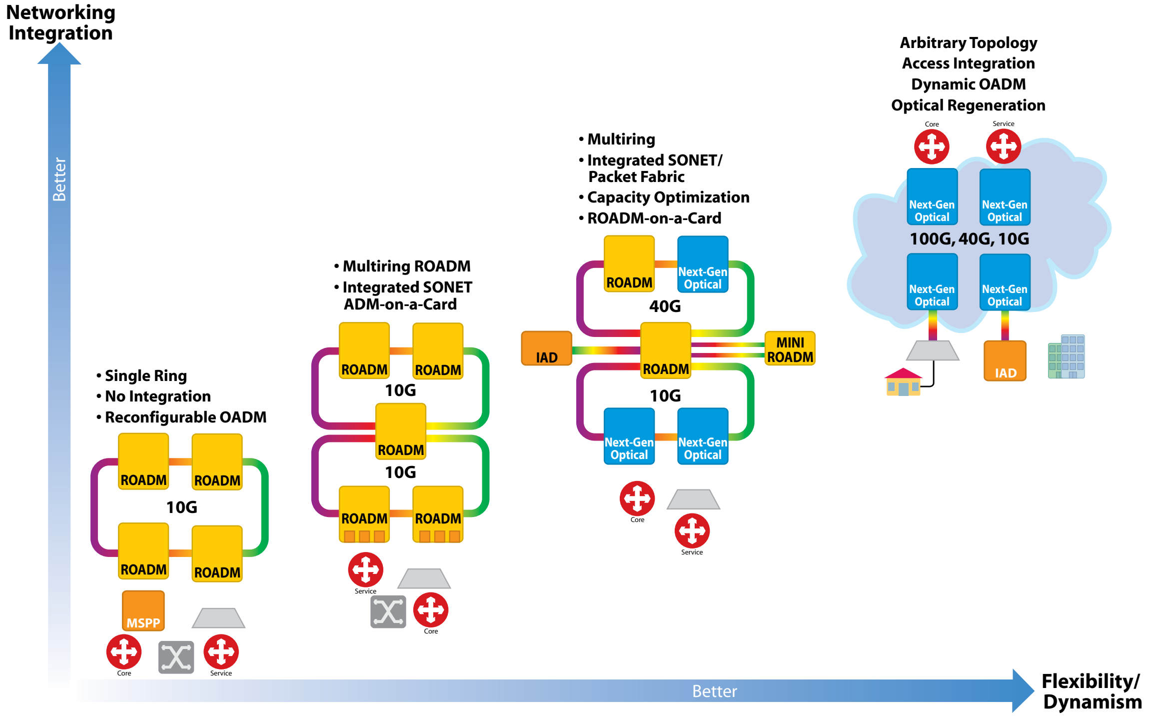


Figure 4: Moving Toward the Lambda-Addressable Network

Fundamental Optical Networking Technology #2—Ethernet

Ethernet transport technologies are also important to manageable scalability. There has been substantial growth in demand for Ethernet from end users, primarily driven by the desire to scale their bandwidth, add services, and support IP-based applications easily. The universal Ethernet jack and associated pipe from end user to service provider can deliver multiple types of services, and users can increase bandwidth without a truck roll. By contrast, a TDM-based service with four or five T1s requires a truck roll and a delay to add another T1 and achieve a similar objective.

