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# Data Center Network Interactive Handbook

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Every data center has a unique set of network priorities, from consolidation and cost control to quick deployment and zero downtime.

This guide takes an in-depth look at the data center Ethernet physical layer, covering typical cable architectures and topologies, fiber cable types, installation recommendations, and network migration strategies.

In addition to the content in this guide, Leviton has the tools and information to help you deploy, manage and upgrade your network. We have experience serving all types of customers, including telecom providers, hyperscale cloud providers, universities, and high-security government installations. You can learn more at **Leviton.com/DataCenter**.

1.

# Standards

## IEEE and Data Center Cabling Infrastructure Organizations Working Together

IEEE determines the proposed transmission method and end-to-end cabling performance required for reliability. For example, the IEEE was responsible for developing the 802.3bm standard for 40 Gb/s and 100 Gb/s over fiber optic cables.

Standards organizations such as ANSI/TIA and ISO/IEC determine the component- and link- transmission performance that is required and specifies the test methods for both. For example, ANSI/TIA is responsible for creating the standard for Cat 6A (Augmented Cat 6) cabling to support 10GBASE-T.

## Key Data Center Standards

**ANSI/BICSI 002-2019** — The Data Center Design and Implementation Best Practices standard covers all major systems in a data center. This includes electrical, mechanical, security and telecommunications and network infrastructure. The standard complements other data center standards, including TIA-942-B, ISO/IEC 11801-5, and EN 50173-5.

**ANSI/TIA 942-B** — The Telecommunications Infrastructure Standard for Data Centers specifies the minimum requirements for telecommunications infrastructure of data centers and computer rooms, including single-tenant enterprise data centers and multi-tenant Internet hosting data centers.

**ISO/IEC 11801-5** — This cabling standard for high-performance networks used by data centers specifies generic cabling within and to the computer room spaces of data center premises, or computer room spaces within other types of building.

**EN 50600-2-4** — Developed by CENELEC, this series of European standards covers data center facilities and infrastructures. EN 50600-2-4 covers telecommunication cabling infrastructure. While it defines requirements for cabling infrastructure pathways and architecture, it does not specify requirements for structured cabling types.

**EN 50173-5** — This European Standard specifies generic cabling that supports a wide range of communications services for use within a data center. It covers balanced cabling and optical fiber cabling.

For timely updates on new standards and active projects from recent committee meetings for IEEE, TIA, and ISO, read the latest **Leviton Quarterly Standards Report**.

2.

# Applications

Not every data center is the same. With many cloud or hyperscale data centers, the data center is the business. For operators of a colocation data center, the needs and requirements can vary based on the tenants. An Enterprise data center needs to be built to last while supporting network upgrades. And in service-provider data centers, supporting critical communications on a large scale is an everyday responsibility.

- Cloud / Hyperscale
- Colocation / Multitenant Data Centers
- Enterprise Data Centers
- Service Provider Data Centers

## Cloud / Hyperscale

A hyperscale data center supports cloud computing and big data operations, with the ability to rapidly scale its applications and storage. These data centers are typically recognized as the key drivers behind the majority of on-demand cloud infrastructure platforms, such as Amazon Web Services (AWS), Microsoft Azure, Facebook, and Google. These data centers may have upwards of 100,000 servers or more, and they are linked with ultra-high speed, high-fiber count networks.

Cloud applications have largely moved away from the traditional three-tier network to the flatter Leaf-spine architecture, where all switches are interconnected to everything directly through the aggregation switches. This creates a non-blocking and lower-latency network that is very scalable. Choosing ultra- high-density patching and multifiber connectors make this possible at the scale needed by the most demanding networks. Once installed, testing, network manageability, and MACs become the key considerations.

> “non-blocking and lower-latency network that is very **scalable**”

## Colocation / Multitenant Data Centers

As more organizations migrate to the cloud, many network functions are moving to colocations or multitenant data centers. In this data center agreement, customers can rely on the expertise of both the data center operators as well as infrastructure manufacturers to make sure their networks are designed with build out, implementation and maintenance in mind. Meanwhile, they can focus on their own network requirements because the data center operator has already ensured a state-of-the-art foundation.

Additional security may be necessary in multitenant data centers. Network security may mean keeping physical connections protected from unauthorized access and accidental disconnection. In addition, closed or locked patching environments help protect physical connections from being disrupted. Even placing your patching up and out of reach can prevent accidental or unauthorized access. And fiber optic Traffic Analysis Points (TAPs) provide access to the network traffic, both to ensure the right performance to monitor network traffic for abnormalities or network intrusion.

## Enterprise Data Centers

Enterprise data centers are owned and managed by a single company and are typically located on-premises with the corporate buildings or campus. These data centers need to be built to last while supporting upgrades to meet growing bandwidth and network demands. A new enterprise data center has a typical planned life of 20 years but will likely see tech refreshes or upgrades every 3-5 years, so planning for cabling with flexibility is key.

Available space will determine how dense patching areas need to be, and you might have some tough decisions to make about your existing cabling and the cabling you plan to install in the future. While enterprise data centers can certainly benefit from the space savings associated with ultra-high density, it is often not a requirement. High- or standard-density solutions provide the patching necessary and allow for easier moves, adds and changes that can occur in an on-premise enterprise data center. Allowing for greater network manageability helps reduce human error, protects against the accidental disruption of neighboring fibers and helps increase airflow to prolong the life of your active equipment

## Service Provider Data Centers

From emergency services to social media posts and carrying the nightly news, service provider networks are the foundation for everything, yet completely invisible to customers. It is imperative service providers continually maintain reliable communications with networks that span the longest distances and include some of the densest data centers around.

> "span the **longest distances** and include some of the **densest** data centers"

Scale-ups for service providers can be at the same time absolutely massive and intensely targeted. This includes physical deployment of containers to accommodate network expansion or allowing for rerouting and redundancy to protect communications through natural disasters. Fiber systems that allow for easy pod connection and disconnection will ease this process, making it repeatable and reliable.

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# Popular Data Center Architectures

The key trends shaping data center architecture choices include virtualization, higher density, cloud computing, lower latency requirements and mobile-device traffic. In addition, the continual demand for faster speeds and new applications has led to the need for greater bandwidth and flatter topologies. There are a range of popular architectures, each with their own pros and cons, depending on your requirements.

## Spine-Leaf Network Architecture

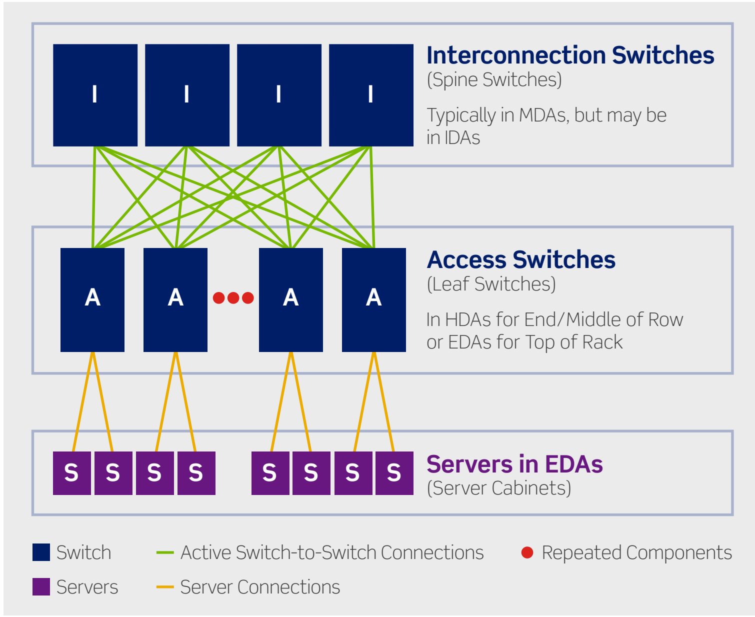
A Spine-Leaf or "fat tree" architecture features multiple connections between interconnection switches (spine switches) and access switches (leaf switches) to support high-performance computer clustering. In addition to flattening and scaling out Layer 2 networks at the edge, it also creates a nonblocking, low-latency fabric.

Compared with a traditional three-tier architecture, Spine-Leaf uses fewer aggregation switches and redundant paths between the access and interconnection switches, thus reducing latency and energy requirements. This architecture is becoming the standard for greenfield data centers. All access switches are connected to every interconnection switch, providing a redundant path. Traffic runs east-west, reducing latency between access switches. This is a very scalable fabric.

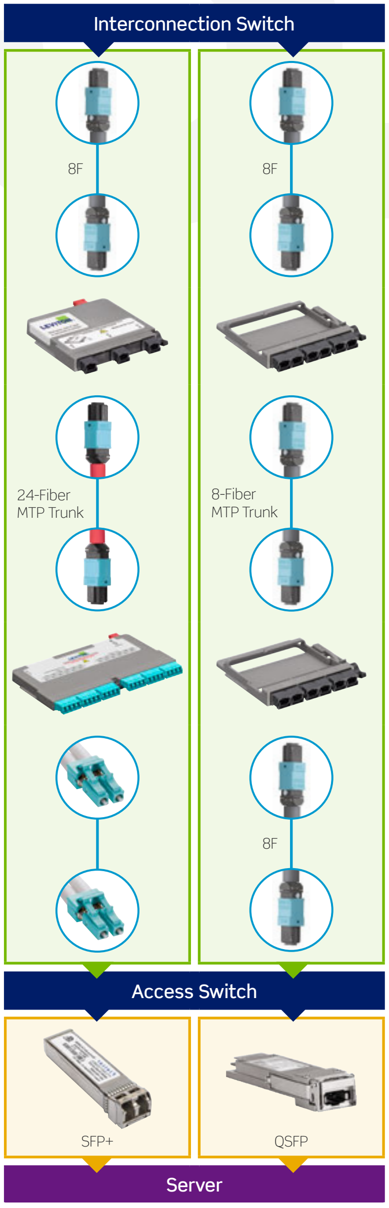
In the example to the right, the interconnection switch is connected directly to the access switch with 12- or 24-fiber MPO trunks and either a conversion module (24-fiber) or MPO adapter panel (12-fiber).

Look to Leviton for an ideal cabling infrastructure for Spine-Leaf designs. Our HDX conversion cassettes easily snap in and out of UHDX panels or enclosures, while our trunks, harnesses, and cords make it easy to migrate from 10 to 40, 100, 200 and 400 G/bs networks to speed tech refreshes, reduce labor and minimize network downtime.

### ANSI/TIA-942-B: Spine-Leaf Architecture




### Spine-Leaf Example for 40/100G



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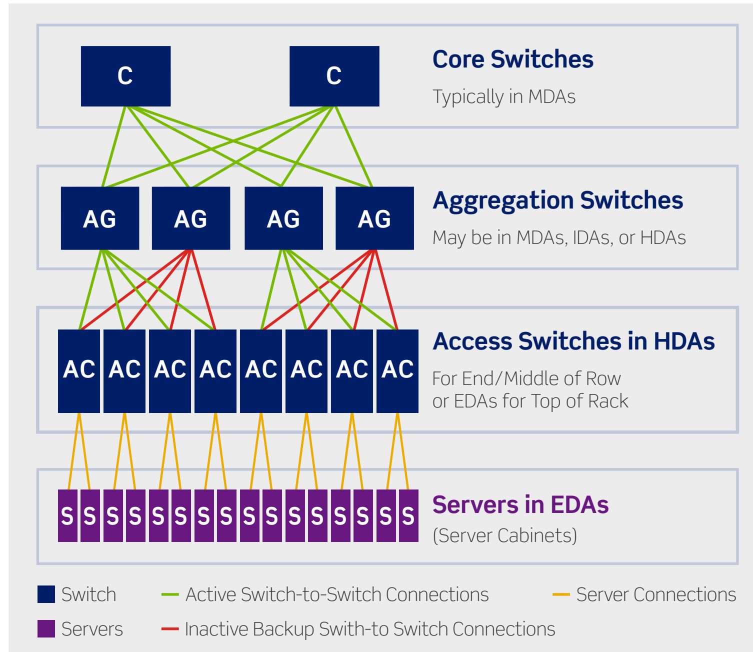
## Three-Tier Network Architecture

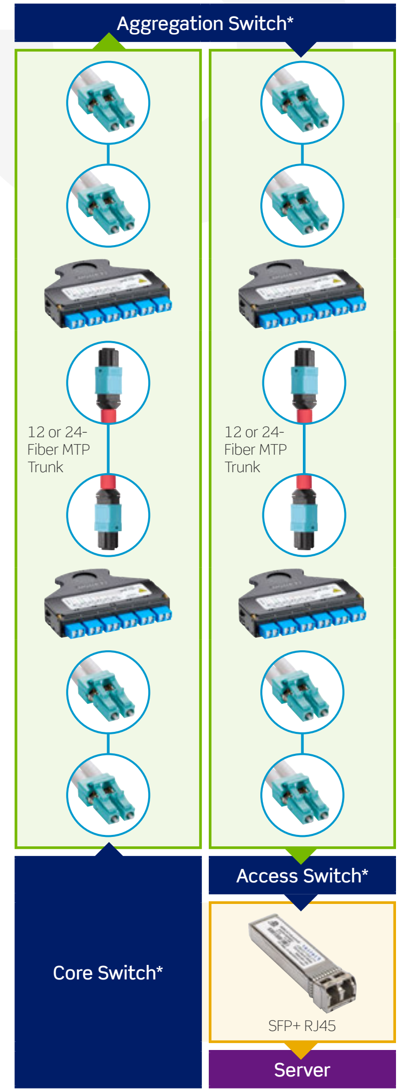
In a traditional three-tier architecture as defined in ANSI/TIA-942-B, servers are connected to core, aggregation and access switches. Three-tier architecture comes with several disadvantages, including higher latency and higher energy requirements.

