High-Speed Optics: Fortify Your Data Center Connectivity

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OVERVIEW

As you may be aware, the data center industry is continuing its rapid change. The fiber optic links that connect your switches, servers and storage—while physically small pieces of your infrastructure—are increasingly significant and important elements of your network.

As the push to higher speed network technologies charges ahead, many data center operators have questions about how to optimize their environment. You may want to know what's happening around 25G and 100G. When will it become mainstream? You've probably heard about active optical cables (AOCs). But you want to know more—why use them and where are they appropriate? You might also have questions about multimode versus single mode optics, or how much fiber to install. Should you install enough to future-proof against multichannel interfaces or is duplex fiber sufficient? Which transceivers support which cable solutions?

This whitepaper contains expert perspectives on today's data center transceiver market. It brings new clarity to this fast-paced area of change. You'll gain the information needed to make better technology decisions that affect your network architecture, topology, energy savings and ongoing costs.

HYPERSCALE VS. MAINSTREAM DATA CENTERS

Hyperscale data centers serving both consumers and cloud services applications have seen remarkable growth over the past several years, and are projected to continue growing rapidly in the near future. Much attention has been focused on serving the needs of these hyperscale deployments, from improving cooling efficiency and increasing bandwidth to reducing latency. Optical interconnects are no exception. Many suppliers are entirely focused on developing optical transceivers for hyperscale operations. This often includes links that are in excess of 500 meters. These football-field sized properties require a unique set of technologies to provide the level of interconnection they demand.

While most data centers are not built to the same magnitude as hyperscale sites, they often can take advantage of the new technical solutions developed to support these facilities.

HYPERSCALE DATA CENTER TRENDS

The needs of hyperscale data centers are driving shifts in optical technology. A common theme has been the shift in data center architectures to accommodate the needs of highly-virtualized or scaled-out application environments. These are spread across a much more homogeneous infrastructure than was traditionally used in enterprise implementations. Generally, this has led to broad changes in network architectures. The industry is moving toward much more scalable, interconnected topologies that provide more capacity, flexibility and performance for virtualized workloads and multi-tenant environments. This is often simplified as a transition from a traditional three-tier enterprise network to a much more flat, scalable two-tiered, leaf-spine network.

As a result of these changing network topologies, there is more emphasis on the physical layout of the structured cabling system and optical transceiver selection. Signal attenuation, optical link budgets and latency on network performance are now important considerations. Additionally, making the right transceiver choice is essential to ensuring high-quality operation across all of these interconnects.
HIGH-SPEED OPTICS: FORTIFY YOUR DATA CENTER CONNECTIVITY

Optical transceivers are a key part of the overall optical link. They provide a connection between the networking equipment and the cabling infrastructure. Over time, transceivers have evolved from board-mounted, fixed devices to today’s hot swappable, pluggable modules. A vendor-supported multi-source agreement (MSA) assures physical and electrical interoperability between all transceiver manufacturers. This makes the design of lower cost and more flexible switches and server chassis possible. These trends support the more modular approach required by today’s data center operator.

Inside this pluggable optical transceiver module, there are several key components. The transmitter, or transmitter optical subassembly (TOSA), is a laser that turns on and off very rapidly. It provides the NRZ data rate required for the network. There is a receiver, or receiver optical subassembly (ROSA), a photodetector that detects the light on the other end. The total optical signal is then converted to an electrical output via integrated circuits (ICs) in the optical transceiver. These are intelligent devices controlled by powerful microcontrollers.

Optical transceivers have been developed in many different physical sizes, often offering different capabilities and port densities. In the last several years, the industry has adopted two primary configurations: SFP+ and QSFP. These configurations support the majority of data center connectivity requirements.

HIGHER AND HIGHER BANDWIDTH

New network topologies are driving an increase in network bandwidth. This is true both in the point-to-point connections between switches and the overall network capacity inside a data center.

The highest performing network data centers today have deployed multiple 10G links from servers to top-of-rack (ToR) switches for several years, driving core network bandwidth from what used to be 1G to multiples of 10G and now to 40G. This is one of the most significant growth areas in the optical transceiver market.

In mid-2016 we started to see the first large-scale deployments of 100G Ethernet into hyperscale data centers. 100G technology isn’t necessarily new. It has been deployed for years in core telecom transport applications. But the introduction of 100G Ethernet into the data center is just the beginning. This will start as server-to-ToR switch connections are upgraded from 10G to 25G, requiring switch-to-switch connections being upgraded from 40G to 100G. In turn, this will lead to deployment of 100G into the core. Within four years, we’ll see another leap forward to 50G base rate that will lead to even higher 200G bandwidth in the core.

ANATOMY OF AN OPTICAL TRANSCEIVER

Core Network Bandwidth Growth
**SFP+**

A small form-factor pluggable (SFP+) is a single-channel transceiver, historically capable of supporting 1G up to 10G Ethernet or 4G to 16G Fiber-Channel. SFPs require two optical fibers, one for transmit and one for receive to complete the optical link. It is connected to this pair of fibers through an industry standard LC connector.

