ViewsLetter ON Provisioning

Issues 16 and 17 from February 2003

Developing Intelligent Fiber Optic Networks

By V. Kaminsky, PracTel, Inc.
Associate, Flanagan Consulting

Despite setbacks in the development of fiber optic network infrastructure, a number of vendors still continue to work on the optical network "automation" process and the development of intelligent networks. Optical switches from these vendors are intelligent enough to at least:

- Learn the topology of a set of nodes, automatically;
- Set up mesh-type network protection;
- Automate provisioning (based on signaling);
- Deal with digital "lambdas" (separate wavelengths that each carry 2.5 Gbit/s, 10 Gbit/s, or 40 Gbit/s);
- Groom lambdas from tributary links;
- Work with Dense Wave Division Multiplexing (DWDM), allowing signal transmission of thousands kilometers without regenerating the signal electrically.

Multiple studies of optical switch technologies support the need for these features and provide many reasons why these technologies have value, why they have to be developed and commercialized--even in times when demand for these switches is almost non-existent. Some references can be found in ViewsLetter #5 "Lambda on Demand in Optical Core may Lead Automation of Carrier Nets."

This paper provides an overview of key products for intelligent optical networks, the core optical switches. The scope was limited by a number of factors. The most serious problem is that, at present, optical intelligent networks are still mostly in development and standardization stages. The client base for optical switches is very small. Rather than provide details, this paper intends to serve as a guide for those working or interested in this area.

Note that ITU recommendations G.872 and G.709 use the term "Optical Transport Networks." In this paper, term "intelligent" stresses the intent of optical network developers to make these networks "self-learning" and "self-organized"; i.e., to enable them to react effectively to changes in customer demand as well on changes in network topology or connectivity.

Initially, the main purpose of optical switches was to support SONET/SDH ring-based architectures, and to allow interconnection of multiple rings. One of the first attempts to create a platform to interconnect multiple optical rings has been made by Lucent (Bandwidth Manager, BWM). It was commercially introduced in the late 1990s. This platform was deployed in a number of networks, mostly supporting undersea cables. It has a very large footprint, and lost its market share to a more compact product from Ciena, the CoreDirector. Its smaller footprint brought further success for optical switching.

BWM also created problems with ring interconnection when a network required support of traffic between stacked rings (that is, multiple rings on the same path but not initially interconnected). More recently, there were the first reports of successful mesh optical networks in which these switches provide intelligence for self-healing, self-organization, and automatic provisioning.

In general, the market for intelligent optical networks, supported by ITU-T standards (G.709, Automatic Switched Optical Network (ASON), G.872, and others), continues to expand, although at a much slower pace than was predicted initially. The bases for such networks are various flavors of optical switching platforms that, in general:

- Interconnect lambdas for 2.5 Gbit/s, 10 Gbit/s and 40 Gbit/s signals;
- Groom tributaries for these lambdas;
- Provide at least STS-1 or STM1 switching granularity;
- Interconnect multiple rings: Multiplex Section Shared Protection Ring (MS-Spring), Bi-directional Line Switched Ring (BLSR), Unidirectional Path Switched Ring (UPSR);
- Protect tributaries using various schemes;
- In later versions, allow mesh-topology protection;
- For mesh topologies, discover spare capacity automatically, and optimize its use;
- Implement various self-healing algorithms;
- Automate and optimize provisioning process;
- Configure either SONET or SDH in software;
- Connect directly with DWDM systems.

This paper divides optical switches into two major groups: one with optical-electrical-optical (OEO) conversion, and another with pure optical processing of signals. Note that recently a hybrid solution has been developed with a platform containing two switching fabrics, one OEO and one pure optical.

1. OEO SWITCHES

These switches convert optical signals to electrical signals at the switch input, switch electrically, and convert electrical signals back to optical at the output of the device.

Nortel Networks
This company commercially introduced the OPTera Connect HDX Optical Switch. The initial switch matrix size of 320 Gbit/s or 640 Gbit/s can expand in a future model to 3.84 Tbit/s. It has a compact design, and with initial switching capacity one shelf of the standard NEBS- or ETSI-compliant bay can host the whole switch. It has granularity of STS-1, and processes lambda sizes of 10 Gbit/s (40 Gbit/s in later versions). On the drop side, the switch handles a number of SONET and SDH signal speeds, starting from OC-3/STM-1. Among other features, it allows direct DWDM interfaces on the line side. Nortel is also advertising a smaller version of HDX, called DX.