MPO 12- or 24-fiber cabling is often implemented between core and aggregation switches, converting to LC cabling at the access switch before SFP+ or RJ-45 patching is connected to the server. The connectivity shown at right is typical for a 10 GbE application in a three-tier architecture.

### ANSI/TIA-942-B: Three-Tier Architecture




### Three-Tier Example for 10G




* MTP cabling to patch panels at each switch

Three tier design architectures benefit from versatile patching systems that can speed deployment and MACs, and minimize wear on your electronics. Leviton HDX, e2XHD and SDX platforms fit in a variety of applications and provide you with density options depending on your requirement. Leviton trunks use best-in-class MTP connectors, and our Premium Series LC Patch Cords feature advanced polishing and assembly techniques, with insertion loss and return loss tested to industry-leading standards.

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## Switch-Fabric Network Architectures

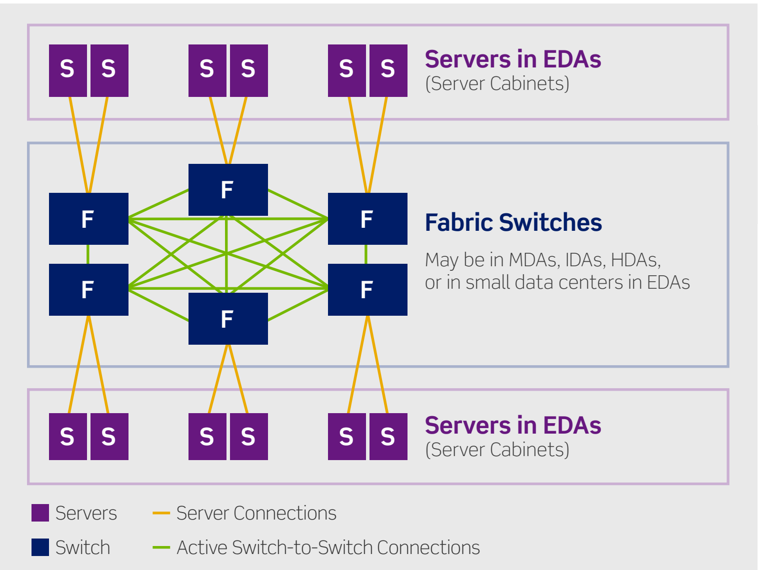
Full mesh, interconnected mesh, centralized and virtual switch are additional examples of emerging architectures included in the published ANSI/TIA-942-B standard. Like the Spine-Leaf architecture, these switch-fabric options provide lower latency and higher bandwidth, and they include nonblocking ports between any two points in a data center.

A full-mesh architecture dictates that each switch be connected to every other switch. This architecture does not scale very well because switches are not typically in an equipment distribution area (EDA) and a fabric is not used for top-of-rack (ToR) topology. A full-mesh architecture is often used in small data centers and metropolitan networks.

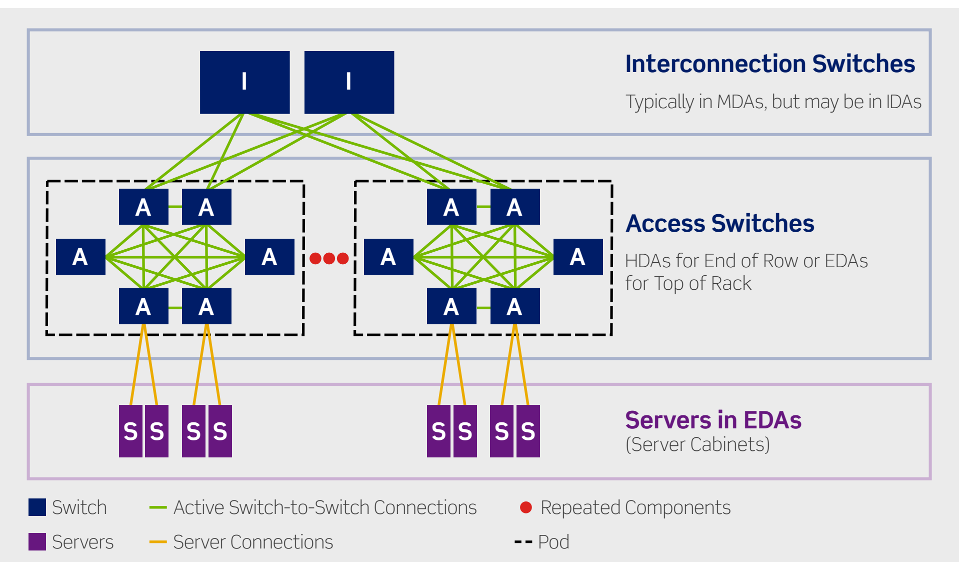
An interconnected-mesh architecture, similar to a full-mesh architecture, is highly scalable, making it less costly and easy to build as a company grows. Interconnected-mesh architecture typically maintains one to three interconnection switches (may be HDAs or EDAs), and is nonblocking in each full-mesh Point of Delivery (POD).

continued

### ANSI/TIA-942-B: Full-Mesh Architecture




### ANSI/TIA-942-B: Interconnected Mesh Architecture

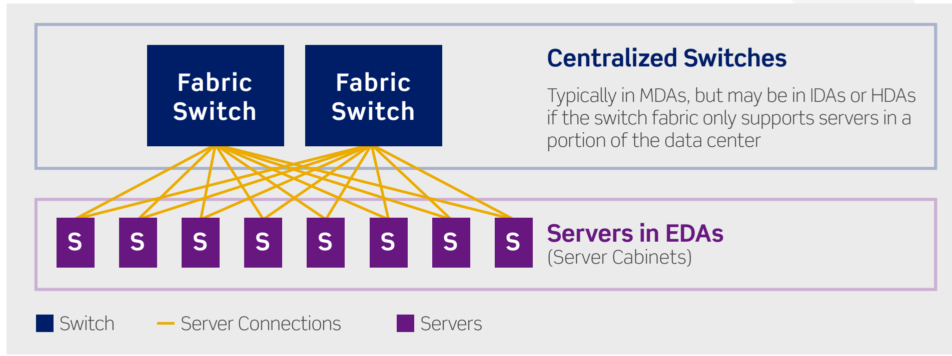


## Switch-Fabric Network Architectures Continued

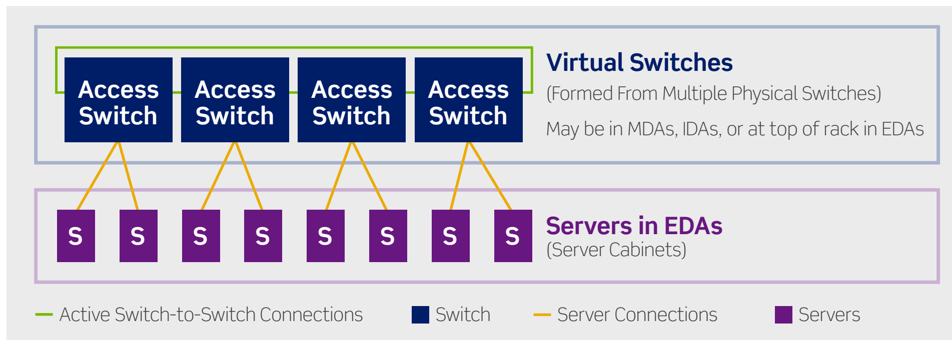
In a centralized architecture, the server is connected to all fabric switches, using simple and low-latency links. Often managed by a single server, a centralized architecture is easy for a small staff to maintain. Port limitations, however, can prohibit this type of architecture from scaling well. As such, like full-mesh architecture, centralized architecture is typically used in small data centers.

Virtual-switch architecture, though similar to centralized architecture, uses interconnected switches to form a single virtual switch. Each server is connected to multiple switches for redundancy, leading to a potentially higher latency. Unfortunately, virtual-switch architecture does not scale well unless a fat-tree or full-mesh architecture is implemented between virtual switches.

ANSI/TIA-942-B: Centralized Switch Architecture




ANSI/TIA-942-B: Virtual Switch Architecture




## Getting Help

With the emergence of newer switch architectures comes a greater demand for flexibility in design, along with the need for greater scalability. Regardless of the architecture, it is important to know how choosing an 8-, 12- or 24-fiber MPO cabling infrastructure will affect your choices in the future. The ideal goal is to install cabling design that maximizes fiber utilization throughout the infrastructure and promotes an easy migration path to support current or future IEEE 100, 200, and 400 Gb/s networks.

It is also important, when upgrading a network, to acquire assistance from experts who understand the evolution of the data center environment and fabric design architecture. Leviton works closely with many leading equipment manufacturers, is active in all next-generation standard developments, and can advise customers on their best possible migration strategy.

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# Edge Data Centers

Many large data centers and cloud providers are decentralizing computing to the "edge," allowing for real-time data collection and processing in order to reduce latency. These data centers will become increasingly important with the rise of 5G applications. Learn more about the edge computing trend and decentralized cabling infrastructure.


- Edge Computing and the Rise of Micro-Modular Data Centers
- Enter the Micro Data Center
- Physical Infrastructure

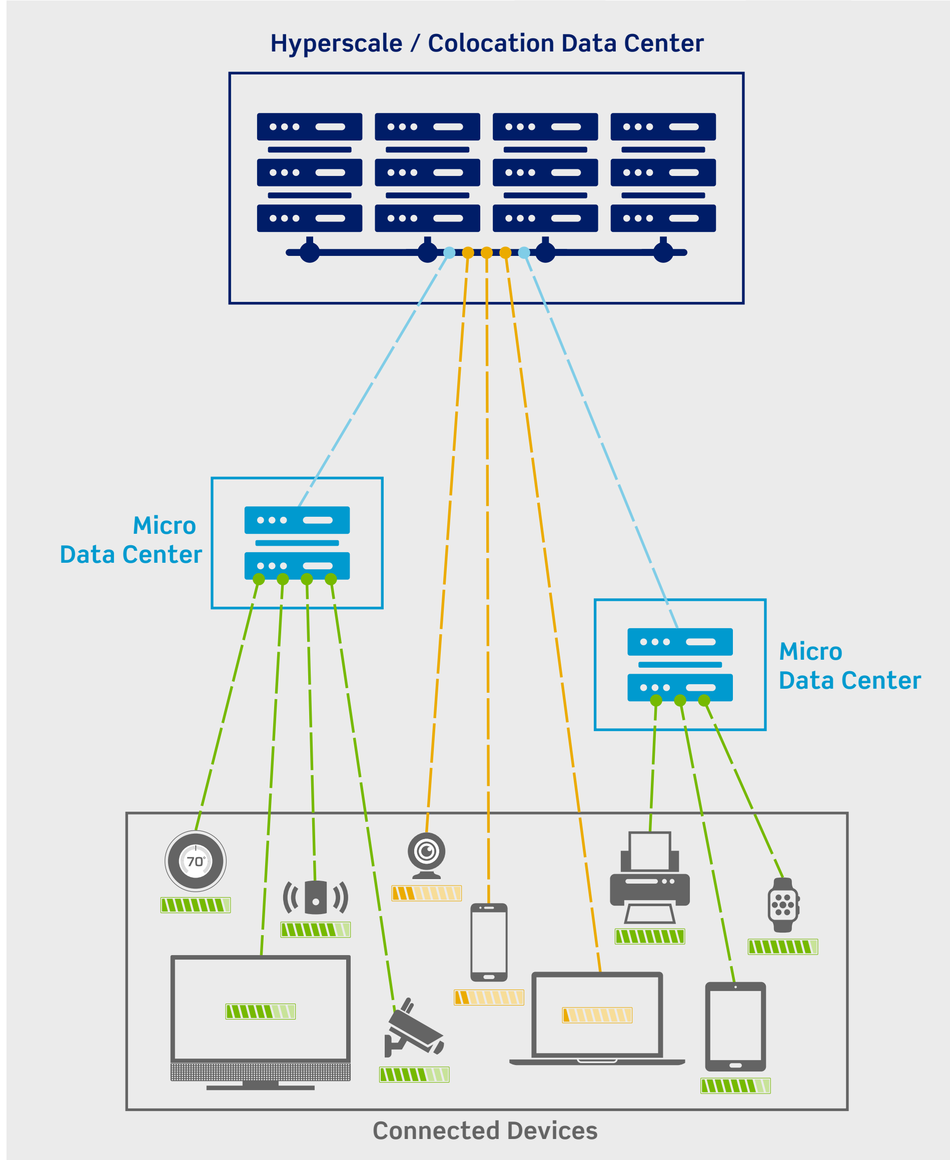
## Edge Computing and the Rise of Micro-Modular Data Centers

Over the last decade, we have seen a significant trend of data centers migrating to hyperscale and colocation services. Faced with surging bandwidth demands, along with the promise of cost savings and greater efficiencies, companies continue to move their data centers off premises to large centralized locations.

However, the internet of things (IoT) has become a major disruptor in this area. With billions of data-generating devices on the market, from vending machines to traffic sensors and fitness trackers, data from IoT needs real-time collection and processing in order to reduce latency. When data centers are far away, they can't always support users when they need real-time responses. Closer proximity between data centers and source devices have a direct impact, and for that reason many large data centers and cloud providers are decentralizing computing to the "edge."