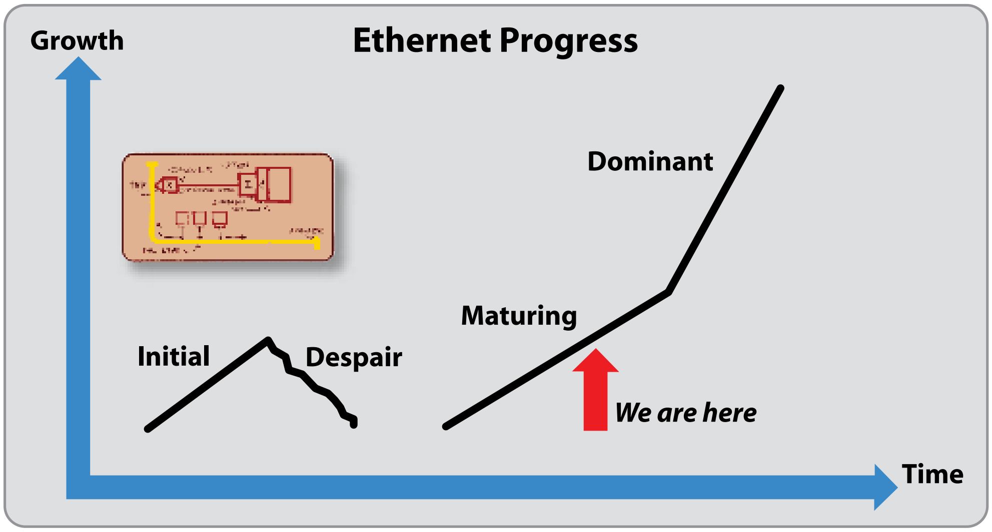


Figure 5: Ethernet Progress

As shown in Figure 5, Ethernet is maturing rapidly. However, it is not yet replacing enterprise packet services such as frame relay, because issues with Ethernet perpetuate TDM-based services. One concerns network manageability, particularly for inter-carrier handoffs. Today, when delivering a frame relay service via a long-haul entity, TDM-based access services are used to get to the frame relay service edge. TDM's robust interfaces for inter-carrier handoffs facilitate precise demarcation and rapid trouble isolation. In addition, TDM services are commoditized and thus available from almost any access provider. The industry is moving to define an Ethernet inter-carrier handoff, and Ethernet is becoming more of a commodity, but things are still not as clear as they are for TDM.

The other issue perpetuating TDM is service quality and service level agreements. Ethernet service quality is improving, but it cannot yet replace the robustness of a true TDM-based private line offering. This is due to the performance and reliability of the Ethernet connection. For example, many switched Ethernet services rely on a spanning tree protocol for protection switching; this cannot provide 50 ms restoration (it is closer to 1.0 sec).

Addressing these issues requires a connection-oriented context in which Ethernet is going to live. This is very different than what has existed for metro Ethernet switched services in the past. Many switched services deployed by large ILECs rely on per-hop priority-based queuing schemes rather than end-to-end connection-oriented, traffic-engineered schemes. Without end-to-end traffic engineering, you're stuck with statistical (soft) QoS.

Figure 6 illustrates the classic problem with hop-by-hop priority based traffic management. In this example, User A submits Priority 1 traffic to the network, which competes effectively with lower priority traffic converging on Node A. However, at Node B, all traffic—including new traffic from Users D and E—is priority 1. Therefore, the traffic from User A may not compete effectively with traffic from Users D and E.

