Optical Services over the Intelligent Optical Network

David Benjamin, Richard Trudel, Stephen Shew, and Ed Kus
Nortel Networks

ABSTRACT

Optical networks are growing at unprecedented rates to accommodate the explosion in data traffic brought on by new Internet and enterprise applications. Coupled with this growth has been the introduction of client devices (e.g., routers, storage devices, and content servers) at the network edge operating at optical line rates. These two trends are changing the fundamental way in which optical transport networks are being architected, deployed, and managed. Emerging intelligent optical networks address the traffic scaling challenge. Additionally, when combined with modern service management technologies, these networks open exciting opportunities for delivering new customized optical services directly to end-users, allowing carriers to fully exploit the economics of optical transport. This article presents a network framework for delivering optical services.

INTRODUCTION: TRADITIONAL ASSUMPTIONS ABOUT OPTICAL TRANSPORT NO LONGER APPLY

Traditionally optical networks have been designed for and deployed in backbone networks as a cost effective technology to meet the demands of highly multiplexed and predictable voice and private-line traffic. In this context the primary network requirements were high reliability and cost points lower than existing electrical trunking solutions. The answer was SONET and SDH-based optical transport systems designed and deployed in ring configurations to provide "5 9's" availability and 50 ms protection. The optical transport layer treated all traffic identically, as "mission-critical." Typically, these networks took months to implement and provided static connectivity over periods of many months or years. Traffic growth was managed by overlaying multiple rings and by deploying higher speed rings. Responsibility for optical transport deployment generally rested with the carrier's network planning organization, whose primary objective was to reduce the "cost-per-bit" in its long-haul network segments or its inter-office trunk network.

The explosion in Internet traffic has invalidated the following assumptions and raised new requirements.

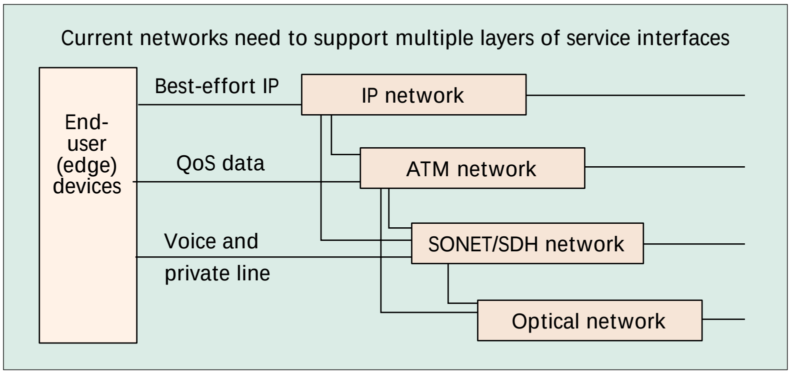
Invalid assumption 1: Traffic growth is slow and predictable — The Internet explosion has diminished the predominance of voice traffic and private-line traffic relative to the now exponential growth of data traffic. Indeed, it is predicted that Internet traffic will continue to grow by 100 percent per year, regardless of conditions in the financial markets [1]. As well, traditional notions of communities of interest and predictable traffic patterns no longer apply as the Internet has created a global marketplace. The traditional approach of building SONET-based ring networks to handle this traffic growth is failing in a number of ways:

- Ring structures have long deployment times, which result in lost carrier opportunities.
- Equipment scaling requires step-function investments as full rings must be added.
- Operational costs spiral as carriers are forced to manage traffic across multiple, independent stacked rings.

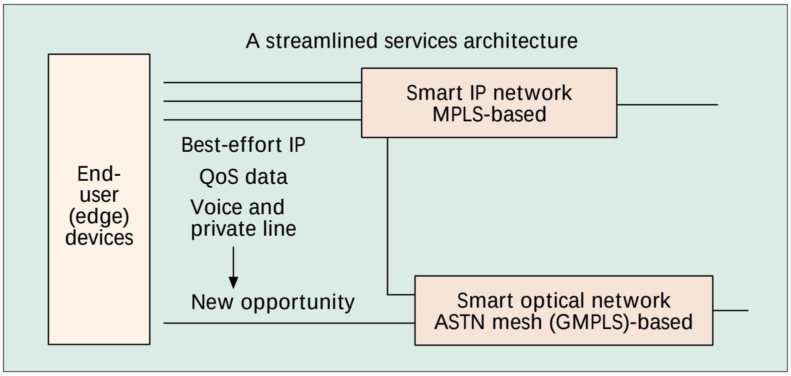
A more dynamic and cost-effective network model is needed to accommodate this traffic growth.