According to the 2018 *Uptime Institute Global Data Center Survey*, more than 40 percent of respondents expect their organization will require edge computing capabilities. The respondents gave a range of answers when it came to how they would meet demand for edge computing capacity, with some using private data centers, some using colocation services, some relying on public cloud services like AWS and Microsoft Azure. Regardless of who does the deploying, much of the edge computing today is delivered in the form of micro-modular data centers.

From the Centralized Server to the Edge



## Enter the Micro Data Center

Micro-modular data centers are essentially IT cabinets with everything built in. They differentiate themselves from other prefabricated data center designs with their ability to pack a lot into a very small environment. For example, one of these data centers can include 20 servers that harness virtualization technology, switches that take up only one or two rack units, cooling, and a UPS system. Need more than that? Just add another "box." This method is quick to deploy, highly scalable, and creates a uniform design so the data center technician knows exactly what's going on.

Many micro data centers also include additional features, such as environmental, UPS, and network monitoring. They also offer physical security, including cameras, biometric security, and fire protection.

While the emergence of micro data centers may be a recent development, the same scaling concept they offer can be found earlier in pod architectures and container environments. They're all modular building blocks that are repeatable and easy to scale up. CIOs today are equipping their tool belt with options that have evolved beyond the "one-size-fits-all" data center, and micro data centers are a natural part of that evolution.

> "modular building blocks that are **repeatable** and **easy to scale up**"

Not only do micro data centers offer a fast, efficient way to address computing needs, they can provide a significant cost savings in comparison to a single centralized data center.

In addition to deployment for edge computing, micro-modular data centers are seeing use in other areas beyond edge computing requirements:

- While more businesses are moving processing to the public cloud, they may still want a small solution internally that is not as large as a secondary data center. If there is downtime or disruption, three or four micro data centers can act as a temporary fix. All a company needs is a little floor space: they don't need to invest in an "environment."
- Power companies and utilities using smart grid technology can leverage their existing infrastructure by adding micro data centers to substations, allowing them to quickly monitor energy use and gather information.
- Ruggedized environments like military or offshore oil operations can quickly deploy a robust, technically proficient environment with micro data centers. A micro data center can be mobile: one could be thrown into the back of a vehicle and away it goes.
- Applications with temporary needs are a great fit for micro data centers. For example, shopping malls can drop a micro data center into a telecom room to support additional kiosks for the holiday shopping season. It can then be removed when no longer needed.

## Physical Infrastructure

Fundamentally, cabling in a micro data center is no different than in a regular data center. However, since some micro data centers can be as small as half-rack heights, they require patching to be as efficient as possible. Ultra-high-density fiber solutions, and in some cases high-density category-rated copper solutions, are essential in these installations. There are cabling systems available today that can patch up to 144 fibers in a one-rack-unit enclosure or patch panel.

> "since some micro data centers can be as small as half-rack heights, they require **patching to be as efficient as possible.**"

These enclosures and panels house compact cassettes, adapter plates, or splice modules, designed for fast deployment. Fiber assemblies like patch cords and cables will use LC or MPO connections. Category-rated copper patch cords will likely come in a smaller outside diameter, and require shielding or foil for protection from signal noise.

And since micro data centers could be used in mobile or ruggedized environments, cabling and connectivity should be robust and protected within the rack.

While cable management is important for managing high-density cabling, it also needs to take up as little space as possible. This means using fiber enclosures or panels with integrated cable managers for bend radius control. Angled patch panels will allow for optimized cable bend radius without needing horizontal cable managers typically found above and below traditional panels in a rack. Also, blank panels may be needed for better airflow, improving thermal management inside the cabinet

Fiber patching, 144 fibers per RU

**Learn about Leviton high-density and ultra-high-density fiber patching systems.**

5.

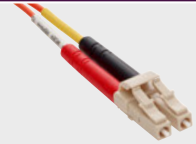
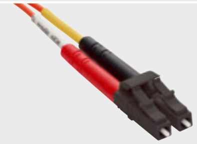
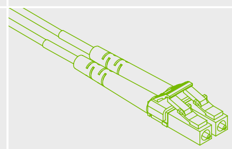
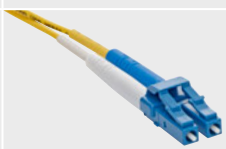
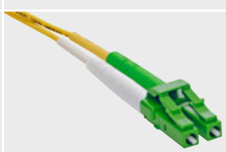
# Fiber Selection

## Multimode Fiber

Multimode optical fiber cable supports multiple light paths within the cable core using a light emitting diode (LED) or a vertical cavity surface emitting laser (VCSEL) light source. Multimode optical fiber will have a 50/125 µm or 62.5/125 µm core/cladding size. Multimode optical fiber is the most common media choice for both backbone and horizontal distribution within the local area network (LAN) including campuses, buildings, and data centers.

The ANSI/TIA-568.0-D standards recommends 850 nm laser-optimized 50/125 µm be installed as the multimode fiber for new structured cabling designs. This includes both OM3 and OM4 classifications to support 10 Gigabit Ethernet and possibly provide a migration plan to support future 40, 100, 200 and 400 Gigabit applications. Both OM1 (62.5/125 µm) and OM2 (50/125 µm) classifications are now considered legacy fiber types.

Color-coding is a big help when identifying individual fibers, cable, and connectors. For example, cable jacket color typically defines the fiber type, and can differ based on mode and performance level. These colors are typically chosen by industry standards bodies.

| Cable Type | Jacket Color | Connector / Adapter Color | Example |
|---|---|---|---|
| OM1 | Orange | Beige |  |
| OM2 | Orange | Black |  |
| OM3 | Aqua | Aqua |  |
| OM4 | Aqua | Aqua |  |
| | Heather Violet | Heather Violet |  |
| OM5 | Lime Green | Lime Green |  |
| OS1 / OS2 | Yellow | Blue |  |
| OS1a / OS2 (APC) | Yellow | Green |  |

### OM1

If the fiber cable in your network is orange, and slate for military applications. There is some legacy orange cable that was available before the OM1 specification. This early cable has a modal bandwidth of 160 MHz.km @ 850 nm, as opposed to 200 for OM1. If you encounter orange cable that is not marked OM1, you may need to assume the cable is 160 MHz.km, limiting 10GBASE-SR to just 26 m (85 ft.).

### OM2

OM2 is 50 micron fiber, which provides a much better modal bandwidth than OM1, 500 MHz.km @ 850 nm. The industry standard color for OM2 orange. Since OM1 is also orange, always check the marking to make sure.

**A reminder:** while multimode fiber comes in either 50 micron or 62.5 micron core size, the ANSI/TIA-568.0-E standard recommends 850 nm laser-optimized 50/125 micron be installed as the multimode fiber for new structured cabling designs. This includes both OM3 and OM4 classifications to support 10 Gigabit Ethernet and possibly provide a migration plan to support future 40 and 100 Gigabit applications. Both OM1 (62.5/125 micron) and OM2 (50/125 micron) classifications are now considered legacy fiber types.

### OM3/OM4

Both laser-optimized OM3 and OM4 cable is aqua, as TIA and ISO did not introduce a new color for OM4. However, some manufacturers introduced the color violet to designate OM4 (heather violet, also known as Erika violet, is often used in Europe). This color designation is important to differentiate the two types, as the modal bandwidth of OM4 (4,700 MHz.km @ 850 nm) is significantly better than OM3 (2,000 MHz.km @ 850 nm).

### OM5

Lime OM5 cable was approved by TIA and ISO in 2017. Note in the chart on the previous page that OM5 has the same modal bandwidth as OM4 @ 850 nm. The main difference between the two options is that OM5 is designed specifically to handle Short Wave Division Multiplexing (SWDM), which transmits four channels on one duplex multimode fiber pair between 850 nm and 953 nm. Currently, there is very little industry adoption of SWDM technologies.

Get a thorough overview of current and forward-looking fiber solutions, including fiber types, connector and termination options, and future applications, with our on-demand webinar Demystifying Enterprise Fiber Networks.

## Understanding Distance Limits with Multimode Fiber

**Multimode optical fiber** is currently the most common media choice for data centers. However, compared to single-mode, multimode does have much shorter distance limitations.

### 1 GB/S Networks

The majority of enterprise fiber networks today still run 1000BASE-SX, delivering up to 1 Gb/s over multimode. OM1 cable will support 1000BASE-SX out to 275 meters, and that distance jumps to 550 meters with OM2 cable. OM3 and OM4 came after the 1000BASE-SX standard was written, so the distances up to 860 meters listed in the chart below are based on the gigabit Fibre Channel values. When IT managers require distances upwards of 860 meters, they will likely want to consider single-mode cable instead of multimode.

### 10 GB/S Networks

Many enterprise networks are moving beyond 1000BASE-SX and transitioning to 10 gigabit networks, such as 10GBASE-SR. This is where distance considerations really come into play. A network using OM1 has a maximum distance of 275 meters for 1000BASE-SX, but it would see a distance limit of only 33 meters for 10GBASE-SR. Similarly, OM2 fiber for 1000BASE-SX has a 550 meter limit, but drops down to 82 meters for 10GBASE-SR. The introduction of OM3 increased that distance to a more usable 300 meters in the enterprise.

| Designation | | | OM1 | OM2 | OM3 | OM4 | OM5 |
|---|---|---|---|---|---|---|---|
| Modal Bandwidth @ 850 nm (MHz.km) | | | 200 | 500 | 2,000 | 4,700 | |
|  Duplex LC | 1000BASE-SX | Meters | 275 | 550 | 860 | | |
| | | Feet | 902 | 1,808 | 2,822 | | |
| | 10GBASE-SR | Meters | 33 | 82 | 300 | 984 | |
| | | Feet | 82 | 269 | 984 | 1,312 | |
|  MPO | 40GBASE-SR4 | Meters | — | | 100 | | |
| | | Feet | | | 328 | | |
| | 100GBASE | Meters | | | 70 | 100 | |
| | | Feet | | | 230 | 328 | |

The distance limit for 10 Gb/s over OM4 is listed at 400 meters, set by TIA, ISO, and IEEE standards based on worse case assumptions. However, these distances can likely extend out to 500 or 550 meters. The 400-meter limit is based on the transceiver having a spectral width of 0.65 nanometers, but most of these transceivers today are 0.47 nanometers, so you can typically extend farther than 400 meters. That's a conversation you need to have with the cabling manufacturer.

### 40 and 100 GB/S Networks

When considering multimode for 40 gigabit Ethernet — namely 40GBASE-SR4 using four transmitters and four receivers — you will need an MPO-style connector, and you can't use older OM1 or OM2 fiber. Also, the distance limits will drop to 100 meters for OM3 and 150 meters for OM4. The original intent of 40GBASE-SR4 was for the data center, with the vast majority of the links in data centers under 100 meters. But enterprise links are typically much longer than 100 meters. These networks will likely deploy 10GBASE-SR throughout the campus, and then 40GBASE-SR4 in server rooms or communications rooms.

"you will need an **MPO-style connector**, and you can't use older OM1 or OM2 fiber"

Moving to 100GBASE-SR4 reduces the supported length further to 70 meters over OM3 and 100 meters over OM4, which is why we are seeing an increase in the deployment of OM4 fiber and the consideration of single-mode, as it is not so distance limited.

To understand the fiber types used to support data rates beyond 100 Gb/s, see chapter 12 of this guide.

## What is OM5 For?

Typically, industry standards and associations set the stage for the next generation of cabling and infrastructure that support network communications. But there are instances when the market decides to take a different route. This is currently the case with the recently standardized OM5 fiber. Even though TIA and ISO/IEC have developed standards for OM5 (TIA-492AAAE, IEC 60793-2-10), this new fiber type very likely won't see wide industry adoption because there is no current or planned application that requires it.

Due to new transceiver launches, coupled with customer perception of their needs and network requirements, the market is ignoring the more expensive OM5 channels and sticking with proven solutions **like OM4 and single-mode fiber**.

For example, Cisco's recently launched 40/100G BiDi transceiver creates a clean line and transition path for OM4 in 40 and 100 Gb/s ports. This new dual-rate transceiver — QSFP- 40/100-SRBD — uses a duplex LC interface. Cisco does not really want their customers to install new cabling: they want them to be able to use their existing OM3 or OM4 cabling and upgrade with new transceivers or new switches. And when data center managers plan for speeds and distances beyond 40 or 100 Gb/s, they will move to single-mode fiber.

| Mode | MMF Type | Reach (Meters) | Total Loss Budget (dB) | BER |
|---|---|---|---|---|
| 40G | OM3 | 100 | 1.9 | 1e-15 |
| | OM4 | 150 | 1.5 | 1e-12 |
| 100G | OM3 | 70 | 1.9 | 1e-12 |
| | OM4 | 100 | | |

Source: Cisco 100GBASE-SQGP 100G Modules Data Sheet, May 2018

Transceiver manufacturers are taking a stand and promoting the benefits of reusing existing cabling backbone to speed network upgrades to avoid network disruptions and unnecessary additional costs. There is nowhere in this path for another multimode fiber like OM5.

The current 100 Gb/s transceivers with the highest sales volumes — and the expected high runners for 200 and 400 Gb/s — all work with OM4 or OS2.

