AGILE OPTICAL NETWORKING: MORE THAN MOVING LIGHT

STRATEGIC WHITE PAPER

For decades now, since the inception of data services and the Internet, unrelenting traffic growth has driven optical networks to unprecedented scale and ever higher bit rates: 100G today, 200G and 400G in the near future. Recently, demand for agile, cloud-based services has created new challenges that require improved network agility and automation in order for network resources to become more readily consumable and dynamic or elastic in their response to demand from higher network layers. Agile Optical Networking enables IT and telecom service providers alike to conquer these challenges and accelerate delivery of cloud, mobile broadband and video-intensive services. Agile Optical Networking builds on Alcatel-Lucent's high-performance coherent transport with managed agile photonics and multilayer service switching and services to address a wide range of applications on a single platform. Both distributed and centralized network intelligence and virtualization ensure the network can adapt to, or even anticipate, the dynamic nature of the emerging wide range of services. Agile Optical Networking enables service providers to realize the untapped potential of their optical network – not just as a resource to transport bits, but as an integral ingredient of the cloud infrastructure that connects end users to their content and applications.

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CLOUD SERVICES DELIVERY – THE NETWORK CHALLENGE

In today's highly mobile, always-on, instantly-connected user environment, applications and content in the cloud need to be delivered to multiple devices on demand. The optical network must become more scalable and, while scalability has always been a mainstay of optical transport, what has changed is the need for the network to become more agile and more "consumable." What follows are some illustrations of how these objectives can be achieved, in combination with compelling economics as providers strive to deliver cloud-based services.

Scalable

Significant advances in electro-optic technologies now allow for higher wavelength capacity and optical transport scale. Innovations in coherent reception, combined with advances in algorithms, complementary metal oxide semiconductor (CMOS) technology miniaturization, analog to digital converter (ADC) sampling speeds, and the introduction of sophisticated modulation schemes lead to higher scale, smaller footprint, and lower power consumption. Harnessing this synergy and scale of tightly integrated networking technologies:

- Delivers 8.8 Tb/s at 100G with a non-disruptive path to 200G, 400G and beyond
- Avoids premature fiber exhaust and photonic line overlays
- Simplifies and more greatly streamlines operational models to address the growing demand for increased bandwidth
- Achieves terabit scale multilayer switching to economically meet unrelenting demand for cloud services

In addition to scale, the network of the future needs to become more agile to address unpredictable traffic dynamics. It must be able to remotely program a client interface in support of an ever-increasing variety of protocols, to configure a service route through the network, including point of origin and destination information, wavelength size, service-level agreement (SLA) parameters, and a host of other information required for assured service delivery. Additionally, the network needs to become more automated: Self-monitoring, self-diagnosing, self-healing, self-restoring, and self-optimizing, and essentially, more self-aware. This enhanced automation achieved by adding more intelligence is a key enabler for the increased agility required for cloud services delivery.

Versatile

The ability to deftly maneuver a wavelength in any direction, in any color, in real time enables great strides in being able to broadly deploy emerging services in the cloud services era. Current reconfigurable optical add-drop multiplexer (ROADM) technology, although reconfigurable and flexible, still lacks the complete directional independence required to achieve true infrastructure virtualization. Several new technologies are maturing so that the networks of tomorrow will be able to exploit the benefits they enable such as colorless, directionless, contentionless – flexible spectrum (CDC-F) ROADM.

An agile optical platform that rapidly adapts to a wide range of services and applications:

- Responds to cloud-based service dynamics with flexible resources
- Virtualizes the network to simplify network control, thus freeing the operator from complex resource details
- Enables elastic network control that adapts to changing application needs and repurposes consumable resources

Dynamic

Intelligent, continuously monitored and self-optimizing resource management:

- Enforces SLA service parameters at multiple layers in the network and takes preemptive action to ensure SLA guarantees
- Rapidly turns up and assures services, without manual intervention
- Anticipates and avoids problems before they occur
- Implements Network Operations Center (NOC) — based life cycle management — plans, deploys, and manages the network from one centralized location

