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Optical Networking 2.0: Trends and Innovations

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INTRODUCTION

Coherent detection has propelled optical networks forward over the last decade, allowing optical systems to meet network traffic growth at ever lower costs per bit. The coherent detection era is not yet over, but it is reaching maturity. Thus, suppliers and their customers must become more innovative in how they address optical total cost of ownership (TCO). Fortunately, continuing advances in hardware and software are helping service providers face this challenge.

This white paper analyzes the key requirements and solutions for optical networks, with a focus on the next 3 years. It also discusses the following opportunities:

- Lowering TCO through a combination of Optical Networking 2.0 advances, including higher data rates, hardware simplification, and advanced operations, administration, and maintenance (OA&M) functions.
- Creating new revenue opportunities for high value customers that are willing to pay more for premium performance and security.

HIGHER DATA RATES

This section details advances to high data rates as optics approaches the Shannon limit. Huawei labels the trend “New Speed.”

The Shannon limit defines how much information can be transmitted in a communications channel. Researchers estimate that the practical limit in dense wavelength division multiplexing (DWDM) is around 1 Tbit/s. The highest performing commercially shipping systems today are capable of 600 Gbit/s per wavelength, and several vendors have announced digital signal processor (DSP) chipsets capable of 800 Gbit/s (though not yet commercially available). The industry is fast approaching the Shannon limit for DWDM transmission in the C band, and incremental gains come at higher and higher costs. The practical limit will be reached before the theoretical limit due to the higher costs of incremental gains. Equipment suppliers and their customers are already seeking new options for expanding capacity beyond coherent detection and higher order modulations.

Near-Term Options for Expanding Capacity

One popular approach that is already being used today, particularly in submarine networks, is to expand transmission beyond the C band frequencies into the adjacent L band frequencies. In addition to new terminals, expanding into the L band requires new line systems that support the expanded wavelength range. With the C band running out of capacity, the L band has become more attractive – particularly for applications where laying new fiber is not an economic option (such as in submarine networks).

As the L band trend emerges, another novel capacity approach is showing promise, especially for greenfield applications. Proposed by Huawei and called the “Super C band,” the approach involves increasing C band spectrum above and below its traditional range. The expansion yields 6 GHz of spectrum/120 50-GHz channels compared to either 4.4 GHz of spectrum/88 50-GHz channels or 4 GHz of spectrum/80 50-GHz channels in the traditional C band.
Although it works on any fiber, the Super C band requires new optics and specialized amplifiers to handle the expanded frequency range. Because Super C band requires a new line system, Heavy Reading expects it to appeal primarily to operators building new routes (or greenfield applications). These operators will benefit from up to 50% greater capacity with a single terminal/line investment compared to a 2x initial investment in building a C + L band network. For these greenfield Super C band builds, the L band can be added at a future date for another increase in capacity. Notably, the Super C band bleeds into the traditional L band and limits it to 4 GHz of added spectrum. A future Super L band system, however, could expand the L band to a full 6 GHz, thereby fully doubling capacity with Super C + Super L.

**Migration from 100G to 200G and Beyond**

The above discussion addresses the high performance end of the market (such as the highest capacity links between hyperscale mega data centers and specific applications, like submarine transmissions, where fiber is severely limited). In metro and long haul DWDM networks today, 100 Gbit/s remains the dominant data rate. According to Ovum, 100G accounted for 70% of total coherent DWDM line-side wavelengths shipped in 2018.

Thus, for more than two-thirds of the telecom market, the current migration is from 100 Gbit/s to 200 Gbit/s in the near term. Ultimately, the market will move to 400 Gbit/s line rates when the technology matures and costs come down (hyperscalers aside).

**Figure 1** shows Ovum’s current line-side DWDM forecast for coherent 100G and 200G and greater data rates. Coherent 100G’s share is expected to drop from 70% in 2018 to 50% in 2022, while the share of 200G+ is forecast to increase from 30% to 50%.

**Figure 1: Global Line-Side DWDM Coherent Wavelength Shipments: 2018-2022**

Note: Excludes 400ZR units.

*Source: Ovum, 2019*
With 400G unlikely to take off in telecom before 2021, there is a strong near-term window for 200G to address network operators’ capacity shortages today. The latest-generation 200G DSPs bring two major benefits compared to early-generation 16QAM-based chips:

- Early-generation 200G DSPs were reach-limited to 1,000 km, but more advanced modulation techniques, including probabilistic constellation shaping (PCS), enable new 200G DSPs to achieve practical reach up to 3,000 km. These greater reaches cover most terrestrial DWDM applications and virtually eliminate the historical trade-off between capacity and reach.