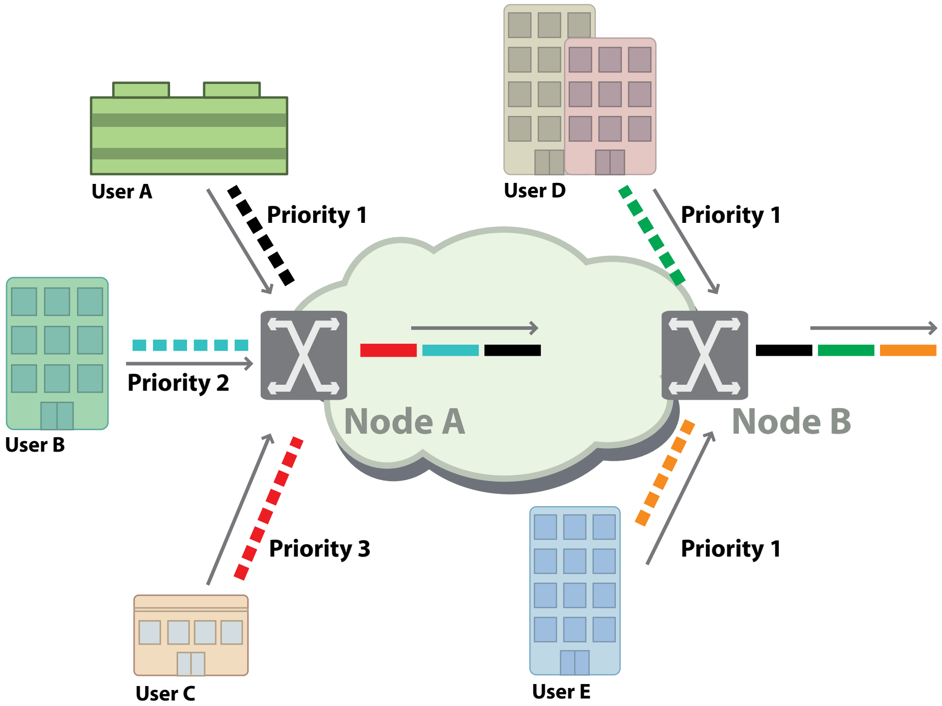


Figure 6: Ethernet Without Traffic Engineering

By contrast, connection-oriented Ethernet reserves resources through the network for each connection, instead of making priority decisions on a hop-by-hop or case-by-case basis. Thus, each connection is guaranteed to achieve the required performance and service quality—whether that service is sensitive to packet-loss, latency, jitter, or a combination.

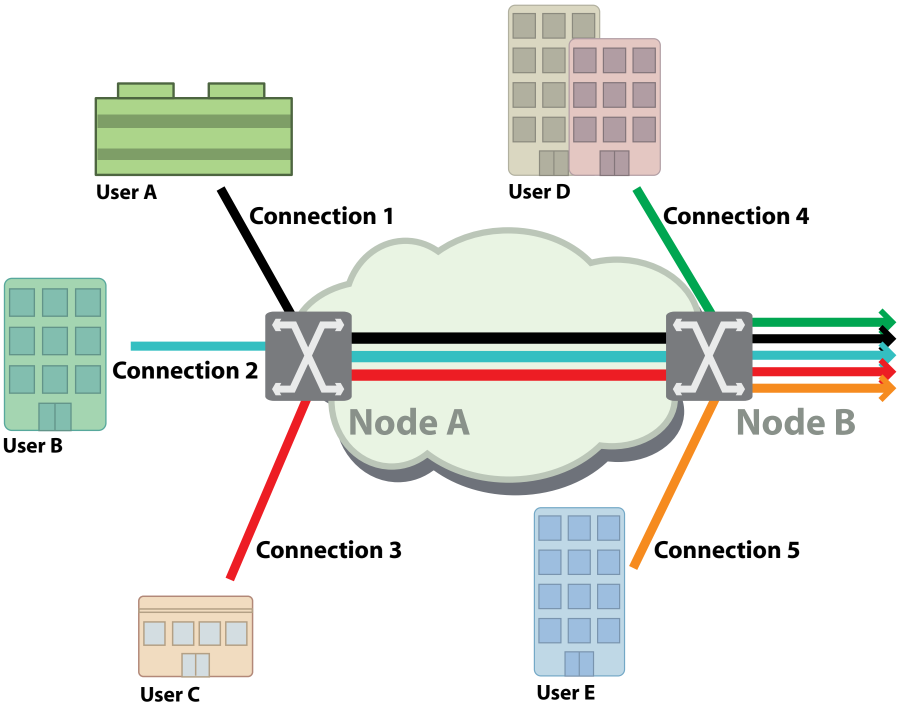


Figure 7: Connection-oriented Ethernet with Traffic Engineering

Several technology options provide this connection-oriented, traffic-engineered, or transport-grade Ethernet solution. Some are already widely deployed, such as Ethernet over GFP over SONET, which was the original way of mapping Ethernet over an optical transport infrastructure. This is a very important service for some carriers, and a very important transport technology for others, because it reserves bandwidth through the network and eliminates competition for resources down the line. Ethernet over GFP over SONET will continue to be part of carriers' overall future connection-oriented Ethernet strategy. But in addition to Ethernet over GFP over SONET, several emerging packet-based technologies promise 50 ms protection switching and resource reservation for guaranteed QoS.

Fundamental Optical Networking Technology #3—SONET

SONET will continue to play an important role in the delivery of circuit-based services. Since most of the access for IP services is over some type of TDM infrastructure, support for IP over PPP over TDM over SONET is going to continue to be important. Packet over SONET is going to continue to be important, as well as continuing to support existing Frame Relay and ATM customers.

The other benefit of SONET-based technology is that it plays an important role in access network redundancy. SONET has been very important in getting traffic from a customer's site to the serving central office in a redundant manner. Ethernet has some redundancy capabilities, but at the physical layer SONET will continue to play an important role.

OTN is also circuit-based, but it is really more of an encapsulation technology for sub-wavelength circuits in a point-to-point architecture. OTN works for simple, point-to-point client-side interconnection between carriers, but is not mature enough for broad-based interoperability among equipment providers. In addition, OTN does not support the grooming, switching, bandwidth management, or the finer levels of granularity that SONET provides.