Invalid assumption 2: All traffic is mission-critical — Along with this growth in data traffic has come a need to attend to a much wider mix of services. For example, traffic generated by free Internet access services requires a lower grade of service than that associated with banking transaction services. The network must provide a range of connection types that better reflect the value of the traffic being carried.

Invalid assumption 3: Optical transport is focused on long-haul networks — Commensurate with the increase in backbone traffic has been an equally dramatic growth in traffic in



■ **Figure 1.** *Current optical transport networks are relatively static, designed to handle highly multiplexed, predictable, high revenue traffic in the core. SONET ring architectures were optimal for this application.*



■ **Figure 2.** *Industry direction is toward a collapsed services architecture. As more clients operate at the optical line rate, there is increasing opportunity to provide an on-demand optical layer directly to these clients.*

access and metro networks. Bringing optical transport services close to the end-customer is now economically attractive. New service providers are emerging to address various segments of this market. These new providers require service flexibility to allow them to handle the service churn, service mix, and service growth characteristic of metro markets. Long-haul carriers will also need service flexibility as they extend their optical networks into the metro space to provide end-to-end integrated service.

Invalid assumption 4: Optics deployed solely for carrier cost-reduction — Routers with SONET interfaces at OC-48 rates are common, while OC-192 rates have started to appear on core routers. Storage devices now incorporate fiber channel interfaces to provide high-speed connectivity within LANs and MANs. Currently these devices support dozens of 1 Gb/s and 2 Gb/s interfaces and will move to hundreds of 10 Gb/s ports over the next 24 months. As optical transport gets closer to the customer, the value of providing differentiated optical services that better match the customer application increases. With advances in optical technology and competition continuing to reduce the "cost-per-bit," a carrier's optical investment will increasingly be measured against its success at new revenue generation.

The above discussion strongly suggests that a new approach is needed for both metro and long-haul networks. The new optical network must not only attend to the scaling issues seen in the last few years but must also provide a platform for delivering an emerging portfolio of optical services.

This article discusses how current network architectures are evolving to deliver optical services. We describe the initiatives to reduce and simplify current service-layering structures. We describe the standards activities targeted at introducing an intelligent control plane over the transport layer. This control plane, combined with the new generation of optical cross connects, will transform today's static transport network into a real-time, switched optical network. We then propose how this dynamic optical transport network should be augmented to deliver a new class of intelligent optical services. Finally, several optical service opportunities are explored.

Toward an Optical Services Architecture: Collapsing of Network Service Layers

The industry's current services architecture is shown in Fig. 1.

In the past these networks primarily supported mission-critical services — voice trunking and private lines. Each layer provided services to ensure high availability and security. High-revenue services made these highly structured networks affordable. However, IP traffic is starting to dominate the service scene (at least in terms of traffic volume). This IP traffic is largely still of a "best-effort" nature. Thus, for a provider facing decreasing margins, costs need to be reduced to make carrying high-growth IP traffic more affordable. To achieve this, the functions provided through multiple layers can be integrated into fewer physical layers.

Service interfaces are becoming large — fast Ethernet, Gigabit Ethernet, and 10 Gigabit Ethernet. SONET OC-48c service interfaces are readily available, while OC-192c interfaces are rapidly emerging. Because service signals of a gigabit per second and more can be economically launched directly into optical wavelengths, the role of SONET multiplexing will diminish over time, leading to additional simplification. (Note, however, that some form of SONET-like management will still be required.)

There is a growing industry consensus toward simplifying the network by collapsing these multiple service layers into two layers — a "smart" IP layer and a "smart" optical layer, as shown in Fig. 2 [2]. (There are some who would argue for a "smart IP" layer and a "dumb" optical layer. In [3] there is an explanation why this latter approach does not satisfy most carrier business models.)