Nortel announced its "Advanced Network Intelligence" will deliver, in the future, full topology auto-discovery, together with pre-planned mesh restoration. It also allows dynamic connection provisioning. This solution features an optical control plane, providing customized, adaptable optical services to bandwidth users. The solution is based on the ASON standard architecture and the routing and signaling protocols associated with Generalized Multiprotocol Label Switching (GMPLS). Special planning tools will allow users to simulate, plan, and optimize mesh networks.

This company stopped developing the OOO switch.

Lucent Technologies
The LamdaUnite MultiService Switch (MSS) was introduced to the market a couple of years ago. It has many features similar to the Nortel product. Initially a 160 Gbit/s switching matrix, it can be upgraded while in service to the standard configuration of 320 Gbit/s. A doubling of this capacity is expected in the near future. Its distinguishing features (among others) are implementation of a Trans Oceanic Protocol (TOP) in a 10 Gbit/s 4F MS-Spring configuration (reducing switching time for very long undersea networks) and introduction of the DS-3 interface. MSS can comprise one or more Terminal Multiplexers, or ADM functions, in a single node. It also can act as a fully non-blocking cross connect.

Lucent is planning to use a control plane called Synchronous Network Navigator (SNN) for mesh networks. As a part of the intelligent network platform, SNN will automate SONET/SDH connection set-up, provide fast restoration, and support automatic discovery of the network topology. SNN will discover available transport capacity and routes, and provide connection management. MSS will support the signaling necessary to actively participate in the SNN.

This company commercially introduced an OOO platform, LambdaRouter, but discontinued it quickly.

Alcatel

This company has different lines of products for SONET and SDH technologies. The Alcatel Core Node Solution consists of an optimized combination of DWDM systems, lambda management, SONET/SDH multiservice nodes and gateways (Alcatel's term for optical switches), and a control plane based on a GMPLS protocol and ASON standards (in the future). It has a centralized algorithm for automatic discovery of spare network capacity. By taking into account a priority level assigned to each network connection and the status of other network resources, a path-selection algorithm expertly regulates access to the shared capacity and restores any path affected by a failure without operator intervention. This plane also will support automatic provisioning by signaling.

Alcatel 1674 Lambda Gate does not have a 40 Gbit/s interface. In R1.0, it occupies two racks with limited functionality of 2.5 Gbit/s and 10 Gbit/s interfaces on both line and drop sides. A typical application interconnects three 10 Gbit/s rings from which 20 Gbit/s ports can be dropped. In R1.1, the switching fabric can go up to 5 Tbit/s, and offers the additional function of the ITU-T G.709 OCh (Optical Channel) interface. The control plane in this release will support a mesh network topology as well as rings.

The 1677 Sonet Link supports SONET applications.

Sycamore

Sycamore's SN 16000 switch is a software-centric, highly integrated switching platform that brings advanced capabilities and manageability to intelligent optical networking, from the metro edge to the optical core. Sycamore is one of the companies that made progress in GMPLS-based control plane development and implementation. This company has demonstrated interoperability of SN 16000 with Cisco, Juniper, and other IP routers in a mesh topology.

The switch provides capacity up to 160 Gbit/s in a single shelf of the standard bay. Its management software supports maximum operational efficiency and multi-dimensional scalability. Network-aware intelligence enables end-to-end provisioning and a business-driven migration toward optical mesh architecture, without compromising the reliability of existing services. Fully integrated, Sycamore's software-rich and scalable suite of BroadLeaf and SILVX SW form a foundation for a flexible, dynamic optical infrastructure - keeping a network open to new possibilities.

The SN 16000 switch is ready to adopt evolving standards from ITU and others for a flexible control plane that will allow effective use of network resources and simplify network operations and provisioning.

Ciena

This company was one of the first to introduce an optical switch, and now it has a mature platform based on relatively old R&D results. The CoreDirector system features include distributed networking intelligence, which enables network-wide provisioning and management as well as a variety of protection capabilities. The CoreDirector is 640 Gbit/s non-blocking, multi-service platform. Its smallest granularity of switched bandwidth is STS-1. The last version of this platform was able to support standard BLSR/MS-Spring architectures. Its distinguishing feature is software configurability for various SONET/SDH interface rates. Ciena also has a smaller version of the switch, CoreDirector CI.

Tellabs

The Tellabs 6500 Transport Switch is a broadband transport platform that performs bandwidth grooming, add-drop multiplexing and cross-connections. Distinguishing feature of this device is its new MetroVantage solution that extends these capabilities to remote locations via metro aggregation/backhaul and virtual cross-connections. MetroVantage shelves can be remoted as far as 25 km from the 6500 platform. It also scales from 20 Gbit/s to 1.2 Tbit/s (in a future release), and is expandable from the smallest system of 384 STS-1s to 49,152 STS-1s maixmum. It does not allow 10 Gbit/s signal processing at the present time. Tellabs offers quick provisioning of broadband circuits. SDH signals will be supported by a different platform.