The chart below shows some of the top-selling 100 Gb/s transceivers:

| Transceiver (100G-) | Switch Vendor | Form Factor | IEEE Compliant | Fiber Type | Distance (Meters) | # of Fibers | Connector |
|---|---|---|---|---|---|---|---|
| SR4 | All | QSFP28 | Yes | OM3 OM4 OM5 | 70 / 100 / 100 | 8 | 12F MTP |
| CWDM4 | | | No | OS2 | 2,000 | 2 | LC |
| PSM4 | | | | | 500 | 8 | 12F MTP |
| SMSR/LRL4 | Cisco, Arista | | | | 2,000 | 2 | LC |
| SR-BiDi | Cisco (40/100), Arista | | | OM3 OM4 | 70 / 100 | | |

continued

## What is OM5 For? Continued

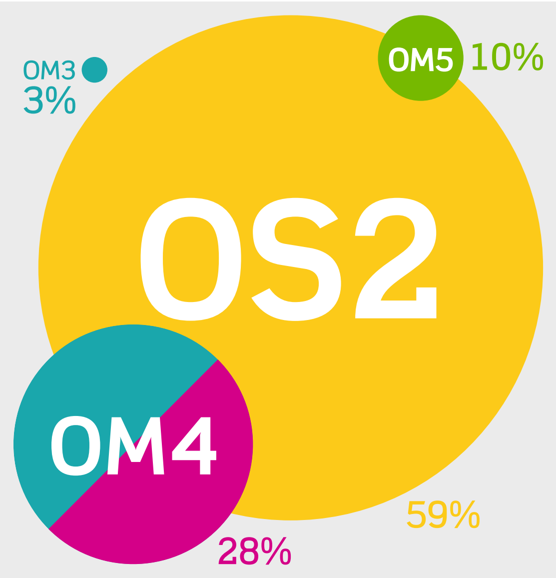
Below are the expected high-volume 200 and 400 Gb/s transceivers:

| Transceiver (200G/400G) | IEEE Standard | Fiber Type | Distance (Meters) | # of Fibers | Connector | IEEE Standard Date |
|---|---|---|---|---|---|---|
| DR4 | 802.3bs | OS2 | 500 | 8 | 12F MTP® | 12-2017 |
| FR4 | | | 2,000 | 2 | LC | |
| SR4 | 802.3cd | OM3 OM4 OM5 | 70 / 100 / 100 | 8 | 12F MTP | 12-2018 |
| DR4 | 802.3bs | OS2 | 500 | | | 12-2017 |
| FR8 | | | 2,000 | 2 | LC | |

When it comes to data center network infrastructure, users are reluctant to replace their entire cable backbone. And even with a greenfield installation, they are unlikely to install something different from their existing facilities unless the added capabilities (bandwidth and reach) are extraordinary. Customer and market perception is crystallizing on OM4 for multimode, and when a jump in fiber type is necessary and OM4 will no longer suffice, single-mode is by far the recognized next step.

This trend is supported by a recent Leviton poll that found a significant jump in OS2 single-mode, compared to surveys from previous years.

**What fiber type would you be installing today to plan for future growth?**




March 2020 Leviton poll of data center network professionals

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## Single-Mode Fiber

Single-mode optical fiber supports one mode of light travel using a laser light source. The core/cladding size of single-mode optical fiber is approximately 8.3/125 μm.

In recent years, more enterprise and data center networks have adopted single-mode fiber optics. Traditionally, single-mode had been limited to applications such as long haul, service provider networks, metropolitan area networks, and backbone distribution for large campuses. However, single-mode is now finding its way into shorter reach applications.

> "single-mode is now finding its way into **shorter reach** applications"

If you are new to single-mode networks and installations, the following points address some prevailing preconceived notions about single-mode fiber — whether true or false — and provide guidance for single-mode testing, cleaning, and inspection.

**Single-mode transceivers are more expensive.** PARTIALLY TRUE
The primary decision to use multimode instead of single-mode over the years has come down to transceiver cost. In fact, there was a point in time when a single-mode transceiver was 7.5 times the price of a multimode transceiver.

However, times have changed, and single-mode transceivers have dropped in cost. This is largely the result of large hyperscale data centers installing more lower cost single-mode transceivers, and as a result reshaping the enterprise and data center markets. Adoption by these companies has reduced the cost of single-mode optics to the point where the cost for 100 Gb/s single-mode transceivers dropped tenfold over the past two years, bringing it in line with multimode fiber transceivers.

**Single-mode only works with duplex connections, not MPO/MTP®.** FALSE
This statement is no longer true. Transceiver vendors are now making single-mode versions that run on parallel optics, in order to reduce costs for shorter data center links. These parallel options also allow for cabling breakouts, which has already become a very popular approach in multimode networks. With breakouts, you can split a 100 Gb/s transceiver out to four 25 gigabit channels. This helps create more efficiency and greater port density in network designs.

**A greater insertion loss is allowed for single-mode compared to multimode.** FALSE
This is no longer a true statement. With cheaper transceivers comes a reduced allowance for insertion loss. Designers especially need to be aware of reduced loss budgets for newer transceivers targeted at data centers. And if your design has multiple connections, you can run into trouble. Be sure to ask specific questions, particularly if you are using MPO/MTP connections.

As an example of stricter insertion loss allowances for 100 Gb/s, consider the channel loss limits shown at right. When you move to new options like 100GBASE-PSM4 and 100GBASE-DR, you are no longer designing for 6 or 7 dB loss but 3 dB.

**Channel Loss Limits**

| 100 Gb/s Ethernet | Channel Loss |
|---|---|
| 100GBASE-ER4 | 15.0 dB |
| 100GBASE-LR4 | 6.3 dB |
| 100GBASE-CWDM4 | 5.0 dB |
| 100GBASE-PSM4 | 3.3 dB |
| 100GBASE-DR | 3.0 dB |

continued

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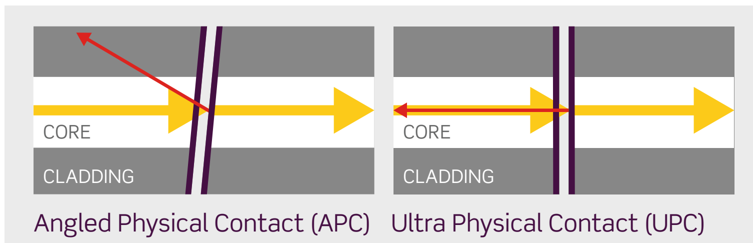
## Single-Mode Continued

**Single-mode brings additional return loss (reflectance) concerns.** TRUE

Return loss is a real concern with single-mode. Multimode is very tolerant of light being reflected back into the transceiver, but single-mode is not. At higher data rates, errors are generated if too much light is received back. This reflectance is a result of small air gaps that can occur at the physical contact (PC) where two connections are joined together, as shown by the yellow arrow in the figure below. Return loss is measured as a ratio (in decibels) of the power of the outgoing signal to the power of the signal reflected back.

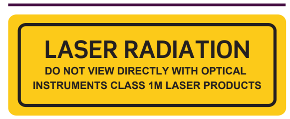
**Reflectance**




All single-mode MPO/MTP® connections use APC, as it is nearly impossible to achieve a good return loss with a UPC MPO over single-mode. With APC, an eight degree angle results in any reflections being directed into the cladding rather than the transceiver, resulting in better return loss.

**Single-mode transceivers use high power lasers, and as a result there are additional safety concerns.** PARTIALLY TRUE

Typically this notion is true for long haul single-mode versions, but not for the lasers used in the enterprise and data centers. These lasers — known as Class 1M lasers — are considered safe for viewing, except when passed through magnifying devices such as microscopes and telescopes.




That said, if you are viewing an end face, make sure your fiber scope has a built-in filter. Eyeglasses or reading glasses are not considered a filter.

**If a single-mode link is too short, the transmitted light could saturate the receiver and require an attenuator to reduce the power of the signal.** PARTIALLY TRUE

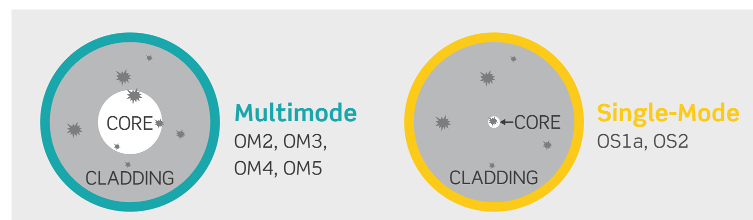
This issue only arises with high powered lasers used in outside plant installations. Data centers typically use low power Fabry-Perot (FP) lasers, with a nominal output of -3 dBm. CWDM4 transceivers use a slightly higher powered laser known as a Distributed Feedback Laser, with a nominal output of 2.5 dBm, but this is still a relatively low power. For Class 1M lasers, saturation of the receiver is not an issue, as long as your link is 2 meters (6.6 feet) or longer.

**Single-mode fiber is more challenging to clean than multimode.** TRUE

This is a real concern. While dirt can collect on the multimode core, light can still pass through multimode's larger 50 μm core size. With single-mode, one speck of dust can block all light. The size of a speck of dust in an office is typically 2.5 to 10 μm. A multimode fiber core is 50 μm, whereas a single-mode core is 8.2-8.6 μm, as shown below. To put these into perspective, a single human hair is 100 μm. That means that, in single mode fiber, data is transmitted through an area that is one-tenth the thickness of a human hair.

Be sure to inspect all connectors before installing and clean them if necessary. Then be sure to inspect them one more time after cleaning.

**Dirt in Multimode and Single-Mode Cores**



# 6.

# Category-Rated Copper Systems

- Category-Rated Copper Systems for 10 Gb/s and Beyond
- Copper Cabling for Top-of-Rack
- Copper Cabling for End-of-Row and Middle-of-Row

6.

## Category-Rated Copper Systems for 10 Gb/s and Beyond

Data centers everywhere are moving quickly to address bandwidth growth. Many data center managers looking to control costs have chosen Cat 6A twisted pair copper for 10 Gb/s applications, since it is the most cost-effective option for access layer networking. In fact, the cost of 10GBASE-T channels is at least 30% lower than alternative SFP+ channels.

Cat 6A makes migration easy. 10GBASE-T allows for auto-negotiation, so two Ethernet devices can connect to each other and select a common transmission speed that both device support. This allows for 10GBASE-T migration to be done in phases for a portion of the network or during a complete network upgrade, giving data center managers some flexibility in terms of timing, disruption, and cost for upgrading the network.

### Category 8

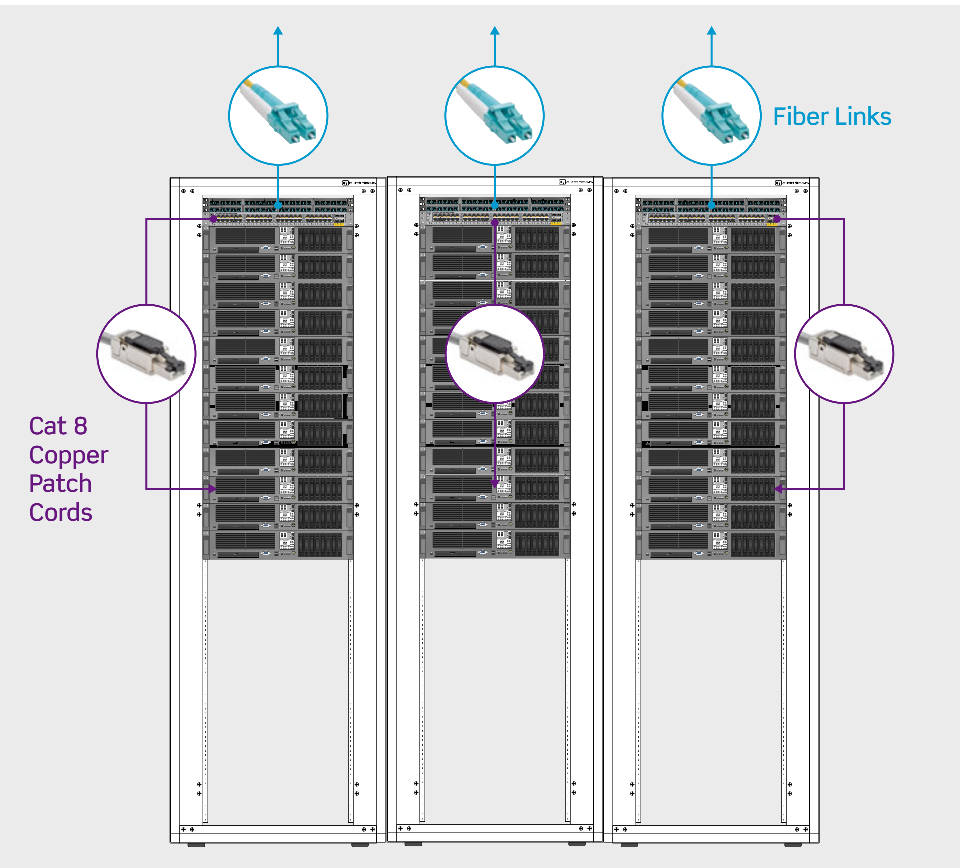
With BASE-T providing the most cost-effective access layer networking option, copper structured cabling solutions will continue to be fundamental throughout the data center infrastructure. 40GBASE-T (and 25GBASE-T) will rely on Category 8 connectivity. The Category 8 specification from TIA and ISO defines channels and connecting hardware up to 2000 MHz and 30 meters, using the standard 8P8C/ RJ-45 interface. This interface allows the cabling system to be backwards compatible with existing Category cabling systems. For data center managers, backwards compatibility and auto-negotiation between active equipment provides huge benefits.