**QUAD SFP+**

The second most common optical transceiver is quad SFP+ (QSFP), which provides four channels of 10G or higher traffic. It has grown in popularity as a high-bandwidth 40G parallel interface, but it can also provide four high-density 10G lanes of traffic. The QSFP transceiver requires an MPO-style connector and uses a small diameter 8 or 12 fiber optical cable. This versatility has led to the industry adopting this form factor and millions of units being shipped for use.

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**100G FORM FACTORS**

The next generation of transceivers is the SFP28, increasing the native data rate per lane from 10G to 25G per pair of optical fibers. The QSFP28 form factor carries four lanes of 25G instead of four lanes of 10G, thus providing an aggregate 100G parallel channel. Both of these transceivers are MSA compliant and utilize the same optical connectivity as their 10G and 40G counterparts, making them drop-in compatible with the existing optical cabling infrastructure.

In addition to these standard optical transceiver solutions, there are two other classes of devices to consider: multi-wavelength devices and active optical cables.

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*Figure: SFP+ and QUAD SFP+ transceivers.*

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*Figure: SFP28 transceiver.*
MULTI-WAVELENGTH DEVICES

Multi-wavelength transceivers economize on the number of optical fibers required in a circuit by using a technique called wavelength division multiplexing (WDM). WDM allows for multiple optical channels to be transmitted on a single optical fiber.

A new product entering the market is called shortwave wavelength division multiplexing (SWDM) transceiver. SWDM is a standards-based technology that combines four different optical channels or lanes and transmits those signals over a single pair of multimode optical fibers. The approach can support 4-10G, 25G or 50G channels or lanes providing for combined data speeds of 40, 100 and 200G per pair of fibers. SWDM uses less power than other multi-wavelength solutions. It is easier to monitor and supports full digital diagnostic functions over OM4 and new OM5 optical fibers. 40G and 100G products are now in production.

ACTIVE OPTICAL CABLES (AOC)

The second device class is Active Optical Cables, or AOCs. These are growing in popularity in mainstream data center applications. Active optical cables got their start in the high-performance computing world, migrated to the hyperscale data center market, and are now finding applications in the enterprise data center environment. Think of an AOC as two optical transceivers combined with an integrated fiber cable.

Like a copper DAC cable, an AOC is a simple, plug-and-play solution. But unlike modular transceivers and cabling plant, there’s no optical interface and no connectors to clean. The cable is pre-engineered to deliver the required electrical data rate. There’s no need to worry about power budgets or optical link performance since the AOC provides the proper optical path and electrical signaling. AOCs are a very robust solution, particularly in data center environments where cabling is routed through hot, dusty, tight spaces.

There are two main reasons to use AOCs. The first is to improve signal integrity, provide more reliable performance, and lower latency. AOCs are also lower in power consumption which is a big reason to replace DACs with AOCs. AOCs are significantly smaller and lighter weight than a copper cable. They are easier to handle while providing better cable management and better airflow and a net savings in total cost of ownership.

The second reason to use AOCs is to replace transceivers in links of up to 30 meters. They are usually installed from top of rack to the end of the aisle or rack-to-rack between dense switch clusters. Many data center operators prefer the simplicity and cost savings of these line-of-sight, point-to-point links versus traditional transceivers.

It’s important to note that AOCs can’t be integrated into your structural cabling. They need to be routed separately. You must account for the fact that both ends are fixed. Therefore, they are typically relegated to within an aisle up to 30 meters.
IS SINGLE MODE BETTER? NOT NECESSARILY.

With the rise of hyperscale data centers, the longer links between aggregation and core layers, and higher data rates, data center managers are focusing a lot more attention on single mode fiber solutions.

Multimode fiber has been the primary media used in data centers for many years. When one considers the total optical link cost model, multimode provides significant cost advantages for shorter reaches and lower speeds over single mode solutions. At 10G data rates, multimode OM3 and OM4 fibers can support link length up to 300 and 400 meters respectively. As data rates increase to 40G and higher, the supported link lengths decrease to between 100 and 150 meters, depending on fiber type. These lengths are still well within the average link length required by most enterprise-class data center environments.

Once link lengths in the data center extend past 150 meters and data speeds increase, single mode is usually the right choice. Single mode fiber has been the stalwart media solution for long-haul, high-speed telecom networks for the past 30 years. Single mode fiber has less attenuation and supports much higher data rates than multimode fiber over very long distances. However, it requires more expensive optical transceiver technology. Even though the fiber is less expensive, the technology to launch light into single mode fiber is much more expensive than multimode. The result is an overall higher optical link cost.