> *"Optical networking elements have been the workhorse cost and manageability leaders to provide metro aggregation and transport, and enable service providers to build scalable networks for profitable service delivery. Packet ONPs represent the next major evolution in optical networking, and allow service providers to enjoy the same well known cost and manageability benefits that optical networking has always provided, only now in a packet-centric environment."*
>
> **Michael Howard**
> **Principal Analyst and Co-founder,**
> **Infonetics Research**

Fundamental Optical Networking Technology #4—Network Automation and Control

Having reviewed photonic, Ethernet, and SONET technology, the last set of technologies to explore are those that improve network automation and control. Several technologies effectively form the toolkit for VLSO, the future of network automation. Traditionally, networks have been built on statically-provisioned circuits with lots of manual operations and fragmented intelligence about network configuration and events. With VLSO, you can leverage the proven capabilities of optical networking elements to create large, dynamic networks with a high degree of unified operations intelligence. The intelligence may continue to be centralized in a particular location, but other parts of the network may also contain intelligence to help with operational applications.

These technologies exist across several layers. At the network element layer, plug-in units and ports can be placed in service when they're installed in the shelf; cabling wizards are available for ROADM equipment; and multidegree hubbing can eliminate back-to-back fiber patching in an arbitrarily complex photonic network. These tools are available today.

Moving up to the element management layer, there are several important tools that exist here as well. Inventory reconciliation allows the EMS to manage network inventory and reconcile this data with a larger, centralized network management database via a standards-based northbound interface. There are tremendous staff hours that are wasted each year because the database doesn't match the inventory that's in the network. An EMS can play a powerful role in reconciling that. There are also powerful new design tools to automate network design and these tools are being integrated into the EMS.

Finally, several management protocols can also help with the VLSO challenge. XML can be used for a machine-to-machine interface and helps in a number of dimensions. It easily integrates the EMS into an upper layer OS environment, and XML can also run natively on the network element. In the future, XML can be used to allow one or two master elements in the metro area to replicate a set of standard configuration and provisioning options to add and commission network elements.

The Importance of the Optical Networking Platform Heritage for VLSO

In addition to the above technologies, the optical networking heritage includes a set of attributes that are essential in building a scalable network.

1. **Deterministic data plane and precision fault/performance management** – Optical networking elements feature a deterministic data plane that makes it easy to troubleshoot network problems. In the router world, you troubleshoot using PING, which essentially only lets you know if you can connect to the remote end. To ascertain what path packets are currently taking, there is TRACEROUTE. This is very different from a deterministic data plane with the accompanying OAM capabilities that provide precise, hop-by-hop fault management and sectionalization.

   In addition, a deterministic data plane allows for meaningful performance management—with such capabilities as binned and thresholded performance monitoring information—and connection testing using PRBS insertion.

2. **Robust management interface** – TL-1 has been the management protocol for optical networking equipment. The benefit of TL-1 is its structured and hierarchical nature; it is very difficult, if not impossible, to delete services when you intend to add them. To add services, you must perform the steps in a very rigid order, and to remove services you must undo the rigid order in sequence. Historically, with packet networking gear, you have management interfaces such as a command-line interface, which while offering flexibility, has been weak on preventing inadvertent deletion or modification of services. One mistake and existing services can be removed as others are added.

3. **Software Upgradeability** – In-service software upgradeability has always been a big benefit of optical networking equipment. Optical networking elements have also delivered the capability to simultaneously run multiple software releases in the network while the network remains stable, compatible, and fully operational.

4. **Network protection and equipment redundancy** – Sub-50 ms protection switching and hot/standby card configurations ensure that network resources are always available. Replacing cards can be done in-service.

Optical networking elements have leveraged this heritage and served as the cost and manageability leaders for aggregation and transport infrastructure. When these benefits are combined to address the new class of problems that come with manageable scalability in a packet-centric world, you can imagine this optical networking heritage evolving to include packet networking functionality.