But what are the practical applications for Cat 8? Where will it be deployed? First of all, these cabling systems make sense for applications requiring speeds greater than 10 Gb/s. This goes beyond the capabilities of Cat 6A, which has the performance specifications and flexibility to handle 10 Gb/s or slower speeds.

Also, Cat 8 systems will be limited to the data center access layer, due to its distance limitations of 30 meters or less in a two connector channel, per IEEE, ISO, and TIA standards. When planning for networks greater than 10 Gb/s in the access layer, the decision of which cable type to use largely depends on the network topology you prefer: **Top-of-Rack (ToR)**, **End-of-Row (EoR)**, or **Middle-of- Row (MoR)**. Cat 8 will be able to support all of these topologies.

## Copper Cabling for Top-of-Rack

The Top-of-Rack (ToR) model uses a simplified cabling scheme — short intra-rack cable runs with a small number of uplinks to the aggregate switches. BASE-T cabling leverages the benefits of auto-negotiation, which allows for two Ethernet devices to connect to each other and select a common transmission speed that both devices support. Auto-negotiation requirements are laid out in IEEE 802.3 BASE-T standards. For example, 25 Gb/s ToR switches can communicate with 10Gb/s servers, whether over Cat 8 or Cat 6A connectivity.




## Other Copper Connections for 25G / 40G

Twisted-pair cabling using RJ-45 connections isn't the only copper option for 25G or 40G networks. Quad small form-factor pluggable (QSFP+) direct attach copper (DAC) passive assemblies were standardized in 2010 through IEEE 802.3ba. They are low-power solutions and have a similar form-factor to SFP+ 10G (and future 25G) assemblies. However, from a structured cabling viewpoint, they have a limited distance of up to 7 meters. With such limited reach, they can not support a wider range of topologies, such as End-of-Row or Middle-of-Row options. QSFP+ DAC assemblies are also not backwards compatible, and can be used for 40G networks only.

## Copper Cabling for End-of-Row and Middle-of-Row

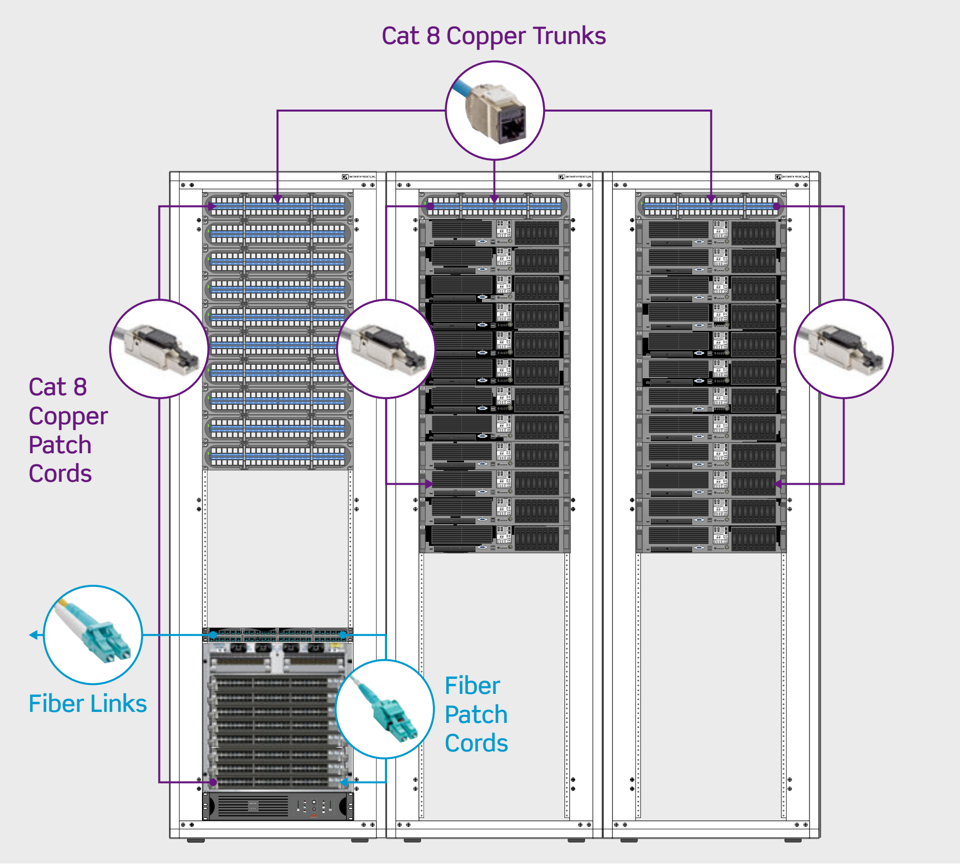
EoR and MoR designs have every server cabled back to a single switch dedicated to a row of server racks. The upside of this structured cabling approach is a simplified management environment with just one switch to manage per row.

These topologies require longer links than those for ToR designs, and for 25 and 40 Gb/s networks in EoR and MoR topologies, your two options are to use Cat 8 or multimode fiber. The longer cabling requirements eliminate short-length DAC assemblies as an option. Multimode fiber offers the benefit of working over longer distances and low power, and it can provide a smaller cable profile. However, the high costs of fiber active equipment makes it an option that not all end users can justify.

Category 8 can support the longer distances required in EoR and MoR designs, but it is limited to 30 meters or less. However, according to IEEE, links of 30 meters or less make up 80 percent of data center connections in the industry. If you require longer distances, fiber is the only option. Cat 8 also offers the benefit of operating over low power: it will not likely require any greater power or cooling requirements than a typical Cat 6A / 10GBASE-T system used today.

Even if Cat 8 is not part of your immediate data center strategy, you may want to anticipate future tech refreshes in your current network infrastructure design. This means considering cable distances, connection counts, shielding, and more. Preparing for Cat 8 now will create a simple and cost-effective migration in the future.

Learn about Leviton's **Cat 6A Cabling System** and **Cat 8 Cabling System**.



7.

# Data Center **Patching:** Patch Panels or Enclosures?

When it comes to choosing fiber patching solutions in a structured cabling system, there are a variety of product options available, but they all fall under two general categories: patch panels or enclosures. A standard 19" or 23" patch panel makes patch cords, trunks, and cables easily accessible from the front and the rear. Enclosures provide extra protection and security at the connection point.

When it comes to rack-mount patching, which do you choose? This largely depends on the type of environment or network application.

- Patching in Open Frame Racks
- Patching in Closed Rack Cabinets
- Additional Security
- Networks Requiring Fast Deployment or Frequent MACs
- Splicing
- Field Terminations
- Pre-terminated Connectivity

## Patching in Open Frame Racks - Enclosures

As racks leave mounted equipment more exposed and accessible, it may be prudent to install fiber enclosures in racks. Enclosures provide extra protection, preventing fiber connections from bumping or jostling. They keep out potential dust or debris, and locking options are usually available for extra security, if necessary.

## Patching in Closed Rack Cabinets – Patch Panels

Unlike racks, network cabinets provide more protection from the elements and added security. While the protection enclosures provide makes sense for open racks, that protection becomes redundant in a cabinet with doors. Also, panels can provide more accessibility in the rear of cabinets — especially helpful for those areas where there is deeper-depth active equipment.

## Additional Security - Enclosures

Most enclosures offer doors with a locking feature, limiting access to only those who are authorized, giving them an advantage over panels. However, there are cases where this added security might be redundant, such as in a high-security data center where access is already limited to a few network managers or technicians.

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## Networks Requiring Fast Deployment or Frequent MACs - Panels

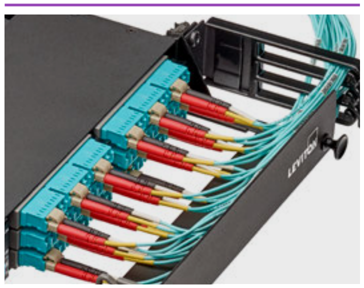
Patch panels allow for faster installations, especially when deploying panels with snap-in fiber cassettes. The open nature of patch panels also makes them easier and faster to access during network maintenance. However, there is also a case to be made for enclosures in high activity areas, as the extra protection they provide can eliminate the potential for accidental bumping or mashing of connection ports and patch cables.


## Splicing - Enclosures

Field splicing creates a more fragile environment for the fiber, and it usually results in a length of loose fiber slack that is better tucked away. While splices are often housed in modules, cassettes, or trays, they are best housed in an enclosure for additional protection.

## Field Terminations - Enclosures

As with field splicing, field terminations of fiber connectors require careful installation and handling, and are better maintained in the protection of an enclosure instead of an open patching field.



## Pre-terminated Connectivity - Panels

Pre-terminated plug-and-play trunks, harnesses, and patch cords come with the assurance of high-quality factory assembly, and are ideal for those who need fast deployment. For these reasons they are a strong fit for a more accessible open patching environment.

8.

# Field Termination

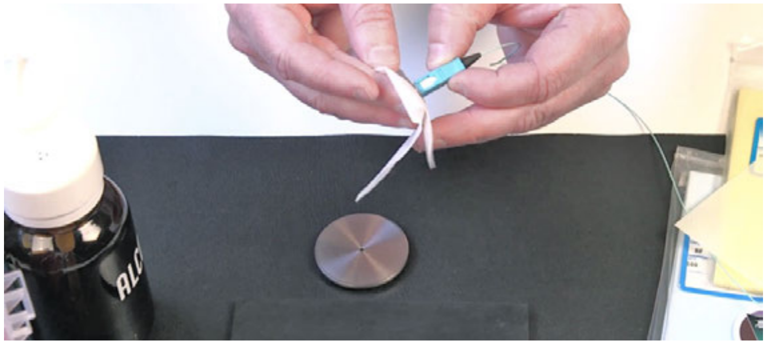
## Options and Termination Walkthroughs

There are three basic approaches to terminating fiber connections in the field: adhesive connection and field polishing, mechanical connectors and no polishing, or fusion splicing using pigtail assemblies. Let's take a brief look at each.

- Field Polish / Adhesive Terminations
- Factory Polish / Mechanical Connectors
- Fusion Splicing

## Field Polish / Adhesive Terminations

Adhesive connectors are a very common option. With these terminations, a 1- or 2-part system adhesive is injected into the connector, and the fiber is inserted. An accelerator or "primer" can be used to cure the adhesive more rapidly.



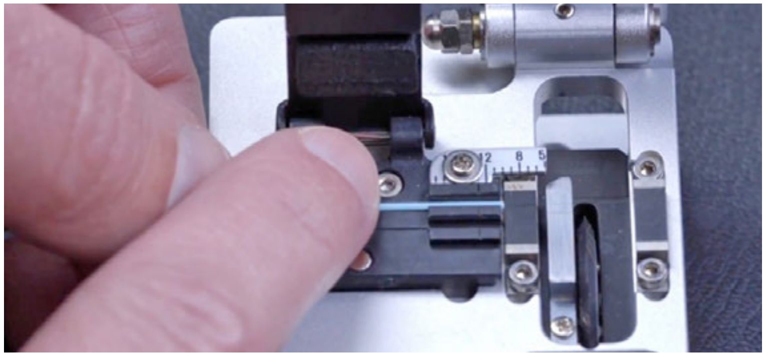
Adhesive terminations are the least expensive option. However, they are very craft sensitive, so labor costs are a consideration. Also, a word of caution: The Telecommunications Industry Association (TIA) has tightened its requirements for single-mode return loss (reflectance), at 0.35 dB. Meeting those requirements becomes much more challenging with field polish connections. With enterprise networks moving to higher speeds, return loss is now more of a concern than ever. Minimizing return loss requires improving your polishing procedures, or choosing a factory polished connector such as mechanical connector.

| | |
|---|---|
| Typical Termination Time | 5-7+ minutes per connector (curing time may vary) |
| Typical Insertion Loss | 0.2 dB |

You can get a step-by-step video guide for terminating Leviton Fast-Cure field polish connectors.

## Factory Polish / Mechanical Connections

Traditionally, mechanical connectors were considered a temporary "quick-fix" solution. However, the technology in mechanical connectors has advanced over the years, and the advantages have made them a higher quality long-term solution. With mechanical connectors, the end-faces are factory-polished and highly controlled, leading to better insertion loss and return loss. When using pre-polished connectors, material costs are higher and will require a precision cleaver but labor costs can be significantly reduced.



Leviton FastCAM connectors are pre-polished, field-installable connectors that eliminate the need for hand polishing, bonding, or epoxy in the field.

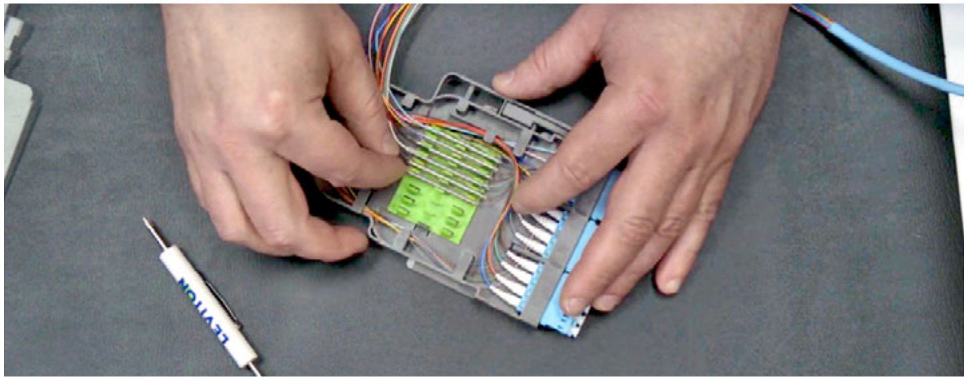
| | | |
|---|---|---|
| Typical Termination Time | 1-2 minutes per connector | |
| Typical Insertion Loss | Multimode: | 0.1 dB |
| | Single-mode: | 0.2 dB |
| | Single-mode SC/APC: | 0.3 dB |

See a video overview for terminating the FastCAM connector with 900 micron fiber.