For mission-critical business applications, most of the existing multi-layer functionality must be retained in some form within this collapsed network. For example, if ATM is excluded from a network, another capability needs to perform such ATM-like functions as traffic management, QoS, and explicit routing for services that require these functions. A new Multi-Protocol Label-Switching (MPLS) layer, integrated in the IP layer, can alternatively perform these tasks [4]. Similarly, SONET provides protection-

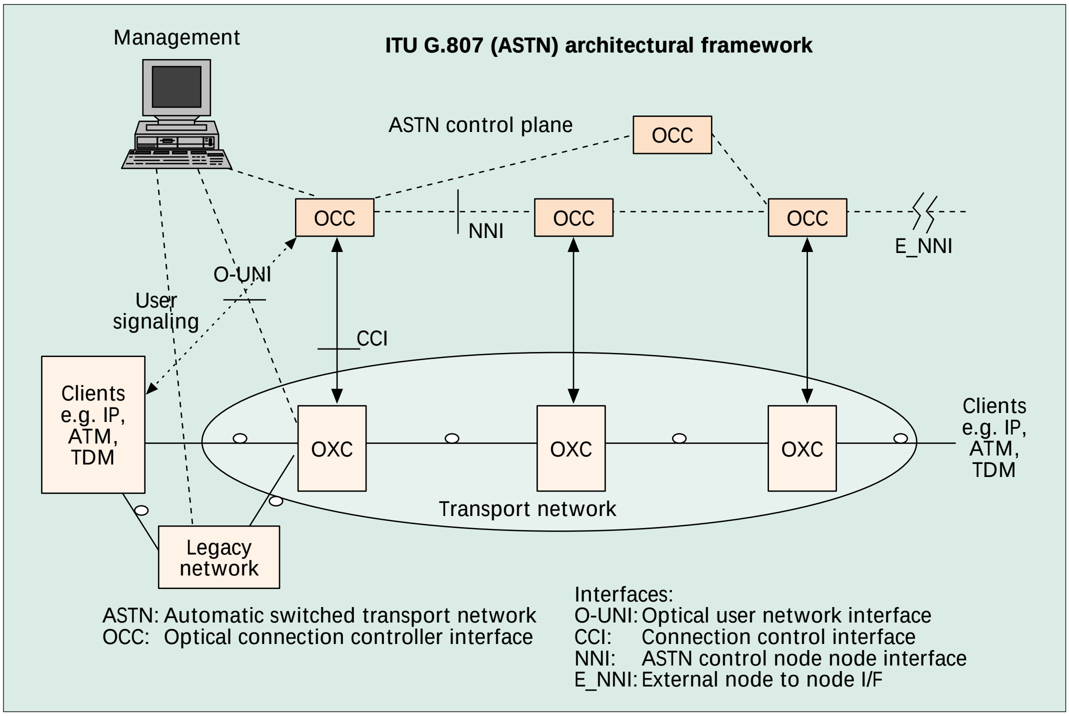


Figure 3. *ITU-T Draft New Recommendation G.807/Y.1301, Requirements for Automatic Switched Transport Networks (ASTN); (May 2001, to be approved).*

The current focus is on specifying a control plane over the optical layer, which, on request from either the end-user or network operator, will dynamically make connections across the optical layer.

switching capability, which, if eliminated, will likely be done by the optical layer for services requiring this capability.

The overall goal is to allow carriers to implement a simpler, lower-cost, more responsive network that is capable of addressing a wider spectrum of service requirements. These requirements range from servicing best-effort IP-centric traffic to mission-critical business traffic. The network will provide the most appropriate and economical level of robustness for each service.

Finally, as mentioned above, the appearance of high-speed interfaces on servers and storage devices provides the opportunity to place some client services directly on optical, bypassing the IP layer. Bypassing the IP layer provides additional cost reduction. These direct optical services fall into two categories:

- LAN-based packet-oriented applications that can be supported on optical Ethernet services
- Circuit-oriented applications (e.g., for storage, video, and file transfer scenarios)

These latter services are addressed in the last section.

Toward an Optical Services Architecture: A Standards-Based Optical Control Plane

The emerging intelligent optical layer addresses the issues raised in an earlier section by providing a scalable, robust, and cost effective optical infrastructure. This infrastructure provides a key building block of an optical services network. Although early products in this area are delivering proprietary solutions, it is essential that a standards-based approach be adopted. Only with standards-based implementations will end-to-end optical services over multi-vendor platforms and over multiple carrier networks be possible. To this end, there is significant effort in various standards bodies working toward this objective [5]. In particular, the current focus is on specifying a control plane over the optical layer, which, on request from either the end-user or the network operator, will dynamically make connections across the optical layer.

