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The Rise of 400G, 800G, and 1.6T Links in the Data Center

The first measure of an organization's success is its ability to adapt to changes. Call it survivability. Organizations that can't make the leap to the new status quo risk customers leaving them behind. For cloud-scale data centers, the ability to adapt and survive is tested every year as increasing demands for bandwidth, capacity, and lower latency fuel migration to faster multigigabit (G) network speeds. During the past several years, network fabric link speeds throughout the data center have increased from 25G/100G to 100G/400G. Every leap to a higher speed is followed by a brief plateau before data center managers need to prepare for the next jump.

Currently, cloud and hyperscale data centers are deploying links with 800G transceivers, while the industry seeks to standardize both 800G and 1.6T transceivers. A key consideration is which optical technology is best. Let's break down some of the considerations, tradeoffs and options of 400G, 800G and 1.6T optical transceivers.

Optical transceiver types

Optical transceivers can be grouped by their supported reach and fiber type. SR optics typically support 100-meter (m) reaches over parallel multimode fiber. DR optics use parallel singlemode fiber up to either 500 m or 2 km in length. FR and LR optics use duplex singlemode fiber and wavelength division multiplexing (WDM) up to 2 km and 10 km, respectively. These optical transceiver types are consistently used for 400G, 800G, and 1.6T as described below.

400G optical transceivers

The optical market for 400G is driven by cost and performance, and transceivers using 4x100G lanes are replacing the earlier iterations that used 8x50G lanes. 4x100G switches and transceivers offer lower cost and power consumption than 8x50G transceivers.

There are several options for optics using parallel fiber at 400G. The IEEE 802.3db standard codified 400G transceivers using parallel multimode fiber. Optics compliant to 400G-SR4 will support 100 m over eight fibers on OM4 or OM5 multimode. A new application, called 400G-VR4, will support a 50 m reach of eight OM4 or OM5 fibers for in-row applications. For parallel singlemode fiber, 400G-DR4 and 400G-DR4-2 will use eight fibers up to 500 m or 2 km, respectively.

Each parallel fiber option in Table 1 uses eight fibers, but because the transceivers accept either an MPO8 or MPO12 connector, only the outer eight fibers are used. This follows a multigenerational trend in which the middle four fibers in a 12-fiber cable are not used—prompting cable companies like CommScope to introduce a line of eight fiber cables that only include the eight fibers used for transmission. When terminated with MPO8 connectors, the eight-fiber cables can be intermated with MPO12 cables and are compatible with all 400G parallel optics.

400G parallel optics

Application	Reach	Fiber #	Fiber type
400G-SR4	100 m	8	OM4, OM5
400G-VR4	50 m	8	OM4, OM5
400G-DR4	500 m	8	SMF
400G-DR4-2	2 km	8	SMF

Table 1

As shown in Table 2, 400G-FR4 and 400G-LR4 were standardized in IEEE 802.3cu and use WDM on duplex fiber. These optics combine four wavelengths on a single transmit-and-receive fiber. The FR optics support a 2-km reach and offer an upgrade path from 100G-CWDM4. The LR optics reach up to 6 km if compliant only to 802.3cu (400G-LR4-6) and 10 km if compliant to the 400G-LR4-10 MSA specifications.

400G WDM optics

Application	Reach	Fiber #	Fiber type
400G-FR4	2 km	2	SMF
400G-LR4	10 km	2	SMF

Table 2

Beginning with the 400G generation, the demand for optics with parallel fiber has grown faster than those using WDM. Optics for parallel fiber tend to offer lower cost and power consumption than WDM optics. Parallel fiber also offers data center operators more flexibility by enabling fiber breakouts. The technology also allows a 400G transceiver with eight fibers on one end to connect to four different 100G transceivers using duplex fiber. Parallel fiber optics are being used for longer links, but WDM optics are not being used for shorter links.

800G optical transceivers

The first generation of 800G transceivers will use 8x100G lanes and parallel fiber. These transceivers will build on 400G transceiver technology and will be included in the IEEE 802.3df standard, which is scheduled to be published in 2024. The IEEE 802.3dj standard project, which is scheduled to be published in 2026, will address optics running on 4x200G lanes.

Table 3 lists parallel fiber optic applications, including 800G-VR8, 800G- SR8, 800G-DR8 and 800G-DR8-2. These applications are designed to support 50 m over OM4 or OM5, 100 m over OM4 or OM5, 500 m over singlemode fiber, and 2 km over singlemode, respectively. Each of these optics will require eight fiber pairs (16 fibers total) for 800G transmission. The connector interface will consist of MPO16 or two MPO8 connectors. The earliest adopters of 800G transceivers will use them as 2x400G, with each 800G transceiver behaving as two distinct 400G transceivers. It makes sense in these cases to have two MPO8 connectors at the interface to support this distinction. In the future, native 800G transceivers will be more dominant and use the MPO16 connector. Nearly all transceiver manufacturers will offer both MPO16 and 2xMPO8 800G transceivers.