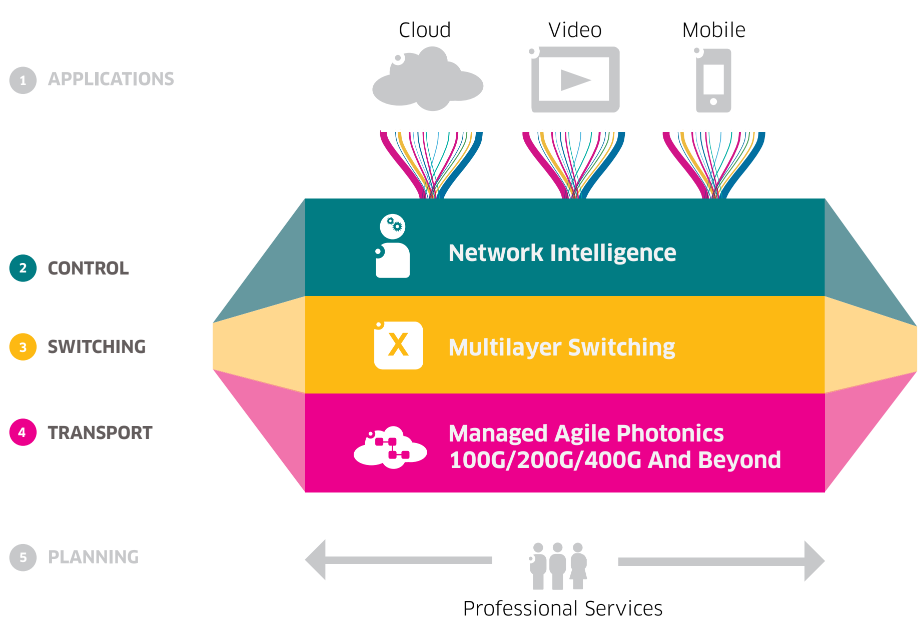
In the past, the network had limited embedded control points. Changes required manual intervention that resulted in slow time to revenue, higher OPEX due to the labor required to implement changes, plus the network itself was generally static. Over time, vendors responded to customers' demand for greater automation and agility by adding control planes for each independent layer of the network.

This improved time to revenue, resulting in operations that were less labor-intensive and more automated. However, disparate operational models for each layer of the network meant that OPEX was still not optimized and did not yet benefit from tighter layer integration. Today, the latest innovations hold the promise of even greater automation and more agile networks. Multilayer control planes with per-flow performance control and multilayer network management can now lead to a more common operational model and offer the possibility of the lowest total cost of ownership (TCO) and shortest time to revenue.

Agile optical networking is the term used in the marketplace to define the confluence of technologies that come together to enable versatile, scalable, reliable, and efficient optical transport networking at 100G per wavelength and beyond. These enabling technologies include:

- Managed agile photonics
- Multilayer switching and services
- Network intelligence

Figure 1. Agile Optical Networking for the cloud services era



MANAGED AGILE PHOTONICS

Managed agile photonics implies that wavelengths support an efficient, intelligent, fully networked photonic infrastructure. It offers compelling economics and scalability when using 100G, 200G, and 400G wavelength capacities. The Alcatel-Lucent 400G Photonic Service Engine (PSE) technology enables the very highest performance of those wavelengths in terms of reach, tolerance to fiber non-linearities, density and power consumption.

Alcatel-Lucent 400G PSE

The 400G PSE is the first-ever commercially available electro-optics chip capable of driving traffic up to 400 Gb/s per channel. Plus, it dramatically boosts the performance of 100G networks today. Built on in-house Bell Labs research, the 400G PSE is designed specifically for the Alcatel-Lucent 1830 Photonic Service Switch (PSS). The 400G PSE delivers the highest possible performance per wavelength at 100G. It possesses the ability to pack more wavelengths into every fiber through waveform engineering — potentially by as much as 33 percent.