ITU's Standard G.807 [6] (previously known as G.ASTN — Automatic Switched Transport Network) is emerging as the global framework for this "intelligent" control plane. The control plane operates over arbitrary network topologies (i.e., ring, mesh, and hybrid) and also connects with legacy networks. The control plane supports a range of restoration options, although restoration requirements themselves are currently outside the scope of the recommendation. The framework specified in G.807 is shown in Fig. 3. G.807 presents a logical framework so that, although the control plane is shown as a functionally distinct plane, it can be physically implemented as software within the OXCs themselves. (Note that we use the commonly used acronym OXC to refer to an optical switch. In this context, OXC can either be an O-E-O or OO switch.)

In Fig. 3 the optical traffic layer provides circuits at various granularities from STS-1 to wavelengths and eventually to bands of wavelengths. The optical traffic layer consists of three important building blocks:

- High-capacity line systems approaching terabits per second, with long all-optical reach of a few thousand kilometers between end-city pairs.

Today's management systems and network planning functions will have to adapt to a new paradigm where a substantial portion of the network control and network knowledge is no longer centralized in the management systems.

- Optical switching platforms that will migrate from opaque to all optical (photonic) over time, with unprecedented open ended scalability via ability to switch lightpaths, bands of lightpaths, or entire line-system fibers. These platforms are explored in more detail in [7, 8].
- Tunable devices (sources, filters, and receivers) offering flexible selectivity, as well as reduced inventory and operations savings.

The control plane is overlaid on the transport network and performs a number of functions. First, unlike today's networks the ASTN-controlled network auto-discovers the resources and topology of the optical traffic layer. This process begins with each OXC discovering its available resources, service capabilities, and local connectivity to its neighbors by exchanging discovery signals between itself and its neighbors. Each OXC reports its local topology information to its associated OCC over the CCI interface. The OCCs, using the node-to-node interface (NNI) and a version of the OSPF (Open Shortest Path First) protocol extended for use on the optical network, collectively and automatically discover the entire transport network topology and available bandwidth.

This up to date topology database is maintained by each OCC controller and allows the OCC to compute complete paths through the network. The OCCs use a modified MPLS signaling protocol called Generalized MPLS that is being developed in the IETF to dynamically signal for a lightpath to be established. In this way, lightpaths can be made, modified, or torn down in seconds. This up-to-date view of the network is also used:

- To obtain current utilization information.
- To collect historical information that feeds planning capacity needs.
- To set triggers for optimization activity.

By distributing routing, the network becomes more robust and is able to support higher signaling performance. Routing scalability can be further enhanced by creating multiple administration domains and by implementing routing hierarchies.

The control plane also supports an optical user-network interface (O-UNI). This interface allows a client at the edge of the network to signal for a connection to be set up or torn down. GMPLS signaling is used for client signaling. Initially the O-UNI capability will likely be used by network management systems to proxy-signal connections on behalf of clients. O-UNI functionality is being assessed in the OIF [9], and requirements will be determined in T1X1 and ITU. Proposed parameters available to the O-UNI include destination port, QoS, protection level, bandwidth, and route diversity.

The External NNI (E_NNI) provides the interface between ASTN networks that are under different network administrations. The E_NNI is a modified O-UNI with some NNI functions for exchanging address and topology summaries. The E_NNI interface is essential for delivering services that span multiple administrative domains.

The introduction of an optical control plane and client signaling profoundly changes how optical networks will be managed. Today's management systems and network planning functions will have to adapt to a new paradigm in which a substantial portion of the network control and network knowledge is no longer centralized in the management systems. Service control, which previously involved largely manual processes, will now be passed to the network layer. Network and service information will also be distributed within the network elements themselves. The following section discusses the future directions of service management in more detail.

The Next Step: Intelligent Optical Network Service Management (ONSM)

Carriers are increasingly focused on offering a broad range of services to their customers, quickly, flexibly, and with increased customer control. Intelligent optical networks with a control plane, as described earlier, are an important step in that direction. The next step is a flexible service management solution that complements the new agile transport network.

