PacketLight™ NETWORKS

WHITE PAPER

400G Now, Ask Us How

Interoperability, openness, and disaggregation – opportunities and strategies for migrating to 400G DWDM and OTN networks

Introduction

In 2010, roughly 2 ZB of data was generated globally. By 2025, that number is projected to reach 181 ZB (Source: Statista). Driven by applications like the Internet of Things (IoT), video streaming, social media, cloud computing, and AI, digital traffic is skyrocketing. As a result, network operators and service providers find themselves struggling with the need to upgrade capacity while retaining the value of their existing infrastructure. Installing new fiber is time consuming and expensive. Adding new low-capacity and spectrally inefficient wavelengths over existing fiber is neither cost effective nor scalable enough to address the surge in bandwidth demand. The latest 400G technology provides the solution.

With the help of transponders, muxponders, and the optical transport network (OTN) protocol, carriers and network providers can improve fiber capacity for new 100/400Gb Ethernet services. These devices also enable them to aggregate a mix of legacy services and transmit them over 400G wavelengths. The approach boosts spectral efficiency and slashes the cost per transported bit. Perhaps just as important, 400G DWDM and OTN equipment puts the focus on interoperability, flexibility, scalability, and ease of integration.

The challenges of upgrading optical transport network capacity

Carriers, municipalities, utilities, campuses, and data-center operators are caught between conflicting requirements. Upgrading transport capacity is a business imperative, but only if it enables competitive pricing. Minimizing operating expenditures (OPEX) includes limiting power consumption and rack space (making compactness a priority). Upgrading needs to be efficient - rolling out new services as little as a month or two ahead of the competition can result in winning more customers. Finally, any solution needs to enable carriers and service providers to keep their existing infrastructure. Organizations have substantial investments in legacy services including Ethernet, Fibre Channel, OTN services, SDH/SONET, and video. An effective 400G framework needs to address all of these concerns.

Smaller footprint, lower cost per bit

In 2007, when 10G direct detection was the peak data rate per wavelength, transmitting 400G required 40-wavelength DWDM systems built in at least 5U chassis-based solutions (see Figure 1). By 2012, more sophisticated coherent DP-QPSK/QAM modulation schemes increased data rates to 100G per wavelength. Systems could reach 400G by using four 100G DWDM wavelengths, and at a better price. But the chassis was still around 4U high.

Today, a higher baud rate, combined with coherent modulation, has made it possible to send 400G over a single wavelength in a 1U footprint, with improved spectral efficiency of the fiber and reduced power consumption and cost per bit.

Figure 1: The evolution of 400G transport - from 40 wavelengths to four and now, one

Open, interoperable, and disaggregated

The technology platforms of previous generations rested on a foundation of proprietary, power-hungry, inflexible solutions that did not scale. Choosing a solution meant being locked into a single vendor and one size had to fit all. Expanding meant buying a new chassis, even if only a fraction of its capacity would initially be used.

In contrast, the development of 400G over single wavelength has been guided by a philosophy of interoperability, openness, and disaggregation.

- **Interoperability**

  Standardization and multiservice agreements (MSAs) are nothing new but with 400G, there has been a particular focus on fostering an ecosystem of interoperable components. The effort goes beyond just packaging, to encompass modulation format, signal processing, and forward error correction (FEC).

- **Openness**

  The developers of the 400G ecosystem have followed the lead of the greater software community with a focus on open-source initiatives. The Open ROADM Project, for example, has developed O-FEC, an open-source FEC code designed to promote interoperability as well as increased function in specific MSAs.

- **Disaggregation**

  In proprietary networking solutions, the optical line systems (fiber, amplifiers, etc.) were bound to the terminal equipment (switches, routers, optical modules). That put users at the mercy of their vendor's ability to innovate. Initiatives focusing on open technologies and interoperable hardware and software have opened the way to network disaggregation.

  In disaggregated networking, the chassis and monolithic solutions are gone. Instead, network architects can separate the functions of an optical transport system such as transponders, muxponders and ROADMs. They can locate each element where it makes sense, with the needed functionality and optimized capacity. Users can upgrade to the latest technology one piece at a time, and since entire ecosystems have sprung up, the level of innovation and the rate of turnover has risen dramatically. Carriers and service providers are no longer restricted in their choices - they are free to adopt whichever version of the latest transport technology best position their network for future growth.

By applying these principles throughout the development process, the fiber-optic industry has developed a user-friendly framework designed to make 400G flexible, scalable, and easy to adopt for a wide range of user needs.

Building blocks

400G Optical Modules

Interoperability starts with transceiver standardization. The proprietary optical transceivers originally used for high-speed optical communications were based on company-specific form factors, locking users into a single vendor's equipment once the link was built. These wired-in modules were large and power-hungry, with low faceplate density and high OPEX. When an optical module failed, replacement was time-consuming. These concerns prompted the shift to pluggable optical transceivers and standardized form factors.

