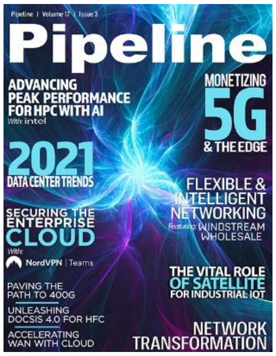

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Paving the Path to 400G Migration

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400G is delivering on its promise of higher capacity fiber optic transport to address the ever-increasing demands for speed and connectivity across metro, short- and long-haul network backbone infrastructure and between data centers. These new capacity levels allow carriers to maximize the value of existing infrastructure while reducing operational costs. Of course, like any new technology, 400G has its challenges.

Upgrades from 10G to 40G to 100G and 200G do not require any changes to the existing carrier infrastructure; they all have wavelength spectral bandwidths that fit into existing 50GHz/100GHz grid optical filters. The 400G capacity over a single wavelength has a much higher baud rate, making it too wide spectrally to pass through fixed 50GHz grid reconfigurable optical add-drop multiplexers (ROADM) and 50GHz channel-spaced filters.

Traditional 50GHz channels spacing mux and demux are standard for 40G, 100G, and 200G networks, but these are not compatible with 400G. In addition, the amplification requirements to meet the link budget of 400G networks are much higher, which account for the losses and gains to the receiver from the transmitter through the fiber.

The entire 400G optical network infrastructure “chain” needs to be fine-tuned to handle these various spectral issues. The mux and demux, ROADM, optical amplifiers, coherent optical transceivers, and digital signal processing (DSP) equipment need to be upgraded to support these new requirements.

Power and cost need to be considered within the equation as well. The 400G fiber optic solutions available today generally consume significantly more power than previous technologies and are much more expensive. Only a few vendors control the market right now, and adopting their proprietary technology means vendor lock-in for the long-term because their 400G solutions do not support the latest multisource agreements (MSA) either.

Two standard approaches to 400G

Two standards dominate the 400G market: the Optical Internetworking Forum (OIF) 400ZR, and the OpenROADM multisource agreement.

The 400ZR implementation agreement has been designed to reduce the challenges and costs associated with network flexibility and high-bit-rate data center interconnect (DCI) requirements. The 400ZR standard creates an economical, footprint-optimized, and simple method for transmitting 400Gb Ethernet over DCI links for short distances, generally up to 80 km. The specification for 400ZR uses higher-order modulation, such as 160QAM and DWDM. Operators can mix equipment from multiple vendors within the same network for the first time with the 400ZR requirements for interoperability at high speeds.

The form factor of the optical module used to deliver 400G has strict power consumption limitations, so the 400ZR DSP has limited functionality and supports only the Ethernet client with its use of the OIF Concentrated FEC (CFEC). This means it's lacking encryption, tunable lasers, and OTN rates.

Another variant of 400ZR – ZR+ – has been pushed by the industry, offering the smallest form factor to push 400G speeds but without the reach limitations of 400ZR. The ZR+ module allows a span of up to 200 km using more powerful signal processing techniques because it requires 15W more than the standard 400ZR specifications. It's the compromise between the telecom and data center market requirements.

Generally speaking, the 400ZR cannot be connected over carriers' metro networks and ROADM infrastructures. Therefore, the OpenROADM multisource agreement by the Open ROADM standards committee has defined a stronger Open FEC (oFEC), which enables carriers to expand metro networks with 400G wavelengths or links.

Going modular

Standards-based 400G pluggable coherent modules help address some of the challenges across the data transport market. For example, the short-distance 400G pluggable transceivers that use PAM4 require multiple lasers, which cannot operate at long distances.Therefore, they use coherent optics that combine amplitude modulation and phase as well as orthogonal polarization in transmission with approximately 64 Gbaud rate. This configuration allows for a single laser to deliver almost 1,000km reach with lower CAPEX and OPEX.

Furthermore, the same modules combined with standard FEC modes and unified management systems eliminate the need for bulky, proprietary, single-source, non-standard modules. These new coherent interfaces have a significantly smaller footprint, with lower complexity and higher efficiency. This optimizes the link budget, consumes less space and power, provides better performance, and reduces cost per bit.

Putting it all together

These challenges have been addressed through standardization bodies, efficient engineering, and collaboration between vendors and users to deliver the latest innovations in fiber optic transmission technology.

The next generation DSP-based on low-cost, low-power 7nm technology supports standard forward error correction (FEC) modes to streamline interoperability and will be available in 2021. This will enable multiple vendors to offer the newest, standards-based pluggable modules – 400G CFP2-DCO and QSFP-DD, which will reduce costs and enable mass deployment.

The network management systems (NMS) of the ROADM devices, which redirect, block, or pass wavelengths across the network, have been upgraded as well, and they now accommodate the 400G bandwidth issues to ensure complex, flex-grid spectrum management.

400G coherent solutions started hitting the market a few years ago, but, even today, they are based on power-hungry DSPs with vendor proprietary FEC and algorithms in a large package, consuming a lot of space and reducing the capacity of the network products. Moving forward, the new 400G solutions will be smaller and consume less power by using pluggable 400G optics from a range of manufacturers.

These new model transponders and muxponders ensure that network operators will continue to enjoy the modularity, flexibility, and low-power capabilities into 400G.

The standardized 400G equipment maximizes the value of existing infrastructure, expanding third-party OTN systems at a significantly lower price point. Adopting 400G will allow operators to leverage the latest optical uplink technologies while benefiting from unprecedented levels of connectivity. The plug-and-play fiber optic modules will lower maintenance costs and total cost of ownership (TCO).

By going with off-the-shelf technologies, enterprises and DCIs can quickly, seamlessly, and cost-effectively upgrade existing, proprietary systems with standards-based technology to create a disaggregated solution. These future-proofed networks will allow them to maintain and grow their existing backbones.

The new 400G infrastructure eliminates the long-term need for significant capital investment by expanding access, metro, short-haul and long-haul fiber optic network backbone infrastructures over existing technologies to support high-capacity services with carrier-grade features and multi-rate and multi-protocol capabilities. They will extend capacities, reduce maintenance costs, and ensure minimal latency, maximum uptime, and the highest levels of security. They will fully increase network efficiency and eliminate bottlenecks. The new modules support transport over multi-degree ROADM networks as well as alien wavelengths.

Service providers as well as enterprises and DCIs will be able to use 400G to significantly expand their business opportunities. Last mile aggregation and optical Layer-1 encryption enhance business growth and service offerings, streamlining operations with high capacity, secure, and scalable fiber optic networks traversing even the longest distances. With 400G, carriers will strengthen the customer experience by delivering robust, scalable, redundant, and low-latency solutions. Adopting and offering the benefits of 400G will allow them to meet customers' ever-growing connectivity demands—profitably.