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# Optical to the Edge

## Agile, long-term pooling and simplified optical to the edge

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# Executive summary

New applications and access technologies are placing increasing bandwidth demands on optical networks. In parallel, end users have enhanced performance expectations, resulting in more stringent service-level agreements (SLAs). In addition, communications service providers (CSPs) have facility and total-cost-of-ownership (TCO) constraints and may not be as automated as possible. Technology is going in the direction of higher capacity and optical transport network (OTN) to the edge to reduce latency. An FMEC strategy will aid cost reduction.

A new aggregation technique based on wavelength selective switching (WSS) is being advanced. Classic customer access rings may not be fully utilized at all times. CSPs historically had the choice of terminating the wavelength at an aggregation site, electronically grooming for optical transport back to the network core. The cost was the optical-electronic-optical conversions. An alternative solution would be to home-run the optical access rings all the way back to the optical core. The cost of this solution was resources expended in nonfull fill situations. With traffic continuing to scale and optical-to-electrical-to-optical transponders (OEOs) adding latency, an optically based grooming solution begins to have an appeal. The upfront cost of the WSS-based solution is the WSS.

The benefits of a WSS-based solution are

- All-optical latency performance
- All-optical network footprint and power draw
- Grooming at aggregation sites for optimal resource utilization

Metro-optimized 100G and 400G also have a strong appeal. The metro coherent digital signal processing (DSP) does not need all the capability of an ultra-long-haul DSP, enabling space and power savings. With integrated transmit and receive functions, the pluggable can further be reduced in size and power draw.

Historical fixed optical add-drop multiplexer (OADM) architecture can be modernized with flexible reconfigurable optical add-drop multiplexers (ROADMS) that can support multiple rings. The transport ROADM can also be used to replace Central Office site-fixed OADMs.

With the hardware refresh, a software refresh also makes a lot of sense. Today's network management systems can perform automated wavelength planning, service provisioning, and performance optimization.

CSPs may consider an agility-enhanced, long-term oriented, pooled, and simplified (Alps) solution to improve TCO and improve the customer experience. Additionally, the ability to speed up planning and provisioning can also aid the sales process and assist with revenue acceleration.

# Applications: Catalyzing and accelerating network growth

## Advanced applications

The digital economy, enterprise adoption of cloud-based services, and 5G-enabled applications are all catalyzing demand for more optical connectivity. The world economy is rapidly embracing digitally delivered services. Enterprises have embarked on an IT transformation, moving from in-house to cloud based. The advent of 5G is enabling a host of applications including video centric, Internet of Things, and virtual and augmented reality. The three macro dynamics cited drive higher capacity onto the optical core and pull high-bandwidth requirements further into the network edge.

## Advanced access

In addition to 5G connectivity growth, Passive Optical Network (PON) networks have also rapidly expanded. The transition from copper to fiber was underway before the COVID-19 pandemic. The work/school/entertainment at home phenomenon dramatically accelerated the need for high-quality bandwidth into home environments.

# Technology trends

## High capacity to the edge

With the growth of video-based services and cloud service, the need for more bandwidth to the edge is readily apparent. In addition to a raw bandwidth increase, end users have heightened expectations for service performance and service wrapper elements.

## Latency reduction

Sophisticated end users are much more attuned to the need for superior latency performance. From the consumer entertainment perspective, end users are attuned to lag in gaming scenarios. Video consumers immediately pick up on jitter issues or latency-induced drops in video quality. For the high-end enterprise community, latency can be the difference between winning or losing business. Mission-critical services are also critically dependent on latency performance.

## Optical transport network to the edge

The trends for high capacity and low latency to the edge are leading CSPs to deploy optical transport network (OTN) solutions deeper and deeper from the network core to the network edge. OTN is a technology for ensuring deterministic performance. It can underpin latency SLAs and ensure they are met.

## Fixed-mobile convergence

Two additional networking trends are fixed and mobile edge convergence and eliminating unneeded legacy optical-electrical conversions, “network hops.” With optical capabilities extended deeper to the network edge, all fixed and mobile service and access types can consolidate onto the optical core. Legacy Sonet/SDH networks can be transformed to optical-fiber deep solutions, eliminating unrequired networks hops.

# CSP challenges

## Fiber, power, and rack constraints

In addition to meeting the challenges of identifying and rolling out new services that are paired with heightened user expectations, CSPs need to work within additional constraints. Available fiber may be limited. Deploying new fiber will be expensive and may be impractical or in some cases not even possible. All CSPs are extremely focused on all the costs of power and are continually looking for ways and means to reduce their power footprint. Physical central-office or colocation space may also be limited. Limited rack space can throttle equipment deployment and network growth.

## Meeting more stringent SLAs

Enterprise and consumer communities have higher expectations for SLAs. CSPs are obligated to meet their more stringent SLAs.

## TCO pressures

TCO pressure is unescapable. The total cost of power in particular has risen dramatically in importance over the last few years. Capital outlay remains, as always, top of mind. CSPs are looking for ways to streamline processes and automate to reduce operational cost burn.

## Lack of automation

CSPs are constantly striving to improve all operational procedures including service activation and turn-up. CSPs wish to evolve from reactive network monitoring to a more predictive stance.

CSPs need to address the development of next-generation service plans while navigating an operational transition to a more automated future.