For 400G over a single wavelength uplink, there are two form factors of note: CFP2 and QSFP-DD.

CFP2

The CFP2 form factor pluggable module has 8 x 50G electrical interfaces for 400G operation, as well as interfaces for other data rates. It has a larger package size that increases its power dissipation, enabling it to support more powerful DSPs.

QSFP-DD

The QSFP-DD form factor integrates eight transmitter and eight receiver electrical channels. It has a similar mechanical footprint to the QSFP28 in terms of panel space, but it is longer and the host board connector design has double the number of pins (DD). It is smaller than the CFP2, which increases faceplate density but also reduces its power dissipation, limiting the level of functionality that it can support.

Feature	CFP2	QSFP-DD
Size	41.5 mm x 107.5 mm x 12.4 mm	18.35 mm x 89.4 mm x 8.5 mm
Max power dissipation	30 W	22 W
Power Consumption	<24W	<16W
DSP functionality	Higher	Lower
Output power	Higher	Lower

Table 1: Specifications overview of 400G optical modules

Line interfaces

The next level of interoperability is the line interface. These standards do not specify module form factors. Instead, they call out parameters like modulation scheme, baud rate, etc. and leave the specifics of the implementation up to the suppliers.

Pluggable 400G transceivers are coherent optical modules with the digital signal processor (DSP) integrated in the module. With these digital coherent optics (DCOs), the user only pays the cost of the DSP when the port is actually in use. The result is a highly scalable solution that enables carriers and service providers to pay as they grow. The functions of DCO pluggable modules are defined by MSAs and implementation agreements, which ensure interoperability and a standard level of performance while giving suppliers freedom to customize and differentiate their products within those requirements.

Open ROADM

The industry launched the Open ROADM Project to realize standard remotely reconfigurable optical networks based on easily integrated vendor-neutral components and protocols.

The Open ROADM MSA specifies CFP2-DCO transceivers. The larger size and greater power dissipation capabilities enable modules support for OTN mapping to allow aggregating mixed services.

OpenZR+

The OpenZR+ multisource agreement defines a coherent interface targeting the regional networking space. These pluggable modules deliver 400G over a single spectral channel. Because OpenZR+ is an MSA for the line interface, it does not require a specific form factor, but CFP2 and QSFP-DD are most commonly used.

The DSPs used for OpenZR+ modules provide O-FEC for affective error correction over metro distances.

400ZR-OIF

Defined by the Optical Internetworking Forum (OIF), 400ZR-OIF is an implementation agreement for a compact, low-power coherent optical interface aimed primarily at the short-reach data-center interconnect (DCI) space. The 400ZR-OIF implementation agreement does not specify a form factor, but QSFP-DD is most commonly associated with it.

The trade-off for the high port density enabled by the QSFP-DD-DCO package is lower power dissipation capabilities and limited functionality. The link budget, dispersion compensation capabilities, and OSNR are reduced compared to the performance of transceivers for the Open ROADM and the OpenZR+ MSAs.

	Open ROADM*	OpenZR+	400ZR
Transceiver form factor	CFP2-DCO	Typically CFP2-DCO or QSFPDD-DCO	Typically QSFPDD-DCO
Modulation format	16QAM	16QAM	DP-16QAM
DSP functionality	Higher	Higher	Lower
FEC	O-FEC	O-FEC	Concatenated FEC (CFEC)
Integrated amplifier	Yes	Yes	Optional
Reach	1200 km	1200 km with CFP2 400 km with QSFP-DD	80 km; 120 km with integrated amplifier
Encryption	Optional	No	No
In-band management	Optional	No	No
OTN compatibility	Yes	No	No
Best used for		Metro point-to-point networks (QSFPDD-DCO) Multi-span point-to-point, rings/mesh topographies (CFP2-DCO)	Data center interconnect (DCI)

Table 2: Comparison of capabilities for 400G MSAs/implementation agreements

400G at the optical transport network level

Migration to 400G requires carriers and service providers to map their existing services to the 400G wavelength. Carriers, municipalities, utilities, campuses, and enterprises currently maintain a variety of services, including Ethernet (10/25/100/400GbE), Fibre Channel (16/32G), and OTU2/2e/4 services. Running those legacy services over 400G is made possible using the following equipment:

- **Transponders** to map client input over to the 400G wavelength
- **Muxponders** to aggregate client interfaces into a single-wavelength 400G channel via OTN
- **ROADMs** to perform fast and flexible wavelength routing, power balancing between channels, and spectral bandwidth allocation

OTN is standard-based optical transport layer. It enables network operators to retain legacy client interfaces and protocols by mapping them over the OTN layer (see Figure 2). The OTN FEC increases transmission distances, reducing the need for expensive and bulky regenerators. Perhaps the single biggest benefit is that the network operator does not need to worry about the individual client protocols. They just manage the common transport layer through a management channel integrated into the gear.