In particular, new service management solutions are needed to provide customers with streamlined processes to control services via self-serve Web portals, including the ability to:

- Dynamically create and modify services.
- Establish flexible SLAs with variable QoS and CoS parameters.
- Monitor real-time service status and performance.

Carriers require service management solutions to:

- Plan, create, and introduce new services.
- Provision services.
- Manage multiple, customer-tailored SLAs.
- Track and report on SLA QoS and CoS performance.
- Bill appropriately for network usage and account for SLA contractual obligations.
- Establish and manage network policies.
- Provide secure network access.

Key functions of the service management solution are shown in Fig. 4 and are discussed below.

Customer self serve — Customer self serve allows carriers to offer customers a tailored, secure Web portal. Customers are able to plan, activate, and modify optical services directly. Customers are also able to view the QoS and CoS status of their optical services, track trouble tickets, attend to invoices, etc. In a dynamic network, the customer self-serve interface would also allow the customer to establish SLAs, provide client access policies, and access security/authentication management.

Customer relationship management (CRM) — Integrated and automated customer relationship management capabilities give carriers the ability to consolidate network, service, and customer information for efficient service delivery and rapid response to customer requests. This capability creates a single view of all customer information, including real-time order capture, customer history, billing data, service availability, and critical network information. A CRM system is used by the carrier's front office support staff in lieu of or in addition to a customer self serve capability.

SLAs and policies — An ASTN-enabled optical network enables a broad range of service classes in addition to supporting standard service quality and operational metrics that are typical of today's transport networks. It will therefore be increasingly important to instantiate customer SLAs and to be able to report upon them, thereby providing customers with the necessary assurances that their service requests are being honored. SLAs may also include aspects such as total number of allowable connections and total bandwidth. Because O-UNI-signaled connection requests bypass the management plane, policies will have to be distributed to the control plane.

Network activation — In conjunction with other functions such as order/workflow management and inventory management, network activation ensures that customer service requests are promptly translated to network connectivity. In an intelligent optical network, network activation uses proxy signaling on behalf of a client to request connectivity to a specified destination with the specified CoS parameters.

Security and authentication — Client network access via O-UNI signaling necessitates the management and implementation of appropriate security and authentication procedures, access keys, and so on, which work in conjunction with the policies noted above.

Billing — Billing will move from a function that today resides purely in the management plane to one that must now take its cue from the network infrastructure. Dynamic events such as connection start, connection stop, connection bandwidth, and so on, which are no longer uniquely controlled from the management plane, must now be recorded.

***ONSM Architecture* —** ONSM solutions will integrate best-in-class, third-party building blocks into a carriers' existing operating and business processes. Also, ONSM functionality will evolve over time as more complex services are introduced. To facilitate this ongoing integration process, ONSM solutions are best designed using industry-accepted standards and open published interfaces. These would include Common Object Request Broker Architecture (CORBA) interfaces and open work-flow architectures.

Putting It All Together: Optical Services Rollout

We call the umbrella of optical services that embrace existing and next generation services *managed optical services* (MOS). These services marry the best of service management and OSS capabilities with dynamic end-to-end optical networking. Managed optical services are characterized by:
- Unprecedented capacity and service customization options.
- Real-time provisioning intervals approaching true bandwidth on-demand.
- Flexibility in SLA management, service performance management, billing, policy, etc.