8.

## Fusion Splicing

Fusion splicing is another option that uses factory polished connectors and will provide excellent insertion and return loss. However, it is also more expensive than field polishing, and will require a greater capital investment as it requires both a precision cleaver and a fusion splicer. The good news is the cost of fusion splicers has come down in price significantly in recent years.




Leviton offers pigtails and splice modules to protect and organize heat shrink fusion spliced fibers inside an enclosure. The modular design enables faster field splicing and simple management of pigtails within the housing. Splice modules eliminate the need for individual splice trays within a fiber enclosure.

| | | |
|---|---|---|
| Typical Termination Time | 1.5-2.5 minutes per connector | |
| Maximum Insertion Loss per Pigtail | Multimode LC: | 0.15 dB |
| | Multimode MTP: | 0.35 dB |
| | Single-mode LC: | 0.25 dB |
| | Single-mode LC/APC: | 0.25 dB |
| | Single-mode MTP: | 0.35 dB |

Learn how to terminate Leviton **Opt-X SDX 24-fiber Splice Modules** and high density HDX **LC** or **MTP**® Splice Modules.

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# 9. Pre-Terminated Cabling

- The Rise of Pre-Terminated Cabling
- Key Benefits
- Tips for Choosing the Right Pre-Terminated Cabling
- Tips for Choosing the Right Manufacturer

## The Rise of Pre-Terminated Cabling

Many of today's businesses rely on advanced, ever-changing technology to increase their agility and flexibility while reducing cost. At the same time, they require mission critical networks that can deliver resilient, fault-tolerant applications for their employees and customers. Because data centers are a capital investment essential to achieving corporate goals, businesses demand unfailing reliability and fast deployment of these critical spaces, while information technology and data center professionals strive to manage complexity and costs.

Modularity is becoming increasingly popular in data center design to properly control scalability and manageability. Whether a top-of-rack, middle-of-rack and end-of-row configuration is deployed, modular designs require minimum investment while allowing for flexibility, growth and maintaining low latency when accessing data.

In the past 15 years, we have seen an evolution in how data center projects are designed and deployed. While a traditional three-phase design-bid-build is still a viable way of doing business under many circumstances, design-build is better geared toward purpose-built facilities such as data centers that are constructed from the ground up and that demand more specialized expertise.

**Pre-terminated optical fiber and copper cabling** solutions are becoming increasingly popular. Designed for rapid deployment, pre-terminated cabling eliminates the need for field terminations. This can significantly reduce installation time and increase network performance to exceed industry benchmarks. Pre-terminated cabling is also factory-terminated and tested before it leaves the manufacturer. It is ideal for data centers that demand performance, flexibility and scalability while still keeping costs and material waste in check.

## Key Benefits

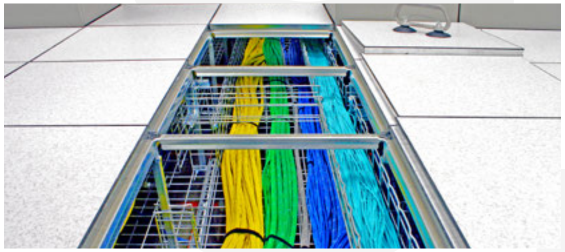
Pre-terminated cable provides a plug-and-play solution for links between switches, servers, patch panels and zone distribution areas in the data center. These solutions include a variety of trunk cables, array cables and plug-and-play cassettes that give data center managers choices to suit specific needs. When compared to field-terminated cabling, there are many reasons to consider pre-terminated optical fiber and copper cabling.

- **It increases speed of deployment.** Field termination is the most time-consuming, labor-intensive part of the cable installation process. Once pre-terminated cabling is delivered, it can be unpacked, readied for deployment, and connected quickly. In many cases pre-terminated cabling can cut installation time by up to 80% over field terminations.

- **It reduces downtime with faster, more flexible MACs.** With pre-terminated solutions, data center managers can make changes quickly based on network growth, business decisions, or shifting requirements. In disaster recovery situations that call for fast, temporary data communications set-up, pre-terminated cabling can minimize business downtime and establish communications quickly. It can also be disassembled quickly when the situation is resolved. The components are reusable for more efficient moves, adds, and changes (MACs).
- **Users avoid time-consuming rework.** Increased network speeds have tighter link budget requirements that can be challenging to achieve with field terminations. Pre-terminated cabling provides more consistent channel transmission characteristics, as the experience level of the field technician no longer becomes a factor. Precision factory-termination processes take place in a clean, well-lit environment, unlike termination in uncontrolled field conditions. This increases the likelihood of clean and uncontaminated optical fiber ports, enables lower loss budgets, and provides overall better electrical transmission. Factory terminations are also guaranteed under warranty, which offer data center managers peace of mind.
- **It removes the need for transmission-performance testing.** With pre-terminated cable assemblies, transmission testing of assemblies is performed by the manufacturer before shipment, and test reports are included with the assemblies. This leaves only continuity testing for copper and fiber per the customer's project and manufacturers warranty requirements, which reduces the time spent testing on-site.

- **It cuts clean-up time.** Pre-terminated solutions allow for quick clean-up due to minimal leftover materials and scrap. Also, because there is less waste and material to clean up, pre-terminated solutions also help meet green design, waste reduction, and material reuse goals.

## Tips for Choosing the Right Pre-Terminated Cabling



Although it doesn't require as much time — or as many installers in the field — pre-terminated cabling does require additional upfront planning and a detailed analysis to establish the cabling and termination routes and lengths needed. From determining the overall architecture, cabling media, pathway systems, elevations, and rack-level details, to understanding the customer's unique requirements for scalability, density, manageability, and deployment schedules, there are considerations that go into planning a pre-terminated cabling infrastructure.

### Architecture and Configuration

It is important to understand what type of architecture and configuration will be deployed, such as traditional three-tier switch architecture, fabric switch architecture, end-of-row, middle-of-row, or top-of-rack configurations. This will help determine the placement of equipment and servers and ultimately impact the cabling termination routes and lengths required.

### Cabling Media

Determining applications and required cable media for copper and optical fiber links is a key part of the planning process. This might include cost considerations, bandwidth needs, distance limitations, equipment interfaces, power consumption, pathway space, and overall lifecycle costs. The environment itself also should be considered, including any electromagnetic or radio frequency interface (EMI/RFI).

"required cable media for copper and optical fiber links is a **key part** of the planning process"

### Migration and Scalability

Knowing the migration strategy and future plans will go a long way in selecting the right pre-terminated cabling components. For example, if there is a need to support a migration from 10 GbE to 40, 100, 200, and 400 GbE speeds, careful consideration must be given to the optical fiber count, connector type, distances, insertion loss budget, and ease of switching out cassettes or other connectivity components.

### Pathways

The position, elevations, required separation, and type of pathway system used can impact the cable lengths. For example, determining whether cabling will be run overhead or underfloor, knowing specific rack heights and clearances, accommodating required separation, and selecting the cable support system (e.g., ladder rack, cable tray, trough) will all need to be determined before calculating cable lengths between equipment and patch panels.

### Cable Runs

To carefully determine pre-terminated cable lengths, it is important to know the rack-level detail of the installation. Bend radius and service loops must be considered, as should the distances to, from, and within each cabinet. With pre-terminated cabling systems, it is important to order lengths that do not come up short while avoiding too much slack in cabinets and pathways. Proper sequencing is also important to ensure that longer cable trunks are laid into trays first for an overall cleaner installation.

### Additional Considerations

From density and airflow in the cabinet, to preferences for polarity and color-coding, proper planning for pre-terminated cabling solutions requires an extremely detailed analysis of the customer needs and specifications. The deployment schedule must also be carefully reviewed and communicated with the manufacturer to ensure on-time delivery of materials.

## Tips for Choosing the Right Manufacturer

There are many options when selection a pre-terminated assembly manufacturer to work with. Search for a qualified, reliable provider that can offer services and features such as guaranteed cabling performance, design assistance, and large quantities of pre-terminated assemblies on time.

All pre-terminated copper or optical fiber purchased through a manufacturer should be tested and verified by a third party to exceed TIA and ISO standards. The manufacturer should also provide 100 percent testing in a quality-controlled environment before the cabling is shipped out to the worksite.

You should also look for these qualities in a manufacturer:

- Quality documentation and warranty, meaning that each product is labeled with a unique serial number for full traceability. Also look for lifetime product, system, and performance warranties.
- Complete design service. Look for a manufacturer that offers technical experts either remotely or onsite at no additional charge to help with topology and infrastructure layout, along with elevations, pathways, and specifications.
- ISO 9001 certification, which includes third-party auditing of manufacturer sites, functions, products, services, and processes.
- Dedicated 24/7 make-to-order facilities that can take on large orders while providing fast turnaround. Orders that are too large (or too small) may be pushed to the bottom of the production pile in some manufacturing environments, but make-to-order facilities prevent this problem.

Addressing data center infrastructure efficiency, deployment time, performance and scalability has driven adoption of pre-terminated structured cabling systems. As data center managers aim to increase bandwidth and processing capacity, they will look for help to implement design plans that maximize space efficiency and reduce operational costs. Quality cabling manufacturers can offer fair pricing, as well as work to establish a true partnership through the warranties, guaranteed performance standards and design services.

To learn more about Pre-Terminated Cable Assemblies and cassettes, or to start configuring for your project, visit Leviton.com/MTO.

10.

# MPO Fiber

Data centers continue to push for increased bandwidth and reduced latency, and demand for rates of faster network speeds and supporting standards have grown dramatically as a result. To handle higher bandwidth, improve network density, and prepare for future upgrades, many data center designers and network managers are moving to parallel optics using multi-fiber push-on connections or MPOs in their fiber network infrastructure.

Here's a helpful breakdown of all things MPO.

## MPO or MTP® Connectors?

MPO connectors are array connectors that have more than two fibers, typically available with 8, 12 or 24 fibers for common data center and LAN applications. Their physical characteristics are defined by IEC-61754-7 and TIA-604-5 (also called FOCIS 5).

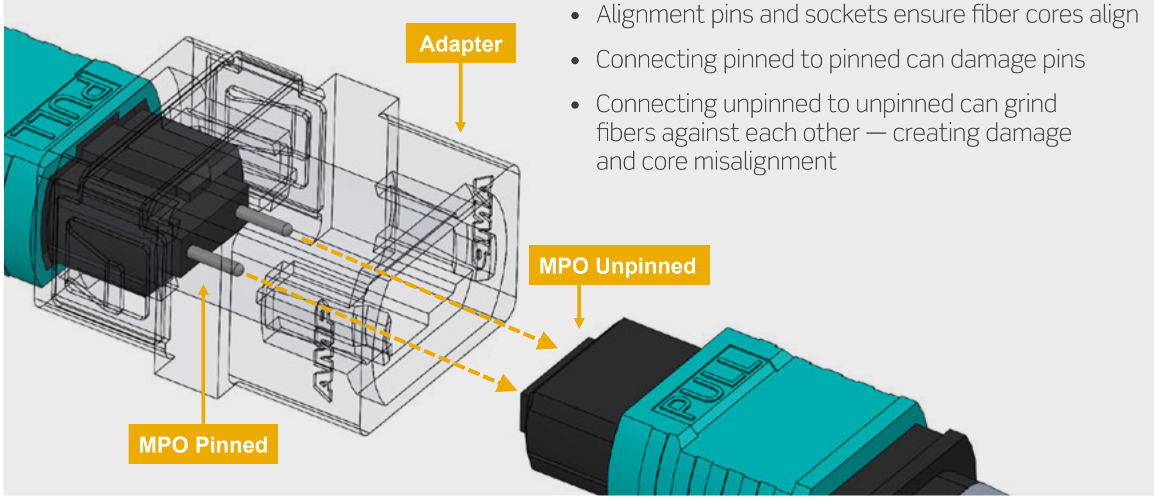
An MTP connector is a commonly used version of an MPO connector. It has multiple engineered product enhancements to improve optical and mechanical performance. Generic MPO connectors are limited in performance and are not able to offer the high-performance levels of the MTP connector.

Unlike single-fiber connectors, which are all male, MPO/MTP connectors are either male (with alignment pins) or female (without alignment pins). When mating the connectors, it is critical that one plug is pinned and the other plug is unpinned. The pinned connector is typically located inside the panel (i.e., the fixed connector is pinned and the connector that is frequently removed and handled is unpinned).