Photonic OAM

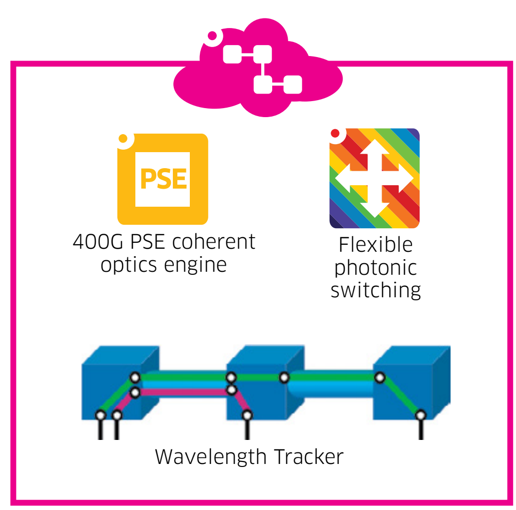
As networks carry ever greater amounts of mission-critical and delay-sensitive traffic, it becomes ever more important to embed monitoring points as close as possible to the physical layer.

Wavelength Tracker, for example, is a unique photonic operations, administration, and management (OAM) feature in the Alcatel-Lucent dense wavelength division multiplexing (DWDM) portfolio that automates the commissioning, turnup and supervision of wavelengths. This innovation inserts a unique management signal onto each wavelength that allows it to be identified and monitored at any point throughout the network, without termination or regeneration. This action provides operators an integrated view of all wavelengths at different points across the network, allowing these wavelengths to traverse the network while being traced, to track the behavior of each wavelength, isolate faults, monitor performance and correlate alarms.

Flexible photonic switching

For years ROADMs have supported remotely configured switching, allowing a wavelength to be added, dropped or bypassed through a node. But as ROADMs were more widely deployed, limitations became apparent. First, back then ROADM ports employed fixed wavelength assignments, meaning that other wavelengths could not be used without an on-site module replacement. Secondly, groups of ports were allocated to optical multiplexers supporting certain directions (east, west), and were constrained by which degree they supported. Also, the wavelength add/drop components design ran the risk of wavelength contention if more than one port on a given degree needed to use the same specific wavelength. Finally, the wavelength assignment conformed to a fixed 50 GHz-spaced International Telecommunications Union (ITU) grid.

Figure 2. Managed photonics: Network photonically at 100G and beyond



These limitations are addressed by CDC-F ROADMs. Until recently, compromises had to be made that limited the scale or ability to simultaneously provide colorless, directionless and contentionless features. The Wavelength Selective Switch (WSS) was an enabling technology. However, hardware complexity would often rapidly increase as the scale and number of degrees that a given ROADM was required to support increased. Fortunately, the latest generations of WSS devices have lowered the economic barriers to architecting CDC-F ROADMs, while simultaneously enabling the ability to switch any wavelength in any direction, without contention.

MULTILAYER SWITCHING

Cloud services are delivered in the form of packets to end users. These services can greatly benefit from an agile optical network which connects users to cloud services and cloud networks to other cloud networks by combining the best features of packet, electrical, and photonic switching in the most appropriate and economically beneficial areas of the network. Packet switching provides aggregation and grooming of the application layers in its native switching technology (such as Ethernet). Electrical switching (Optical Transport Network [OTN] and Synchronous Digital Hierarchy/Synchronous Optical Network [SDH/SONET]) maximizes wavelength efficiency and support for carrier-class performance, reliability, and seamless interworking with existing management systems. Meanwhile, photonic switching is essential for high-capacity wavelength transport, to occur both economically and at the lowest level of power consumption.

Muxponders and transponders

A significant amount of CAPEX and OPEX can be saved by employing muxponders and transponders as not all services require bit rate and protocol independence. This is especially true when the majority of these services is sourced and is destined to the same location, with no regeneration required. Because not every client needs packet or OTN switching and aggregation, savings can be derived by transparently multiplexing subrate services directly onto a wavelength or mapping a service, such as 100 Gigabit Ethernet (GigE) directly onto a 100G wavelength.