# Introducing the Alps-WDM solution: Agile, long term, pooling, and simplified

## Agility with operations automation

Network operations have also evolved. Each wavelength can now be equipped with a digital optical label containing wavelength path, frequency, bandwidth, and power information. Network management tools can now use all of the available wavelength information to conduct automated planning, provisioning, and automation. Beginning with wavelength planning and routing, topologies can be visualized and available resources displayed. Automated wavelength planning tools can recommend the optimal wavelength plan in minutes, improving the planning cycle dramatically.

With the optimal plan in place, services can be commissioned and provisioned in an automated manner, transforming the length of another task from days down to minutes.

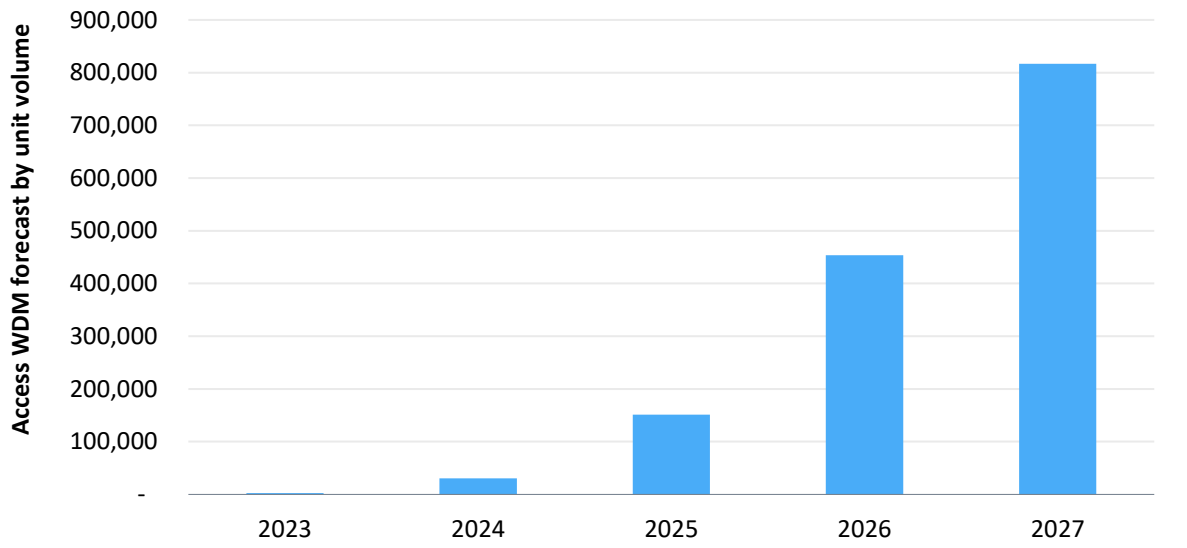
Telemetry data collection, storage, and analysis has also taken steps forward. Optical power levels can be tracked over time. Suboptimal conditions or degradation situations can be identified with recommendations to retune and automatically adjust before a customer-affecting event happens.

All the new capabilities identified can improve many operational processes, functions, and parameters, leading to an overall improved TCO stance.

## Long-term oriented via very high bandwidth

The new next-generation network edge solution begins with extending dispersion compensation module (DCM) free fiber to the network edge. New metro-focused, 100G, coherent solutions will be a significant bandwidth-performance, cost per bit, and operational upgrade over older, lower-speed, DCM-based solutions. New metro-optimized modulation techniques such as m-QPSK can be used to meet metro performance requirements while minimizing space, power draw, and cost. Metro-focused DSPs are power optimized, leading to lower power consumption. Integrated transmit-receive designs enable a smaller footprint per bit. Today's 10G metro uplinks can evolve cost-effectively to 100G, providing sufficient bandwidth to support today's needs with headroom for long-term growth.

**Figure 2: 100G Access wavelength-division multiplexing (WDM) coherent forecast, 2023–27**






Source: Omdia Optical Network Forecast – 2022–27

# Pooling: Advanced aggregation techniques to maximize resource utilization

CSPs have had an historical challenge of fully utilizing all network resources available from the network edge into the core. Access rings may only be partially filled but “home-runned” all the way back into the network core, partially filled the entire way. Deploying an edge-optimized WSS can facilitate “network pooling” at that point. Aggregation can be performed deeper in the network, leading to higher utilization through the middle mile into the network core. Access ring bandwidth can be allocated onto uplink bandwidth on demand as needed to maximize resource utilization. The more elegant aggregation function enables both capex and operational savings. With superior overall utilization rates, the network equipment and the cost requirement is reduced. With less equipment required, the space and power for individual sub-racks is reduced for an opex saving.

# Simplified with optical cross-connect solutions

Many CSPs see the value of evolving from historical fixed OADM technologies to today’s advanced ROADM and optical cross-connect solutions (OXC). Fixed OADMs had the appeal of low Day 1 costs in low-bandwidth scenarios. The limitation of fixed OADMs becomes apparent as bandwidth scales and as reconfiguration needs arise. Bandwidth is stranded, and the initial fixed OADM cost advantage is eroded. ROADM/OXC with M×N WSS technologies have rapidly advanced, proving their worth for elegantly and efficiently managing and supporting wavelength routing at significant scale.

Utilizing modern bandwidth management techniques will not only aid the opex cost line but can also accelerate the revenue line via time-to-market efficiencies. Advanced all-optical switching OXCs were first deployed in the high-capacity core nodes then migrated to the network aggregation and edge layers. A tremendous value of optical switching is in minimizing the optical-electrical conversions that were required in earlier generations of transport equipment. A signal can be transport from access origin to network core destination in one optical hop with no OEO required. One hop paired with flexible optical grooming reduces latency and speeds up provisioning times.

# Appendix

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