The Emergence of the Packet Optical Networking Platform

Packet ONPs are the newest class of optical networking equipment, custom designed to solve the packet networking problem. These platforms are the modular fusion of the key transport technologies reviewed earlier, including:

- Photonic/ROADM technology for highly efficient bandwidth growth and streamlined operations
- Connection-oriented Ethernet transport based on VLAN tag switching or PBB-TE technology to provide private-line equivalent QoS and reliability
- SONET and TDM-based bandwidth management for ongoing multiprotocol needs and sub-lambda management and for leveraging existing network investments

These attributes are finally available on a single addressable optical networking element that has all the operational capabilities of optical networking elements described earlier. These devices provide a stable foundation for scalable network architecture, and a means to deliver the Connected Experience.

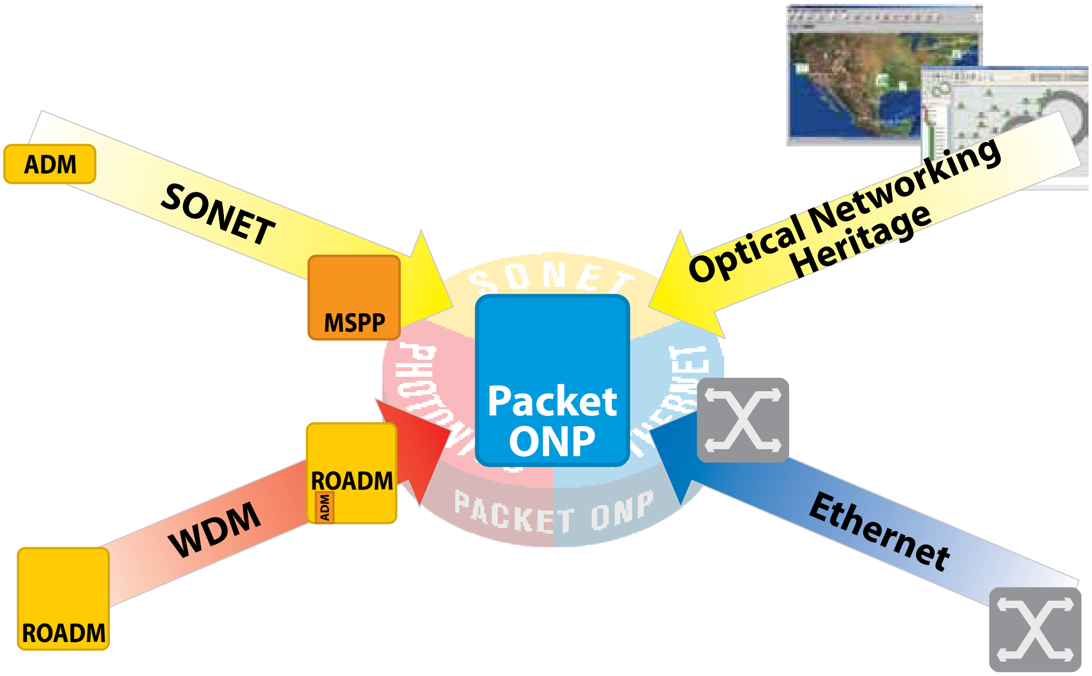


Figure 8: The Fusion of Optical Networking for Packets

References

[1] BurstMedia "Online Insights," Volume 06.04

[2] Sunan Han, Sam Lisle, and Greg Nehib, "Economic Considerations Drive Choice of Triple-Play Transport," *Lightwave* magazine, June 2007.

Acronym	Descriptor
ATM	Asynchronous Transfer Mode
CLI	Command Line Interface
DWDM	Dense Wavelength Division Multiplexing
EMS	Element Management System
FR	Frame Relay
GFP	Generic Frame Protocol
HDTV	High Definition Television
IEEE	Institute of Electrical and Electronics Engineers
ILEC	Incumbent Local Exchange Carrier
IP	Internet Protocol
ITU	International Telecommunications Union
MAC	Media Access Control
MMOG	Massively Multiplayer Online Gaming
MSPP	Multiservice Provisioning Platform
OAM	Operations, Administration, and Maintenance
ONP	Optical Networking Platform
OS	Operating System
OTN	Optical Transport Network
PACS	Picture Archiving and Communication System
PBB-TE	Provider Backbone Bridging with Traffic Engineering
PPP	Point-to-Point Protocol
QoS	Quality of Service
RFID	Radio Frequency Identification
ROADM	Reconfigurable Add/Drop Multiplexer
SONET	Synchronous Optical Network
TDM	Time Division Multiplexing
VLSO	Very Large-Scale Operations
VoD	Video on Demand
XML	Extensible Markup Language