> "it is **critical** that one plug is pinned and the other plug is unpinned"

### Pinned and Unpinned Connections

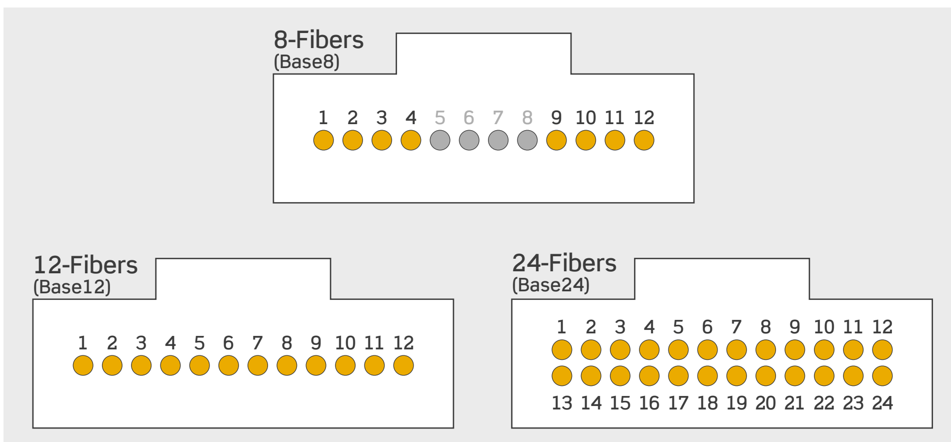
- Alignment pins and sockets ensure fiber cores align
- Connecting pinned to pinned can damage pins
- Connecting unpinned to unpinned can grind fibers against each other — creating damage and core misalignment



## Cabling Types: Base8, Base12, and Base24

There are pros and cons to using 24-fiber cabling versus 12-fiber cabling. When it comes to density, 24-fiber cabling has an advantage over 12-fiber, since higher density connectivity in the enclosure leaves more rack space for active equipment, reducing the total amount of rack space required for patching. With 24 fibers, enclosures can have twice as many lanes with the same number of ports as 12-fiber.

This is even more apparent in 8-fiber parallel optic applications. A Base8 or 8-fiber cabling infrastructure actually uses 12-fiber MPO connectors to achieve 40, 100, 200, or 400 Gb/s channels. In these cases, only 8 of the 12 fibers are used, meaning fully a third of the connector capacity is dark or unused. This is highly inefficient and adds to the congestion of cable pathways and management solutions. In Base24 or 24-fiber cabling infrastructure, you get the flexibility to run three 8-fiber channels in one cable. This provides 100% fiber utilization in the connector, reducing cable tray congestion and ensuring a strong return on your infrastructure investment.



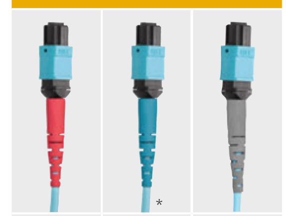

Using 24 fiber connectors requires planning on the front end to ensure proper polarity and routing. Manufacturers providing a 24-fiber solution should work with the network designers and administrators to ensure success. Data centers will need to inevitably upgrade their networks to accommodate 100, 200, and 400 Gb/s, and sticking to 12-fiber MPO configurations may actually be more challenging and expensive in the long-run, since switch speed upgrades and other network modifications are more difficult.

### Cassettes

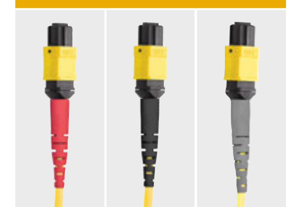

24-fiber MTP® (cassette back view)


12-fiber MTP (cassette back view)

### Multimode Color Coded Boots on MTP


Red 24 Fiber | Aqua 12 Fiber* | Gray 8 Fiber

### Single-Mode Color Coded Boots on MTP


Red 24 Fiber | Black 12 Fiber | Gray 8 Fiber

* OM4 cabling color may vary based on regional requirements (e.g., cable and connectors are heather violet in Europe)

## Color Coding

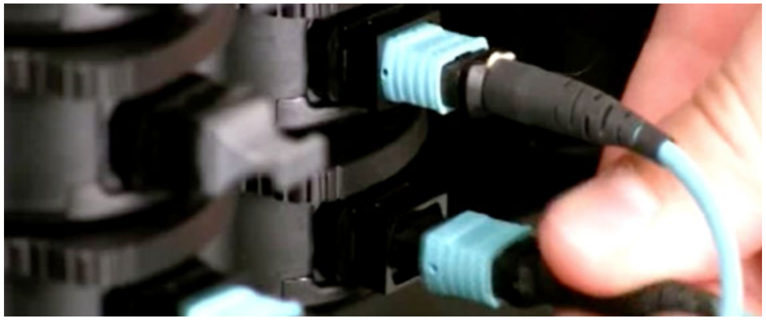
Because of the universal mating capability of some MPO connectors, it is possible to connect a 12-Fiber MPO to a 24-fiber MPO. But doing so will result in improper mating and can cause some confusion during moves adds or changes or when new network administrators are working on legacy installations. **Leviton offers color-coded boots** to assist in this task. On both single-mode and multimode connectors, a red boot indicates a 24-fiber connector, a 12-fiber connector is aqua on multimode connectors or black on single-mode connectors and a gray boot an 8-fiber connector. Similarly, for adapters, a red MTP adapter or coupler indicates a 24-fiber connector and black a 12-fiber connection.

## Cleaning Considerations

> “MPOs can be more **challenging** to keep clean”

MPOs can be more challenging to keep clean than other connector types, since the connector interface has multiple fibers in it, unlike the LC connector. Keeping 8, 12 or 24 fibers in a single connector end-face clean can be difficult. Fortunately, the prescription for cleaning is simple: inspect before you connect. If it is clean, go ahead and connect. If not, then reclean and reinspect.

Typically, it’s recommended the cleaning process starts with dry cleaning, and if anything is embedded, moving to wet cleaning, and then finishing with dry cleaning. But with MPOs, we recommend starting with wet cleaning. This is because more and more of the cleaning solutions on the market are for wet cleaning. Additionally, wet cleaning is anti-static, and MPOs are very prone to static, making it easier to attract dust floating in the air. Contractors just need to be careful that when cleaning the bulkhead, the ribbon doesn’t get too wet. But overall, using wet cleaning and then dry cleaning is a great way to tackle the challenge.



You can learn more about Leviton's offering of MPO connectivity — including trunks, harnesses, patch cords, adapters, and cassettes — at Leviton.com/fiber.

11.

# Fiber Polarity

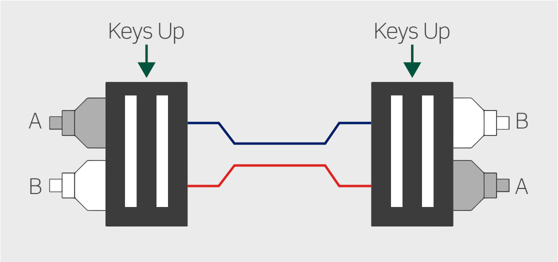
Several methods are used to maintain polarity for optical fiber cabling systems. The guidelines described and illustrated in this section cover duplex connector systems and array connector systems. Following one duplex polarity method and one array polarity method consistently will simplify channel connectivity in an installation.

## Duplex Polarity Systems

Duplex systems should use A-to-B polarity. TIA published polarity connectivity methods in the mid 2000s to help installers install and select the right components. The TIA-568.0-D Standard (Commercial Building Telecommunications Cabling Standard) defines the A-B polarity scenario for discrete duplex patch cords, with the premise that transmit (Tx) should always go to receive (Rx) — or "A" should always connect to "B" — no matter how many segments there are.

A duplex patch cord with A-B polarity is considered "standard", as seen in the example below. When facing an open port in the "Key-up" position, "B" will always be on the left and "A" will always be on the right.

**A-to-B Duplex Optical Fiber Patch Cord**

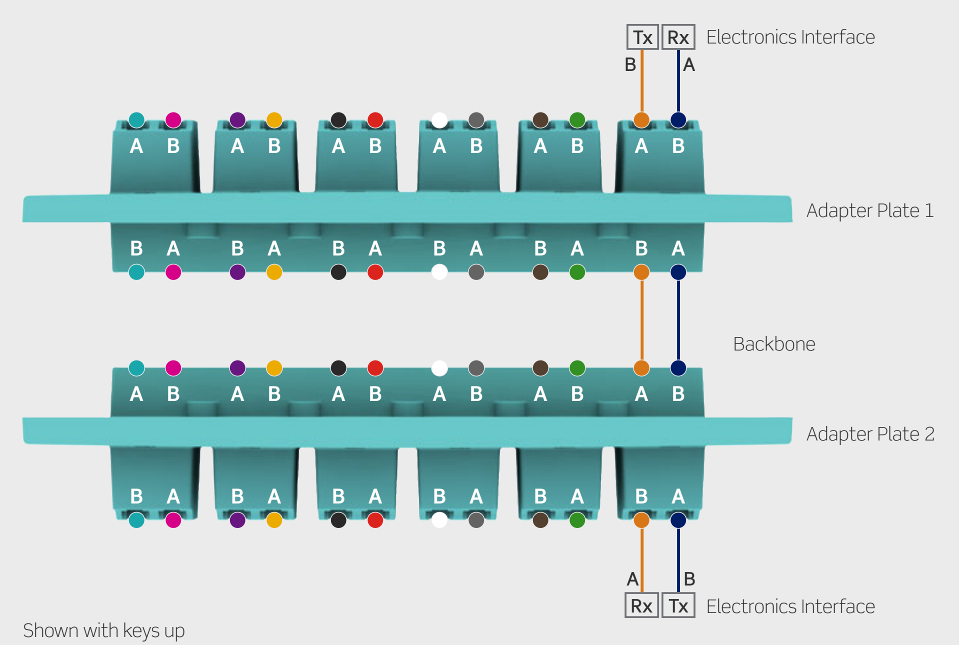



### Adapter Plate to Adapter Plate

For backbone and riser multifiber cable, installers should always follow the color code and numbering system below for A-B polarity, as defined in TIA-598-D Optical Fiber Cable Color Coding.

The connection should be between adapter plate rows with the connector key sharing the same orientation. When a connection occurs between adapters in the same keyway orientation, the multifiber colors (blue, orange, green, brown, etc.), will remain the same on each side.

**Examples of Backbone Cable Connections Between Two of Leviton's Duplex LC Adapter Plates**




If you're in doubt, just remember: if you use standard A-B patch cords and follow the color codes above, you will always maintain standard A-B polarity, regardless of the number of the number of segments between the transmitters and receivers.

## Multifiber Polarity Systems

To send data via light signals, a fiber optic link's transmit signal at one end of the cable must match the corresponding receiver at the other end. While this concept might seem simple, it becomes more complex with multi-fiber cables and MPO connectors. Industry standards name three different polarity methods for MPOs: Method A, Method B and Method C:

**Method A** (or straight-through method) uses a trunk with a key up MPO/MTP® connector on one end and a key down MPO/MTP connector on the other end so that the fiber located in Position 1 arrives at Position 1 at the other end. The transmit-to-receive flip occurs in the patch cords.

**Method B** (or inverted method) uses key up connectors on both trunk ends to achieve the transceiver-receiver flip so that the fiber located in Position 1 arrives at Position 12 at the opposite end, the fiber located in Position 2 arrives at Position 11 at the opposite end and so on. This method simplifies the design requirements for trunks and patch cords, but requires specific pairing of cassettes, as the polarity flip occurs in the cassette.

**Method C** (or pair-flipped method) uses a key up connector on one end and a key down on the other end like Method A, but the flip happens within the cable itself where each pair of fibers is flipped so that the fiber in Position 1 arrives at Position 2 at the opposite end, and the fiber in Position 2 arrives at Position 1.

**Universal** polarity looks similar to the Method B configuration, but allows for the same interchangeable cassette on both ends of a Method B trunk in the fiber channel. This reduces the complexity of a fiber network, ensuring consistent polarity and streamlining network deployment.

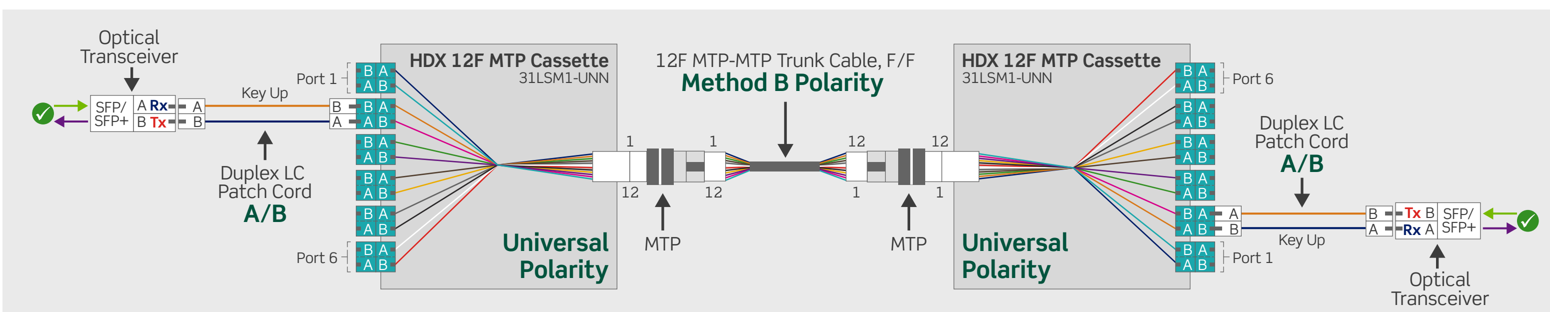
| | Method A | Method B | Method C | Universal |
|---|---|---|---|---|
| Cassettes | Same | Different | Same | Same |
| Trunks | Straight Through | Ferrule Flipped* | Pair Flipped | Ferrule Flipped* |
| Patch Cords | Different | Same | Same | Same |

*The connector ferrule containing the row of fibers is rolled on one side of the cable where fiber from position 12 arrives in position 1.