Many data center operators ask if they should move to single mode fiber to future-proof their networks for 50G, 100G and beyond. The answer is—not necessarily. It’s a combination of link length and data speed that drives the decision. Further, multimode fiber continues to improve and the industry is significantly investing in its future. In 2016, the industry ratified OM5, or wideband multimode fiber. While not increasing the overall link length, this provides a path to support 25 and 50G, 100 and 200G transmission with SWDM transceiver technology.
WHERE TO USE AOCS, MULTIMODE AND SINGLE MODE

AOCs are most useful within the rack, in a server to TOR configuration or rack-to-rack from the TOR switch to the aggregation level of switching and beyond. They are particularly suited to higher density environments due to their light weight and ease of management.

Many data center operators ask about the cost of multimode versus single mode and duplex versus parallel. The answer depends on your situation. The vast majority of fiber links in a data center are less than 100 meters. That means multimode suffices for most environments. Consider the total optical link requirements: number of fibers, patch panels and density, as well as the transceivers and your future upgrade plans. The results can be surprising. Typically, multimode is the lowest cost solution up to 150 meters.

Multimode is still the most common fiber deployed. More than 75% is either OM3 or OM4 and has many competitive advantages, including:

- Lower total cost than single mode fiber when the complete optical link is considered
- Easiest to deploy and manage as connectors are robust and easy to clean
- Provides the lowest power consumption

Use single mode when you have to. This is generally when your maximum link length exceeds multimode capabilities (usually 100 to 300 meters, depending on data rate). In both cases, use SFP+ for single channel, 10G and beyond; QSFP+ for quad channel, 40G, 100G and beyond. Lastly, single mode is also used to support inter-building networks. There are many types of transceivers that provide high speed circuits for long distance segments such as: 2km, 5km and 10km.

TO 25G AND BEYOND

The bulk of today's server interfaces are still 1G and 10G, though 10G has overtaken 1G in the total number of transceiver ports shipped and 40G is growing rapidly. There is currently a shift toward 25G for Ethernet servers. 25G transceivers are available today in multimode and single mode modular formats and AOCS. The industry won't stop at 25G. You'll see single-channel 50G interfaces, and eventually, single-channel 100G interfaces. There's a lot of focus on quad channel for hyperscale today, but this form factor will be used extensively for the enterprise market going forward.

Meanwhile, the next step in higher speed optics, quad channel QSFP28 modules and AOCS for 100G, are beginning to ship. You'll see both multimode and single mode in production deployments in early 2017.

Single-channel and four-channel pluggable transceivers will continue to make up the majority of the market. Single channel won't go away. For the majority of data center customers, this will be the preferred form factor.
THE FUTURE OF ETHERNET DATA RATES

With all the questions that can arise in data center design, one constant is that Ethernet data speeds will continue to increase. An industry consortium called the Ethernet Alliance publishes a roadmap of Ethernet speed targets, standards and timelines for standardization looking out 10 or more years. On deck are 200, 400 and 800G/second transmission speeds.

The good news is that the industry has standardized on the single channel/quad channel paradigm with base rate SFP single lane solutions of 10, 25 and 50G. This provides upgrade QSFP multilane solutions for 40/100/200G. By standardizing on the single lane/quad lane architecture, data center designers can be assured that their cabling infrastructure will seamlessly migrate as technology advances.

MULTIMODE CONTINUES TO THRIVE

The death of multimode has been vastly overstated. A healthy future is assured. The industry is continuing to invest heavily in the development of new multimode technology to meet the needs of next-generation data centers.

Here are four pillars of multimode technology:

1. New transceiver technology allows you to reuse your existing multimode fiber plant from 1G, 10G up to 25G on OM3 and OM4.

2. SWDM technology allows four channel interfaces, 40G and 100G, to be transmitted on duplex LC multimode without the drawbacks of bidi.

3. New laser technology for multimode extends beyond 25G to 50G per lane and beyond.

4. A new multimode fiber type (OM5) is emerging that will leverage SWDM technology and allow increased speed, increased channel count and extended reach for multichannel devices. This will be important for 200G and 400G in the future.
WHAT WE’VE LEARNED

• There isn’t one data center market—there are many. There’s a broad array of optical interface choices for every type of deployment. Whether you’re in many small data centers or hyperscale properties, optical transceiver choices exist to match your needs.

• Most data centers are not hyperscale but can utilize many of the same technologies being created to support the hyperscale market.

• Multimode continues to be the fiber of choice. There’s no reason to believe it will go away, especially for the majority of data center operators who have properties of less than 250,000 square feet.

• The single channel and four channel paradigm of pluggable optical transceivers will continue and be the best choice for most data center operators.

• AOCs are a good choice for intra-rack and inter-rack connectivity, particularly less than 30 meters.

• 25G Ethernet and the related 100G Ethernet transceivers are just entering the market. You’ll see a significant ramp-up in volumes in 2017.

• Watch for SWDM4 transceivers for 40G and 100G over duplex multimode, and pay attention to the SWDM alliance.

Our optics experts are ready to help you future-proof your data center. Contact them today at highspeedoptics@wesco.com.