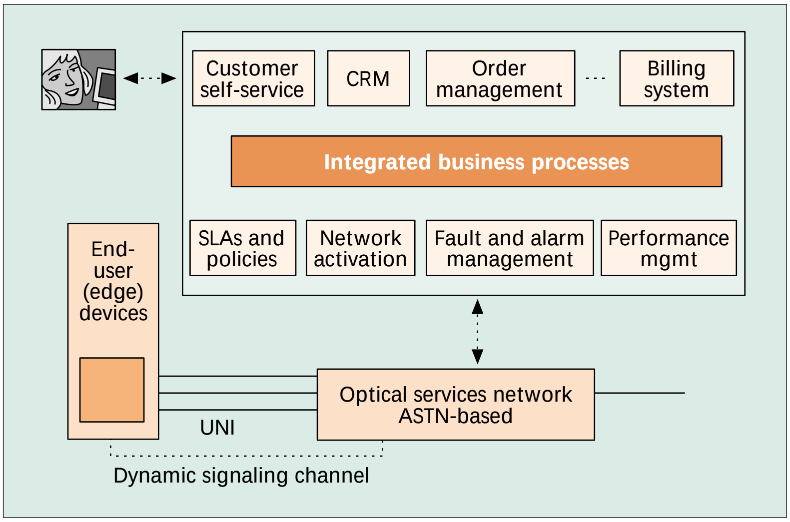


Figure 4. *Intelligent optical network services management provides the framework for efficiently developing, deploying, and maintaining new services.*

- End-to-end connectivity enabled by dynamic networking.

We define a *service* as the solution a service provider sells to an end-user. An application refers to the specific and tailored use of a *Service* by the end-user.

This section presents the expected MOS rollout (Fig. 5) that aligns customer needs with technology availability. These network services not only generate revenue on their own, but also provide important building blocks for a wide range of increasingly sophisticated services. Service providers have already started to roll out their first MOS offerings using new service management software over their existing network infrastructures. These services will evolve rapidly as intelligent optical networks and service management infrastructures are introduced.

Service set 1 (a.k.a. lambda leasing and provisioned bandwidth) is being delivered using today's DWDM and SONET networks with enhanced forms of manual provisioning. These network services support end-user applications such as LAN inter-connectivity, storage area networks, and bandwidth wholesaling in relatively static environments. These services improve upon traditional provisioning technology by
- Capturing customer requests through a Web portal.
- Allowing negotiation of simple service-level agreements.
- Automating trail provisioning.
- Monitoring SLA compliance.

An automated back-office workflow system eliminates many of the manual procedures. Using these technologies, services can be provisioned in minutes. These services are driving the deployment of many of the ONSM technologies described in the previous section.

Service sets 2 and 3 in Fig. 5 are the two basic intelligent network services under review in the OIF [9]. Users requesting PBS connections typically would use an ONSM Web portal interface. The ONSM layer signals the control plane on behalf of edge clients. BOD supports direct

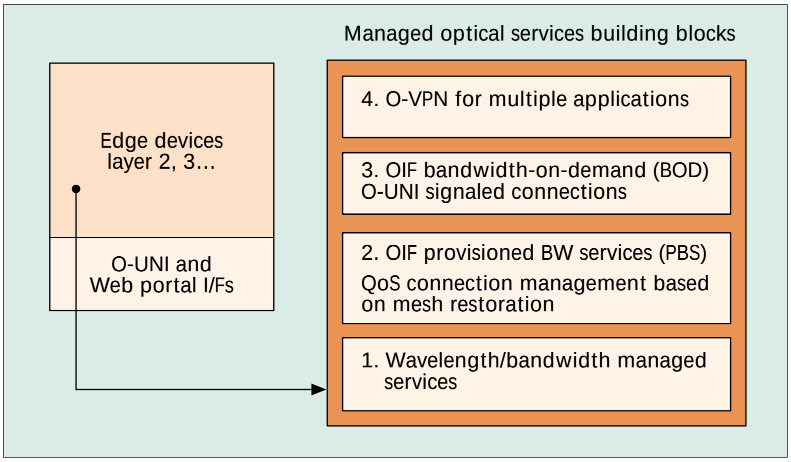


Figure 5. *This figure shows the expected rollout of new optical services. The rollout of these services provides increasing customer control over the transport network.*

client signaling through the O–UNI to the control plane. Service sets 1–3 focus on delivering single point-to-point connections with a specific restoration class of service. Several broad classes of mesh restoration are under discussion:

- Platinum service: less than 50 ms restoration.
- Gold service: 200–300 m.
- Silver service: several seconds based on "redialing."
- Bronze service: involves no transport restoration.
- Pre-emptible service: extra traffic.

Service set 4, optical virtual private network (OVPN) services, provide a secure and manageable environment that allows a group of clients to fully exploit the flexibility of the switched intelligent optical network. OVPNs will be used to support a variety of applications, including:

- ISP edge router networks.
- Content delivery among a network of servers.
- Bandwidth trading between carriers.
- Storage WANs for enterprise networking.