Tellabs stopped development of its OOO platform, the 6700.

NEC
This company's product, the SpectralWave Universal Node Broad Band Manager, offers various transport services of SDH/SONET, PDH, and Gigabit Ethernet in flexible network topologies such as linear, ring, multiple rings, and etc. It can interface drop-side signals from 2 Mb/s to 45 Mbit/s for the PDH hierarchy. The product can manage 2.5 Gbit/s and 10 Gbit/s lambdas.

Enavis
T::CORE is designed to offer optimized cost-performance starting with its smallest configuration of 320 Gbit/s, up to 5 Tbit/s. T::CORE provides a high level of availability, keeping service provisioning and service protection separate. This platform collapses the functionality of multiple network elements such as DCC, OCC, and E/OADM, into a single highly optimized network element (NE). The key elements of the T::NET management and control system include automatic topology discovery, resource dissemination, Point & Click connection provisioning, and network-wide end-to-end path protection and restoration. Service providers know OPEX is dramatically influenced by ease of service provisioning and on-going network maintenance. T::NET capabilities help carriers reduce OPEX with automatic discovery, including Plag&Play neighbors and resources introduction, as well as status and topology identification. These distributed, dynamic routing capabilities allow rapid, cost-effective turn-up of new nodes and additional bandwidth without extensive line operations required today.

Polaris
This company's OMX Optical Transport Switch was developed, mainly, for metro applications. But it also can be used in backbone networks. Its switching fabric has a granularity of VT1/DS1 to STS-Nc signals, including transmuxing of M13 traffic. A GMPLS-based control plane and OIF UNI support effective automation of provisioning and seamless multi-vendor interoperability. InelliOp management center combines EMS, CORBA-based gateway, and planning tools.

Metro-Optix
This company developed a line of CityStream products, which combine a traditional ADM, DCS, FR access device, ATM service access multiplexer, ATM edge switch, IP router functionality, and DWDM system--all in one shelf of a standard bay. An interesting feature of this product is that the same multi-port DS-3 module will support any combination of clear channel DS-3, ATM DS-3, packet based DS-3, or transmutiplexed DS-3s. This protocol agility also extends

to the optical interfaces. Protocols for each type are programmable on a per port basis. Among other topologies, it supports mesh configurations.

AcceLight
This company has demonstrated its PXS 540 products. These products combine in one device TDM+Optical+Packet switched services. It allows point-and click provisioning among multiple networks.

Movaz
This company introduced a varied line of optical switches. RAYexpress is customer premises/MAN equipment scalable from one lambda (2.5 Gbit/s or 10 Gbit/s) up to a mix of four protected or eight unprotected individual add/drop channels. It has an extremely small footprint suitable for CPE. A GMPLS-based control plane supports it.

RAYstar Wavelength Switch and OADM can serve either as a pure optical switch, or as an OEO switch. It can interwork with multiple RAYexpresses, deployed in customer locations.

Tellium
The Aurora Optical Switch currently ships with 1.28 Tbit/s capacity and is scalable to 20 Tbit/s. As mentioned above, vendors of these products, at the present time, face a dramatic drop in demand, and it is unclear how far Tellium went after making a couple of sales. The Aurora Optical Switch has 2.5 Gbit/s and 10 Gbit/s interfaces (OC-48/OC-48c/STM16/STM16c, OC-192/OC-192c/STM64/STM64c). Tellium affiliated with NEC to utilize NEC DWDM systems with the switch.

The software that powers this switch, StarNet Operating System, uses a number of algorithms and protocols for achieving fast and seamless mesh restoration at the optical layer. Such restoration can be provided at the OC-48/STM16 level. Through the use A-Z provisioning and standards-based routing and signaling protocols, the Aurora switch enables automated delivery of new optical services. This switch can expand its capacity while in service.

TeraBurst
This company has a line of products based on a switching fabric that is protocol and rate transparent. The OMS 2100 is a lambda-level optical switch for applications in small and medium sized networks. It starts with 200 Gbit/s

switching matrix, which can go up to 800 Gb/s in the future. The OMS 2200 is a larger switch scalable from 160 Gb/s to 640 Gb/s. The OMS 3100 is a switch that can go to 2.56 Tb/s. The company offers various protection schemes, including mesh protection. IQWorks OS in the control plane, based on GMPLS, automatically discovers network topology.