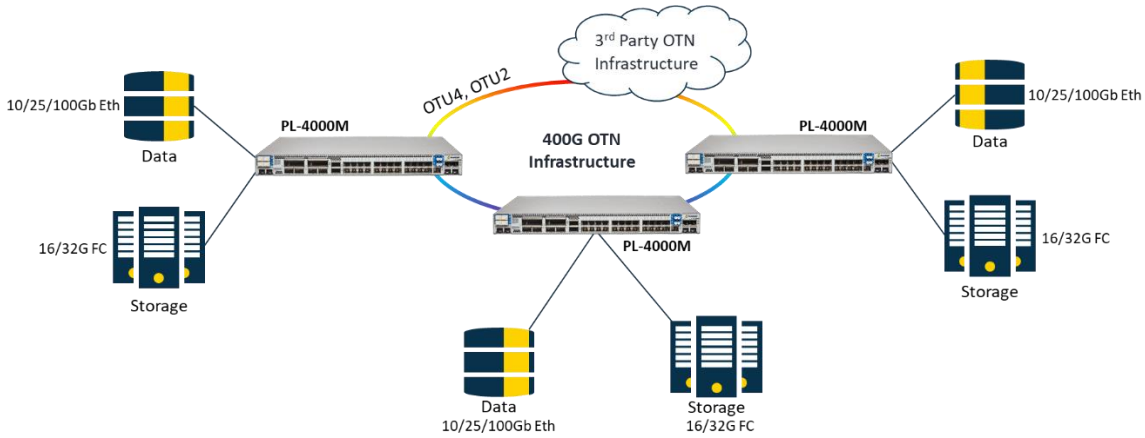

Figure 2: OTN muxponder aggregating legacy services into optical transport units.

Using single-wavelength 400G to build capacity

The interoperability, flexibility, and ease-of-use of today's 400G DWDM and OTN equipment let them be tailored to many different applications solve a variety of problems address of a variety of challenges. Here, we present a few examples.

Sample application #1: Simple upgrade to beat the competition

The challenge:

A carrier needs to upgrade network capacity to roll out new services such as encryption while continuing to leverage its legacy infrastructure. The company currently offers a mix of protocols including Ethernet, Fibre Channel, voice, and video. They require a simple upgrade path to beat the competition to market and a flexible, scalable architecture to quickly address changes in bandwidth demand.

The solution:

The alien wavelength approach allows carriers to either repurpose an existing wavelength or take advantage of a leased wavelength on a third-party network. PacketLight's PL-4000M 400G muxponder aggregates multiple services and transmits them over a single 400G wavelength with or without encryption (see Figure 3). Services include 10/100/400Gb Ethernet, 16/32G Fibre Channel, and OTU2/2e/4; the PL-4000M also features four QSFP28 ports for 100G and 24 SFP+/SFP28 ports for the remaining clients. For the uplink, it uses dual 400G CFP2-DCO pluggable optics.

The PL-4000M includes management software for end-to-end provisioning, and integrates a mux/demux, EDFAs, and an optical switch in a 1U device. The muxponder provides a full demarcation point between the service and the OTN/DWDM uplink, delivering full visibility and performance monitoring of both line OTN and the service interfaces. Users can also take advantage of built-in encryption capabilities.

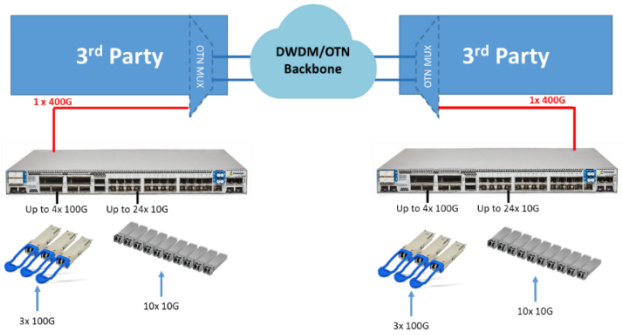

Figure 3: PL-4000M 400G muxponder for alien-wavelength solution

Sample application #2 – Upgrade to high-capacity DCI

The challenge:

An Internet exchange provider needs to rapidly upgrade DCI transport capacity to be able to offer customers 400G links. The platform has to be flexible, easy to manage, and fast to deploy.

The solution:

PacketLight's PL-4000G 400/OIF ZR-compatible coherent transponder enables providers to easily and effectively roll out new 400GbE and 100GbE services when upgrading existing networks. The device delivers up to 4.8T in a 1U chassis, using 12 separate 400G uplinks with QSFP-DD-DCO pluggable optical modules. The result is a flexible platform that lets users effectively pay as they grow (see Figure 4).