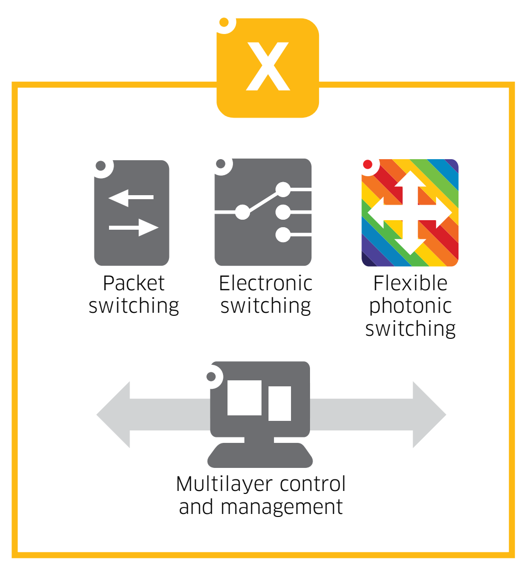
Electrically-switched OTN transport

Optical Transport Network is an integrated approach to providing switching and multiplexing in either electric or photonic, or in both domains. OTN defines adaptation and multiplexing to carry packet-based services transparently with client data rates ranging from 1 Gb/s to 100 Gb/s. The electric Optical Data Unit (ODU) layer supports switching granularities matched to the client's service rates and effectively fills the payload carried on the wavelength or optical channel (OCh) layer of OTN.

Integrated packet transport

Until recently, most deployments of packet over wavelength division multiplexing (WDM) have utilized point-to-point wavelengths with basic grooming through virtual LAN (VLAN) multiplexing or OTN. Delivery of such Ethernet Private Line (EPL) or Ethernet Virtual Private Line (EVPL) services with different levels of transparency has been

Figure 3. Multilayer switching: Groom flexibly to deliver services at the most economical layer



sufficient to meet most needs. In this case, packet networking is performed by external switches or routers. However, support for more sophisticated multipoint services indicates a need for integration of Layer 2 (L2) aggregation into WDM platforms while providing L2 networking. An integrated L2 over a WDM solution can leverage statistical multiplexing of services from multiple sites, support delivery of E-LAN and E-Tree multipoint services, and provide quality of service (QoS), Ethernet service OAM and SLA monitoring.

Alcatel-Lucent's Integrated Packet Transport feature provides carrier-grade L2 transport, switching and networking plus OTN aggregation converged in the 1830 PSS. This single OTN/WDM platform introduces a new generation of streamlined packet optical transport, spanning access through the core network. More so, it leverages the power and value of the Alcatel-Lucent Service Router Operating System (SR OS) to enable a fully managed packet solution with a common service, operations, and management model across the Alcatel-Lucent optical and IP/Multiprotocol Label Switching (MPLS)/Ethernet portfolio.

NETWORK INTELLIGENCE

Today's optical network intelligence tools are intended for everyday use as part of a network's life cycle management. Optimized and automatic network planning and engineering tools allow for real-time decision making without human intervention.

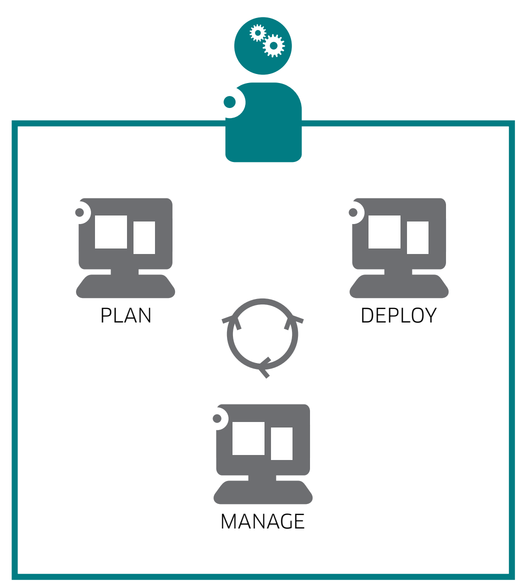
Optimized, automatic network planning and engineering

Considering that a wavelength selective switch has a switching capacity of up to 70.4 Tb (consisting of 8 degrees x 88 wavelengths of up to 100G per wavelength), it is essential that traffic be groomed effectively and efficiently in relation to the relatively small electrical (or OTN) switching capacity of 4 Tb or 8 Tb. Multilayer design optimization ensures that the 100G wavelengths are filled efficiently. Advanced routing and feasibility algorithms ensure that traffic which does not require grooming and aggregation through the electrical matrix bypasses the matrix photonically. This not only reduces costs, but also reduces the burden on the smaller electrical matrix, thus also maximizing bandwidth efficiency. Additionally, multilayer design optimization ensures the services are ideally routed with respect to their SLA parameters, such as latency and resiliency specifications, resulting in reduced CAPEX and an extended network lifespan.