- While early-generation 200G DSPs required 75 GHz spectrum to achieve long distance transmission, some new-generation 16 nm DSPs can pack 200 Gbit/s data rates within 50 GHz spacing to achieve the same performance. The tight spacing is significant because it means existing fixed grid optical line systems can be used for 200G without requiring a line system upgrade to flex spectrum.

As they address today’s capacity shortages, these new DSPs could also prolong the lifespan of 200G – even as 400G ramps up. Not all operators will be ready to upgrade line systems for 400G or be willing to sacrifice reach.

**HARDWARE SIMPLIFICATION**

This section addresses systems-level innovations aimed at simplifying hardware as networks become more complex. Huawei calls this trend “New Site.”

Beyond increasing capacity, operators look to reduce space and power and increase the modularity of optical systems. These trends were initially driven by the hyperscale internet companies (such as Google, Facebook, and Amazon). They are gaining traction in traditional telecom as network operators seek to lower TCO in networks and adopt innovations pioneered by the hyperscalers.

The increasing popularity of high speed DWDM pluggable modules in telecom is perhaps the most prominent example of the hyperscale-driven hardware innovation today, but the trend extends well beyond the modules themselves to include full optical systems. This systems-level hardware innovation has two main goals:

- Simplify networks and network elements
- Assure that hardware is an enabler for the software automation that runs on top

The analog optical layer must not be the bottleneck that prohibits the lower costs, automation, and interoperability promised by software automation (i.e., software-defined networking [SDN]). For the first time, the commercialization of colorless, directionless, and contentionless (CDC) ROADM hardware has made the photonic layer programmable from end to end, a necessity for applying software automation to photonics.

However, in large hub sites, the proliferation of ROADM nodes is leading to a new level of complexity and fiber management challenges that threaten to diminish the benefits gained. In these large sites, thousands of interconnected ROADM fibers must be manually managed and physically moved, but this process is manual, time-consuming, and prone to human error. The connectivity also consumes significant footprint in the central office.
Today, a new class of product – the all-optical, or photonic, cross-connect (OXC) – offers an innovative hardware approach to hardware management. The OXC automates fiber management through the use of an optical backplane that also eliminates potentially thousands of fiber connections between large-scale optical elements.

In an OXC, all the connectivity is handled through the backplane with no external fiber connections needed. The backplane itself contains all the physical fiber connectivity hardwiring each port to every other port, thus eliminating the need for any external fiber connections. With all possible fiber connectivity options hardwired in the backplane, internal liquid crystal on silicon (LCoS) wavelength selective switching (WSS) elements steer individual wavelengths from port to port as required. Wavelength steering is performed through software control and is thus fully automated.

To be clear, CDC ROADMs will continue to play a major role in networks for many years to come. However, the OXC has emerged as a promising option to simplify connectivity in large-scale hub locations. A pioneer in this class of product, Huawei’s OXC has been commercially deployed in networks at China Mobile (China) and XL Axiata (Indonesia), among others.

SOFTWARE AUTOMATION WITH OA&M

The term “SDN” is used less often today, but the concept is far from dead. Rather, operators now understand that software-driven automaton is essential to lowering TCO and meeting customers’ network requirements. Regardless of whether the term SDN is used, software innovation must be coupled with hardware innovation. Figure 2, from a 2018 Heavy Reading global operator survey, shows global operators’ SDN deployment stage at that time.

**Figure 2: Global Operator SDN Deployment Stage: 2018**

- **Deployment**: 34%
- **Trials**: 18%
- **PoC**: 21%
- **Education phase – pre-Proof of Concept (PoC)**
- **Company is not interested in SDN**: 1%

N=142

Source: Heavy Reading, Charting the Path to Network Automation & Disaggregation, February 2018
Although the move to full SDN and true intent-based networking will take years, software automation is delivering significant operational and efficiency benefits in OA&M, provisioning, and troubleshooting today. Huawei calls this trend “New Smart OAM.”

For example, automated, real-time network discovery – based on global network views and real-time data collection – delivers immediate operator benefits even without automating service provisioning. Accurate understanding of full inventory is critical for network modernization efforts, allowing technicians to take down old ports and systems without causing wider service outages. Heavy Reading calls this a “read-only” use case, and it is being used by some operators today.