The key feature of these products is that TeraBurst switching fabric is analog, i.e., it is transparent to signal formats and rates and switches analog signals. The TeraBurst system contains an analog electrical switch fabric (think of a cross-bar switch, that handles electrical streams in a manner similar to an all-optical fabric. The wideband switch is essentially a millimeter-wave device that enables the system to switch the analog electrical equivalents of lambdas. This switch provides strictly non-blocking route selection within the fabric for connectivity from any input port to any output port. A 64x64 switch can accommodate non-blocking switching of 64 OC-192/STM64 signals, or any combination of lower rates.

2. OOO SWITCHES

Development in this class of switches was dramatically affected by the overall slowdown in telecommunications. Companies such as Lucent, Tellabs, and Nortel stopped all R&D in this area, and discontinued already introduced products due to a lack of market demand. The surviving products, in many cases, became hybrids--combining an OEO matrix with separate OOO matrix on the same platform.

All OOO switching at the present time uses MEMS (micro-electromechanical mirrors) technology. Competition between OEO switch vendors and OOO switch vendors led to the dramatic reduction in price for OOO switches.

Calient Networks
The DimondWave Photonic Switch provides seamless scalability from 8 to 4096 ports. The ports are transparent for signal rates from Fiber Channels to OC-768. It has a selective OEO support for bridging legacy applications such as Fiber Channel and Gigabit Ethernet applications. The latest information is that development of this switch was put on hold.

Corvis
The Corvis Optical-Convergence Switch (OCS) is a hybrid, which combines two different switching fabrics (OEO and OOO) under a single hardware platform,

control plane, and NMS. This solution's OEO fabric can serve as an edge switch, grooming STS-1/VC4 traffic and performing SONET/SDH aggregation required for network efficiency and reconfiguration for ingress into the core transport network. The switch also can provide lambda switching using the OOO fabric for higher bandwidth services that do not require grooming and aggregation.

Alcatel
In a future release (R2.1), Alcatel promised to introduce two fabrics in the 1674 Lambda Gate, one being OEO, and one pure optical.

Sorrento Networks
This company developed a switching platform, TeraMatrix, based on MEMS technology. The platform can handle up to 64 lambdas. A control plane uses GMPLS software.

Conclusions

This paper provides a comprehensive survey of the commercially available optical switches that provide a basis for optical intelligent networks. There are a number of reasons to develop such networks:

- Improve network survivability;
- Improve network reliability;
- Increase the number and speed of lambdas;
- Make restoration process less dependent on the network topology;
- Increase the number of nodes in a network region;
- Provide dynamic network reconfiguration;
- Simplify provisioning process;
- Automate provisioning process;
- Simplify network operations;
- Reduce spare capacity costs.

These reasons are pushing vendors to develop intelligent optical networks, for the deployment of 40 Gbit/s pipes--they still look for a brighter tomorrow. In any case, this paper shows that a growing number of manufacturers are working in the area of optical intelligent networks, despite a market at the present time where demand for these network applications almost does not exist.

Optical intelligent networks will combine a large bandwidth (in Tbit/s) with a sophisticated control plane. So far, all indications are that this control plane will be based on the GMPLS protocol (current G.8080 does not specify a particular protocol for a control plane, it outlines only an architecture). This control plane supports many network features: self-restoration, adaptive spare capacity, shared spare capacity, automatic provisioning, and others. It is also envisioned that with an intelligent network structure it would be easy and cost-effective to build homogenous networks that span all of today's boundaries--unifying access, metropolitan, core.

The ultimate end-user customer dreams of the OOO switch as the next-generation technology. But it is OEO switches that are implemented, in limited numbers, in networks today.

The Author

Dr. Vladimir Kaminsky has been working in telecommunications for over 30 years. He started his carrier in Europe, where he worked on effective coding of digital information for various types of communications channels. During the last twenty years, he held engineering and management positions in Bell System companies. His responsibilities included analysis of technical and economical solutions for broadband optical networks in support of product planning and development. He has worked on the design and implementation of major carrier networks.

His practical experience combined with an extensive academic background give him a deep technical understanding of telecommunications technologies, such as SONET, SDH, DWDM, satellites, and terrestrial transmission.

Feedback, Please

This extended, in-depth report is something new in the ViewsLetter. Let me know if you liked it--or didn't to info@flanagan-consulting.com.

--William A. Flanagan, Editor and Publisher

Flanagan ConsultingSM

A service of W. A. Flanagan, Inc.

Publisher of *ViewsLetter on Provisioning*

Telecommunications Analysts and Consultants

Uniquely Experienced In Voice and Data Networking

Ph: +1.703.242.8381 Fx: +1.703.242.8391

www.flanagan-consulting.com

Office: 45472 Holiday Drive, Suite 3, Dulles, VA 20166 USA