Accurate, continuous, autonomous, and ubiquitous monitoring

100G networking relies on measurement. Measurement is critical to better understanding network performance. Photonic OAM can include the measurement of variables such as power, signal noise and latency. Power measurement can be used for continuous, autonomous, and automatic power balancing of individual wavelengths and groups of wavelengths along multiple touchpoints in the network for an end-to-end service. Photonic measurements can also be correlated to SLA objectives for each service carried on a wavelength.

Figure 4. Network intelligence: Accelerate service delivery and automate operations



SLA assurances can be classified and verified with granularity down to a gigabit basis as services are mapped into ODU containers. These assurances can then be scaled to several terabits through control plane intelligence. Layer 1 and Layer 2 service monitoring consists of measuring and reporting things such as bit error ratio, frame loss and latency. A control plane can be configured to react automatically to a failure or degradation in the network with or without human intervention.

Multilayer network intelligence

Additionally, a multilayer control plane is capable of automatically uploading predefined and preconfigured parameters associated with a Layer 0 asset (for example, a wavelength or route), such that it may be reflected in the higher OTN or electrical layer. This multi-layer awareness and correlation enhance superior SLA assurances and increase levels of resiliency. Finally, a multilayer control plane can assist in further differentiating services with support for enhanced SLAs. Service restoration can be coordinated between packet, electrical and photonic layers so that it is achieved at the most economical layer while still respecting target SLA guarantees. Future integration and correlation with the packet or Ethernet has the potential for even more service enhancement.

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Video is increasingly consumed in new, more bandwidth intensive forms and from a greater variety of screens. Broadcast video is becoming only a small fraction of consumed video as streaming video on demand (VoD) becomes the norm due to its convenience and increased personalization. Concurrently, a rapidly growing number of smart devices are connecting to the network. The utility of these devices is defined by how much bandwidth is available. In combination with cloud service in this emerging era, an untold amount of bandwidth will be required in a more readily consumable and dynamic manner. These trends will impose a significant number of new network requirements relating to SLAs, reliability, QoS and security.

Alcatel-Lucent's approach to Agile Optical Networking enables service providers to realize the untapped potential of their optical network — not just as a resource to transport bits, but as an integral ingredient of the cloud infrastructure connecting end users to their content and applications.

ACRONYMS

ADC	analog to digital converter
API	application programming interface
CAPEX	capital expenditure
CDC-F	colorless, directionless, contentionless – flexible spectrum
CMOS	complementary metal oxide semiconductor
DWDM	dense wavelength division multiplexing
EPL	Ethernet Private Line
EVPL	Ethernet Virtual Private Line
GigE	Gigabit Ethernet
GMRE	Generalized Multi-Protocol Label Switching Routing Engine
ITU	International Telecommunications Union
L2	Layer 2
MPLS	Multiprotocol Label Switching
NOC	Network Operations Center
NPT	Network Planning Tool
OAM	operations, administration, and maintenance
OCh	optical channel
ODU	Optical Data Unit
OPEX	operating expense
OS	operating system
OTN	Optical Transport Network
PSE	Photonic Service Engine
PSS	Photonic Service Switch
QoS	quality of service
ROADM	reconfigurable optical add-drop multiplexer
SAM	Service Aware Manager
SDH	Synchronous Digital Hierarchy
SLA	service-level agreement
SONET	Synchronous Optical Network
SR	service router
SR OS	Service Router Operating System
TCO	total cost of ownership
VLAN	virtual LAN
VoD	video on demand
WDM	wavelength division multiplexing
WSS	Wavelength Selective Switch

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