Another read-only use case is automated correlation of data across domains (and possibly network layers), which can then be used to analyze the network and identify anomalies in its structure. Such anomalies are prevalent, since the vision of the network as dictated by its planning team is often not fully implemented by the operations team. Service characteristics can be improved based on real-time data gathering, correlation, and software analysis. This is also being done by some leading operators.

Newer is the combination of real-time data collection and machine learning and predictive algorithms (typically called “AI”). The goal is to accurately characterize the current network state and predict its future health based on network data inputs and sophisticated software analysis. Using predictive health, operators can identify networks risks in advance of failures and then take measures to proactively avoid the failure scenario.

Similarly, real-time data collection and machine learning can be combined to perform automated root cause analysis when network failures occur. Historically, identifying root causes from failures that set off a storm of alarms has been a labor-intensive and time-consuming process, with consequences that can make national news headlines. Applying data modeling and machine learning, advanced new software can strictly narrow – or even specifically identify – root causes from faults.

**NETWORK MONITIZATION: OPTICAL NETWORKING 2.0 USE CASES**

The Optical Networking 2.0 innovations discussed in this paper not only contribute to lower TCO for operators but can also boost top-line revenue through premium optical services. Operators are migrating to Ethernet services, and over-the-top (OTT) software-defined wide-area network (SD-WAN) services are gaining traction in enterprises. At the same time, critical services still require high bandwidth (10 Gbit/s-100 Gbit/s), low and guaranteed latency, guaranteed bandwidth, and highly secure connectivity. These stringent service requirements are ideal for Optical Transport Network (OTN) wavelengths – and financial services firms, healthcare, and governments are prime verticals. Operators can take advantage of Optical Networking 2.0 hardware and software advances to increase OTN’s appeal for customers that are willing to pay premium prices. Significantly, leading operators are doing this today, as discussed in the two profiles below.
Global Network Operator: Targeting the Financial Sector with Low Latency SLAs

A global operator was near end-of-life with its synchronous digital hierarchy (SDH) installed base and facing increasing competition but wanted to take advantage of new revenue opportunities. In particular, the operator saw premium pricing opportunities in financial services and government with high bandwidth, high availability, low latency, and highly secure services. This operator selected premium OTN, which scales well beyond SDH line rates, and plans to introduce latency-committed services initially targeted at the financial community. Latency commitments will be based on measured network latency. Major enterprise locations have been identified, along with measured microsecond latency circles that enable highly compelling service-level agreements (SLAs).

Applying self-service portals to the OTN network, this operator will enable a fast-provisioning bandwidth-scheduling and bandwidth-on-demand capability. It will provide enhanced self-management capabilities via a portal capable of flexing bandwidth and SLA visualization. With the combination of performance and advanced features, the operator expects to charge a premium for these new services.

Global Mobile Operator Deployed a Dedicated OTN Service Overlay

A global mobile operator working in highly competitive market conditions also sees opportunity in premium OTN. With access to substantial capital and available fiber, the operator was in a position to execute a bold vision. It chose a complete overbuild and constructed a dedicated OTN service network. The premium private line network overbuild included a 200G flexible mesh backbone network. The national network included 150 central nodes with OXC and OTN switching clusters. OTN was deployed to large enterprises and aggregation central offices. Low latency was enabled by optical pass-through "one-hop connections." Optical-electrical-optical conversions from legacy SDH ring handoffs were eliminated.

Centralized network management controls 300,000 network elements, including customer premises equipment. Telemetry measurement intervals were set up at minute levels, enabling a "fine-grained" network monitoring. Online portals were deployed, including a sales quote portal and a tenant portal. For the operator, the Optical Networking 2.0 advances boost both network efficiency and revenue.

SUMMARY AND CONCLUSION

As network traffic and complexity increase, new innovations in hardware and software are needed to address operators' optical networking needs. These innovations are at the heart of Optical Networking 2.0, which aims to accomplish the following:

- **Improve transmission efficiency:** Advanced DSPs not only drive data rates closer to the theoretical Shannon limit, but also squeeze greater efficiencies from existing line systems and data rates. 200G transmission in 50 GHz spacing and expansion into the Super C band are examples.

- **Reduce hardware complexity:** Next-gen hardware increases the modularity of systems while also reducing space, power, and overall costs. The OXC is one example here.
- **Improve operational efficiency**: Combining real-time data collection, machine learning, and predictive algorithms automates OA&M, provisioning, and troubleshooting tasks to reduce opex. Innovations such as real-time inventory, predictive health, and automated troubleshooting are examples.

Combined, these innovations reduce operator TCO from both a capex and opex perspective. They also open doors to service enhancements – such as OTN private lines – that boost top-line revenue.