The PL-4000G also incorporates comprehensive line and service performance monitoring, as well as remote management via an out-of-band optical supervisory channel. The device integrates a mux/demux, EDFAs, and an optical switch. With amplifier, range is 120 km.

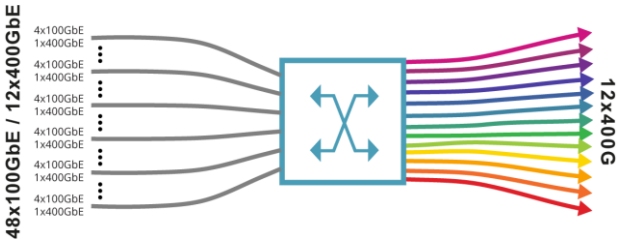

Figure 4: A diagram of the PL-4000G transponder

Sample application #3: Respond to bandwidth demands - multiservice aggregation of 400G

The challenge:

To respond to market demands ahead of the competition, a service provider needs to easily roll out multi-rate mixed services. They require a flexible solution in a compact form factor that makes the most of their data center space and minimizes OPEX.

The solution:

PacketLight's PL-4000M 400G muxponder is designed to aggregate mixed services and transmit them over dual 400G CFP2-DCO uplinks. It is a modular and cost-effective solution for adding multi-rate Ethernet and Fibre Channel, and OTU2/2e/4 services. The 1U chassis ensures cost-savings and standards-based pluggable coherent modules guarantee interoperability.

Streamlining migration

Successfully migrating to 400G requires more than just building blocks. Here are some tips on the best way to go from strategy to execution:

- **Define your goals:** What is your bandwidth roadmap? You have to know where you are going before you can determine the best route.
- **Establish your budget**: Consider the short- and long-term project budget and the time horizon for deployment.
- **Determine your starting point:** What mixture of legacy services do you need to support? Do you have an existing network or are you starting with a greenfield installation? If it is a brownfield installation, what is your network architecture/topology? What is your fiber attenuation and what are your link lengths? If it is a greenfield installation, you still have considerations when building your network. In both instances, include key parameters such as space constraints and power budgets.
- **Take advantage of the technology**: Focus on disaggregated architectures and leverage interoperability. Focus on boxes that combine functions, such as integrated management and encryption. Look for ROADMs with integrated capabilities.
- **Start small and plan to scale**: With the modern framework and ecosystem, there's no reason to get trapped in a proprietary system. Take full advantage of interoperability, openness, and disaggregation. Use DCO pluggables to pay as you grow.
- **Don't forget the human factor:** Consider your level of in-house expertise. 400G technologies are designed for simplified integration, but you may still benefit from the assistance of an integrator or at least a vendor partner.

Conclusion

With the rapid growth of data-intensive applications and technologies, carriers and service providers face unprecedented bandwidth demand. The 400G framework has been designed to address their needs through a focus on interoperability, openness, and disaggregation. The 400G supplier ecosystem is expanding rapidly. The result is increased availability of components, reducing cost and making it easy for carriers to address the changing needs of the market. PacketLight plays an active role in this vibrant ecosystem. With our broad portfolio of compact, economical solutions, carriers can outpace the competition with faster data rates and new services, while maximizing their investment in legacy infrastructure.

Further reading

Products for 400G over single wavelength

400G Muxponder - High capacity transport platform for delivering 400G over a single wavelength for coherent metro, long haul, short hall and DCI applications. Click here for more information.

4 x 400G Transponder / Muxponder - High capacity transport platform for DCI, metro and long haul applications, delivering up to 4 x 400G wavelengths. Click here here for more information.

4.8T Transponder - Integrated transport platform for delivering 100GbE and 400GbE over 12x400G wavelengths, for high capacity DCI applications. Click here for more information.

Technology information

400G over Single DWDM Wavelength – go to the webpage

Why 400G and why now – go to the article

Upgrade Your Fiber Optic Network to 400G - Go to the article

The Road to an Interoperable 400G Future - Go to the article

Find out how PacketLight's 400G product portfolio can help you upgrade your network capacity and roll out new services. Contact info@packetlight.com

About PacketLight

Established in 2000, PacketLight Networks™ offers a suite of leading 1U metro and long haul CWDM/DWDM and OTN solutions, as well as Layer-1 optical encryption for transport of data, storage, voice and video applications over dark fibre and WDM networks. PacketLight provides the entire optical layer transport solution within a highly integrated compact platform, designed for maximum flexibility, easy maintenance and operation, with real pay-as-you-grow architecture, while maintaining a high level of reliability and low cost. PacketLight works with an international network of resellers and partners to provide you with a complete set of network services, with installations worldwide.