800G parallel optics

Application	Reach	Fiber #	Fiber type
800G-VR8	50 m	16	OM4/OM5
800G-SR8	100 m	16	OM4/OM5
800G-DR8	500 m	16	SMF
800G-DR4	500 m	8	SMF
800G-DR8-2	2 km	16	SMF
800G-DR4-2	2 km	8	SMF

Table 3

The Terabit BiDi MSA released a specification for 800G transceivers using eight multimode fibers (see Table 4). These transceivers (800G-VR4.2 and 800G-SR4.2) will support either 50 m or 70 m over OM4, and will support 70 m and 100 m with OM5. These optics operate bidirectionally, with each fiber transmitting and receiving simultaneously. VCSELs of different wavelengths are used to generate separable transmit and receive signals. OM5 is the only multimode fiber specified to support multiwavelength operation, which is why it offers longer reach. BiDi enables 800G transceivers with 100G lanes to operate using only eight fibers.

800G BiDi optics

Application	Reach	Fiber #	Fiber type
800G-VR4.2	50 m/70 m	8	OM4/OM5
800G-SR4.2	70 m/100 m	8	OM4/OM5

Table 4

Among the duplex singlemode options, there are also 800G optics that are really 2x400G-FR4. These transceivers require four fibers at the connector interface and typically use two duplex LC connectors belly-to-belly. These transceivers are also good candidates for very small form factor (VSFF) connectors like SN or MDC.

Once IEEE 802.3dj standardizes 200G lanes, then singlemode transceivers—including 800G-DR4, 800G-DR4-2, 800G-FR4 and 800G-LR4—will be specified. Like their 400G counterparts, the DR optics will use eight fibers up to 500 m or 2 km; the FR will use duplex fiber up to 2 km; and LR will use duplex fiber up to 10 km (see Table 5). These optics will be a drop-in replacement for 400G and use the same cable plant as 400G.

800G WDM optics

Application	Reach	Fiber #	Fiber type
800G-FR4	2 km	2	SMF
800G-LR4	10 km	2	SMF

Table 5

To date, IEEE 802.3 has not set objectives for 200G VCSELs and multimode fiber. This is not surprising and is consistent with previous generations. For each new speed, singlemode transceivers are specified first as it is easier to achieve high-speed signaling with these more complicated transceivers. Multimode optics are lower cost and lower power, and their standards typically take more time to develop. Industry experts are confident that 200G VCSELs will be standardized in a future project.

1.6T optical transceivers

Beyond 800G, the next-generation transceiver will use the letter "T" for terabit per second. Doubling the data rate from 800G leads to 1600G (or 1.6T). The Terabit BiDi MSA has already specified 1.6T transceivers that use multiwavelength VCSELs and multimode fiber. As shown in Table 6, 1.6T-VR8.2 will support 50 m over OM4 and 70 m over OM5. For longer reaches, 1.6T-SR8.2 will support 70 m over OM4 and 100 m over OM5. Both these transceiver types will use 100G lanes and 16 bidirectional fibers. The MSA calls out MPO16 connector interfaces as the preferred connector for these applications.

1.6T BiDi optics

Application	Reach	Fiber #	Fiber type
1.6T-VR8.2	50 m/70 m	16	OM4/OM5
1.6T-SR8.2	70 m/100 m	16	OM4/OM5

Table 6

Early singlemode 1.6T optics will be 1.6T-DR8 and 1.6T-DR8-2. Both will use 16 parallel singlemode fibers (or eight fiber pairs) and support 500 m and 2 km reaches, respectively (see Table 7). These optics will use the same 200G lanes developed for 800G but will increase the lane count to eight. Like 800G-DR8, these 1.6T transceivers will likely be available with MPO16 and 2xMPO8 connector interfaces.

1.6T parallel optics

Application	Reach	Fiber #	Fiber type
1.6T-DR8	500 m	16	SMF
1.6T-DR8-2	2 km	16	SMF

Table 7

Multimode vs. singlemode

For links less than 100 m, data center operators have a choice: Do they deploy singlemode or multimode optics? While some in the industry consider singlemode fiber the more future-proof option, multimode offers many advantages. Data centers that deploy the latest speed transceivers will pay twice as much for a singlemode optic than an equivalent multimode optic. Over time, the price difference will converge; multimode transceivers are only slightly less expensive than singlemode when the speed is a few generations old. One thing that will not change is the amount of power consumed. Multimode transceivers consume 1-2 watts (W) less energy than singlemode, leading to 2-4 W power savings per link.

Over time, transceiver technology will migrate to shorter and shorter reaches. As lane speeds increase, multimode fiber will likely replace copper cables for in-row applications. An obvious example is the use of multimode fiber in artificial intelligence (AI) clusters. We anticipate multimode fiber to remain a key part of data center networks for many more generations.

Conclusions

Transceiver innovation continues at a fast pace. The transceivers selected for a data center impact the fiber cable and connectors needed. CommScope is actively engaged with the transceiver ecosystem to ensure that our customers have the right connectivity for their networks. Read more about steps you can take today to ensure your fiber infrastructure is ready for this future at www.commscope.com.

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CO-118685-EN (03-24)