The edge devices in an OVPN create and delete connections between them as directed by higher-layer application software. As in IP-VPNs, the network provides auto-discovery mechanisms and consolidates billing and SLA management among clients in the same group. Standards for OVPNs are starting to be addressed in the IETF [10].

SUMMARY

This article has presented the drivers and requirements for delivering new services on the intelligent optical network. A number of key elements will need to be provided and integrated, including:

- A dynamic optical transport layer.
- A standards-based signaling and routing control plane based on the emerging global G.ASTN framework.
- A robust and standards-based service management plane.

Managed wavelength and bandwidth services are driving the deployment of new service management solutions over today's networks and will play an increasingly significant role as new intelligent optical networks are introduced. OVPN is an important building block for a variety of applications. OVPNs provide the appropriate closed and secure environments needed to manage the flexibility of the emerging intelligent optical networks.

REFERENCES

[1] DWDM, SONET, and Photonics: The Emerging All-Optical Network 2001–2006, 2001/05/02, Insight Research.

[2] J. Gruber, "The Drive to IP on Optics," The Carrier IP Telephony 2000 Comprehensive Report, IEC, pp. 113–23.

[3] J. Gruber *et al.*, "Architectures for the Optical Internet," *NFOEC*, July 2001.

[4] D. Su *et al*., "Standards: Standards Activities for MPLS Over WDM Networks," *Optical Networks*, vol. 1, no. 3, July 2000, pp. 66–9.

[5] M. Mayer, "ASON Standardization within the ITU," *IIR Conf.*, Barcelona, Spain, Nov. 2000.

[6] ITU-T Draft New Recommendation G.807/Y.1301, Requirements for Automatic Switched Transport Networks (ASTN), May 2001, to be approved.

[7] J. Gruber and R. Ramaswami, "Moving Toward All-Optical Networks," *Lightwave Mag.*, Dec. 22, 2000, pp. 60, 62–4, 66, 68.

[8] B. Rajagopalan *et al.*, "IP Over Optical Networks: Architectural Aspects," *IEEE Commun. Mag.*, Sept. 2000, pp. 94–102.

[9] User Network Interface (UNI) 1.0 Signaling Specification (unapproved), cont. no. OIF 2000.125.3, Dec. 8, 2000.

[10] D. Fedyk *et al.*, "BGP Based Auto-Discovery Mechanism for Optical VPNs," Internet Draft draft-fedyk-bgpvpon-auto-00.txt, Mar. 2001.

BIOGRAPHIES

DAVID BENJAMIN (benjamin@nortelnetworks.com) is a senior product manager in the Intelligent Optical Signaling group at Nortel Networks. He is responsible for defining and delivering new optical services over the emerging switched optical network. He joined Nortel Networks' Research and Development division (then Bell-Northern Research) in 1975 and has held various design and management positions related to switched services. He holds an honors degree in electrical engineering from McGill University and a M.Sc. in communications and digital signal processing from Princeton University.

RICHARD TRUDEL (rtrudel@nortelnetworks.com) is a senior brand manager within the Optical Networks group at Nortel Networks. He joined Nortel Networks in 1987 and has served in various managerial positions in operations, design, and marketing of access, microwave radio, and wireless products. In 1998 he joined the High Capacity Optical group and is now responsible for the development of the optical control layer strategy and its evolution. He holds a B.Sc. degree in electrical engineering from the University of Sherbrooke and an MBA from Ecole Des Hautes Etudes Commerciales in Montreal.

STEPHEN SHEW (sdshew@nortelnetworks.com) is a senior architect in the Optical Networks unit at Nortel Networks. In his fifteen years at Nortel he has participated in the development and specification of distributed routing protocols, traffic engineering optimization tools, PNNI, and MPLS signaling. His current involvement is with the automatic switched transport network (ASTN). He holds a B.Sc. degree in computer science from Carleton University and a M.Sc. from the University of Toronto.

ED KUS (edkus@nortelnetworks.com) is a senior product manager for Preside optical management products at Nortel Networks and is responsible for the evolution of management applications in support of new optical technologies and optical services. He joined Nortel Networks' Research and Development division (then Bell–Northern Research) in 1985 and has held various design and product management positions in switching, intelligent network (IN) services, and network management. He holds a B.Sc. degree in computer science and mathematics from McGill University.