Once a polarity plan is chosen, it's important that polarity maintenance is consistently checked to make sure transmitters are transmitting to receivers and vice versa. This shouldn't be hard, but systems do need to be tested whenever they're configured or updated. There are several ways to check for polarity, and testing can be done on the trunk (installed portion of the link) or on the individual channels.

Careful planning and consideration is required when deciding on which polarity method to implement. MPO solutions utilizing 24-strand connectors, array/parallel optics polarity and migration strategies using HDX, e2XHD, and SDX components are available on the Leviton website at **Leviton.com/fiber**.

### Universal Polarity



12.

# Migration
## Tactics

As 400 Gb/s switch options entered the market only recently — introduced by manufacturers in late 2018 and early 2019 — adoption has yet to take off. However, many expect 400 Gb/s to see real adoption in 2020-21, and data center market analyst Dell'Oro expects 400 Gb/s shipments to reach 15 million ports by 2023. This section provides an overview of bandwidth trends, and offers network migration options for 100, 200, and 400 Gb/s.

## Trends in Network Speeds

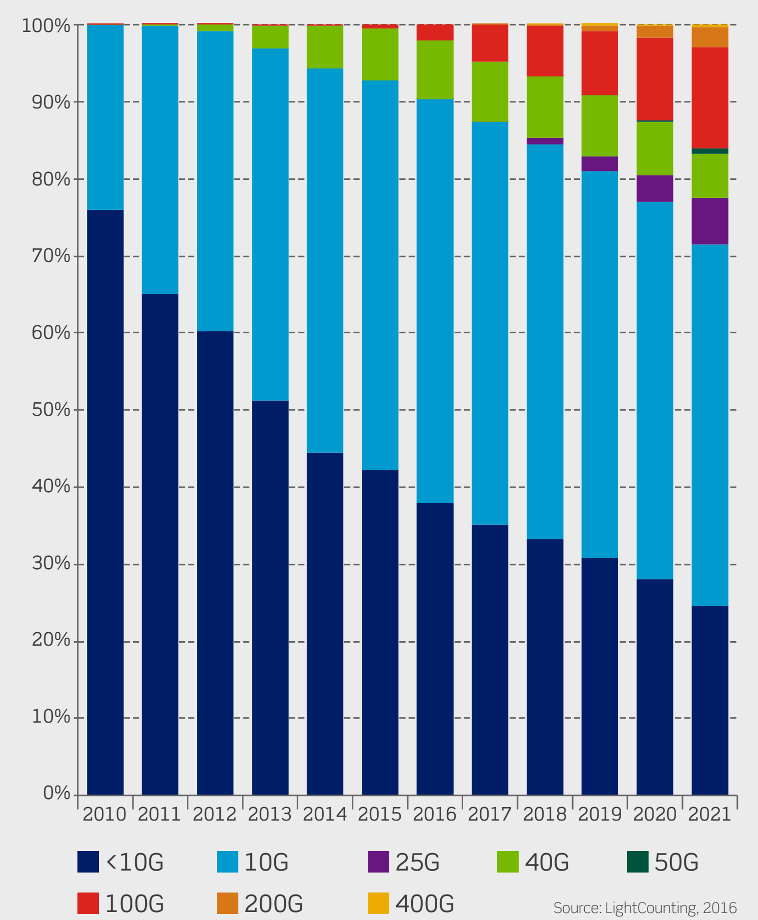
Data centers are rapidly evolving to address rising volumes of network traffic. Faced with increasing bandwidth demand and the need to adapt and scale quickly, many organizations with small or medium data centers have moved to cloud service providers or have outsourced to colocation facilities. In addition, many large enterprise data centers with traditional three-tier architectures are changing to "flatter" leaf-spine architectures, creating lower latency and more scalable designs. As these data centers adapt, one trend has become clear: while both cloud data centers and large enterprise data centers invest heavily in next-generation network infrastructure, they deploy different types of optics and cabling systems.

Today, while 10 Gb/s transceiver modules make up a large portion of the market. 40 Gb/s transceivers will remain steady for the next couple years, but the strongest growth will come from 100 Gb/s and higher, driven by cloud environments. This is an unprecedented number of options that data center managers will need to evaluate and design their networks to support.

Current enterprise data centers primarily use 10 Gb/s switches and 1 Gb/s servers. These networks are migrating to 25 or 40 Gb/s uplinks and 10 Gb/s servers.

Cloud networks have operated at 40 Gb/s uplinks and 10 Gb/s at the server for the past several years. As pointed out earlier, these networks will move to 100 Gb/s uplinks and 25 Gb/s at the server. We can also expect future migrations to 200 and 400 Gb/s uplinks and 50 and 100 Gb/s at the server.

**Transceiver Modules by Speed, Percent of Total**



Source: LightCounting, 2016

As this trend continues, the market in general will find single-mode a more enticing option. For example, 100G-PSM4 single-mode technology, created in 2014 by a multi-source agreement group, is currently the same price as 100G-SR4 multimode transceivers. PSM4 transceivers were specifically designed as a low-cost option for 500 meters or less, using an 8-fiber MPO/MTP® connection. Just as important, the price for long-reach single-mode solutions such as 100G-LR4 has dropped and will continue to drop over the next several years.

12.

## Looking Ahead to 200/400 Gb/s

400 Gb/s switches — first introduced in late 2018 and based on 12.8 Tb/s chips — bring not only much faster speeds but greater network density. The ability for switches to enable high density breakout scenarios with 100 Gb/s ports translates into a lower total cost of ownership per port.

Transceiver shipments of 100 GbE have grown much faster than expected. The most popular options have been 100G-CWDM4, a single-mode two-fiber solution with a two-kilometer reach, and 100G-SR4, a 100-meter multimode solution. These options will continue to see strong adoption in the next several years, but 100 Gb/s ports are expected to peak in 2020 or 2021 and make way for 400 Gb/s switches, according to Dell'Oro.

While new 400 Gb/s switches come at a significant cost, they will likely drop in price as early adopters in the cloud service provider and telecom industries purchase more 400 Gb/s switches over the next several years. Those cloud providers continue to gobble up more of the data center space, as large players such as Amazon AWS, Microsoft Azure, Google, and IBM are predicted to make up half of all data center servers by 2021, according to the Cisco Global Cloud Index. These data centers are moving to 100, 200, and 400 Gb/s uplinks now or in the near future.

## Transceiver Options

One variable yet to be resolved is the number of fiber strands used to deliver 400 Gb/s. Currently, switch manufacturers have plans for connectors with 2, 8, 16, 24, and even 32 fibers. Given how quickly the market is responding to higher speeds — and how measured standards bodies can be — some of the options introduced are proprietary or based on multisource agreements (MSAs). Between proprietary and standards-based options, there are now a range of options, but a few favorites are emerging.

> "switch manufacturers have **plans for** connectors with 2, 8, 16, 24, and even 32 fibers"

The latest transceivers for 200 and 400 Gb/s introduce several new terms that indicate the number of channels and fiber modes: SR8, DR4, and FR4. The "SR" suffix denotes short reach (100 meter) multimode, with "8" indicating 8 optical channels. The "DR" refers to a 500-meter reach, with "4" for 4 optical channels. The "FR" denotes a 2-kilometer reach, with the "4" for 4 optical channels.

With 200 Gb/s transceiver options, only two are available on the market today: 2x100-PSM4 single-mode and 2x100-SR4 multimode. These are proprietary options introduced by Cisco, and they both rely on 24-fiber MTP® connectors. While transceiver options using two LC fibers or 8-fiber MTP connectors (1, 2, and 4 below) are defined in IEEE standards, they have not yet been introduced to the market.

continued

## Transceiver Options Continued

The transceiver types outlined in yellow below highlight the options likely to become the most common over the next several years. Both 400G-FR4 and 400G-SR4.2, originally introduced MSA between manufacturers, are currently in development by IEEE. 400G-FR4 is being drafted under IEEE P802.3cu and is expected to be published in late 2020, while 400G-SR4.2 will be defined by IEEE P802.3cm, with a target publication date of December 2019. The 400G-SR4.2 transceiver specification created by the 400G BiDi MSA is called 400G-BD4.2. Other 400 Gb/s transceivers not mentioned on this list include interfaces under development that will reach beyond 10 kilometers.

It is important to note that the majority of 100, 200 and 400 Gb/s transceiver options are for single-mode networks, due to the bandwidth and distance capabilities. This trend is also partially a result of decreasing cost — as adoption by cloud companies with major purchasing power have reduced the cost of single-mode optics — and recent standards committee activities continuing to promote more single-mode options for higher speeds.

| 200G Transceivers | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| | 200G-FR4 | 200G-DR4 | 2X100-PSM4 | 200G-SR4 | 2X100-SR4 | 2x100G-CWDM4 |
| STD | IEEE | IEEE | Prop. | IEEE | Prop. | Prop. |
| MFR | None | None | Cisco | None | Cisco | Cisco |
| Form Factor | TBD | TBD | QSFP-DD | TBD | QSFP-DD | QSFP-DD |
| Breakout Option | No | Yes | Yes | Yes | Yes | Yes |
| Fiber Type | OS2 | OS2 | OS2 | OM3 / OM4 /OM5 | OM3 / OM4 /OM5 | OS2 |
| Distance (meters) | 2,000 | 500 | 500 | 70 / 100 / 100 | 70 / 100 / 100 | 2,000 |
| # of fibers | 2 | 8 | 24 | 8 | 24 | 4 |
| Connector | LC | 12F MTP® | 24F MTP | 12F MTP | 24F MTP | CS |

| 400G Transceivers | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| | 400G-FR4* | 400G-DR4 | 400G-XDR4 (DR4+) | 400G-SR8* | 400G-SR4.2 (BD)* | 400G-2FR4 |
| STD | IEEE/MSA | IEEE | Prop. | IEEE | IEEE/MSA | Prop. |
| MFR | Arista, Cisco, Juniper | Arista, Cisco, Juniper | Arista, Juniper | Arista | Cisco | Arista |
| Form Factor | QSFP-DD, OSFP | QSFP-DD, OSFP | QSFP-DD, OSFP | OSFP | QSFP-DD | OSFP |
| Breakout Option | No | Yes | Yes | Yes | Yes | Yes |
| Fiber Type | OS2 | OS2 | OS2 | OM3, OM4, OM5 | OM3, OM4, OM5 | OS2 |
| Distance (meters) | 2,000 | 500 | 2,000 | 70 / 100 / 100 | 70 / 100 / 150 | 2,000 |
| # of fibers | 2 | 8 | 8 | 16 | 8 | 4 |
| Connector | LC | 12F MTP | 12F MTP | 16F / 24F MTP | 12F MTP | CS |

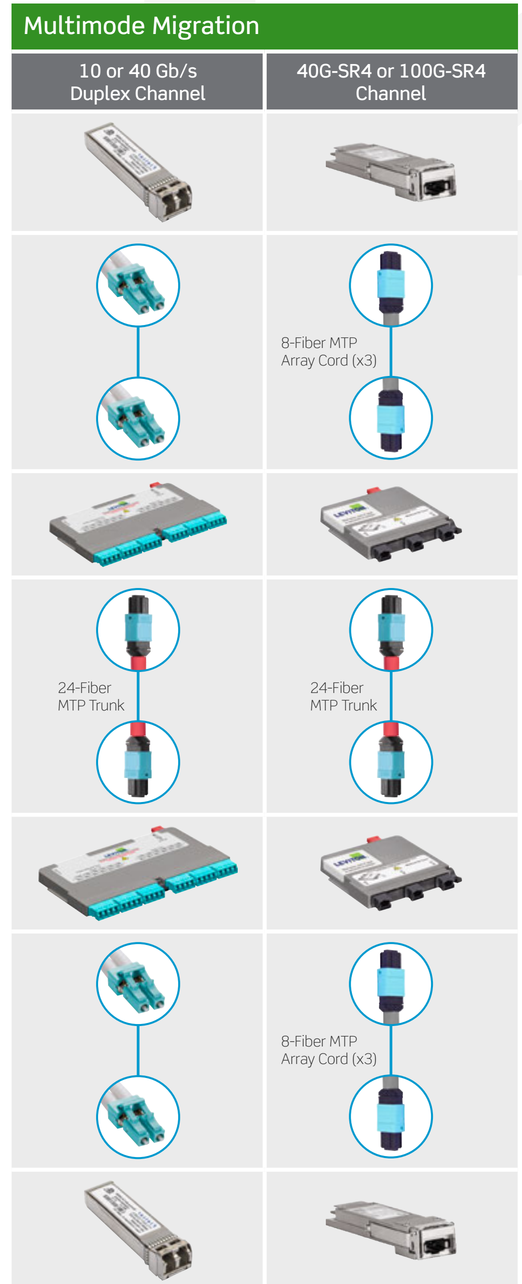
* For SR4.2, IEEE802.3cm estimated to be published in January 2020. For FR4, IEEE802.3cu estimated to be published in Q4-2020
Notes: Does not include long reach 10 Km options. "SR16" or "FR8" options not available on market. Other proprietary options are being developed

## Enterprise Cabling Network Migration Options

The majority of enterprise data centers already have multimode cabling installed, and 85% of these optic links are 150 meters or less. As mentioned earlier, most of today's enterprise data center applications use 1 Gb/s down to the server, with 10 Gb/s uplinks. With over 12 different 40 Gb/s transceiver options and 10 different 100 Gb/s transceiver options available on the market, infrastructure engineers must design their networks to be flexible and able to support any of these potential topologies. Below are some ideal migration paths for enterprise data centers to take advantage of existing multimode cabling while moving to 10, 40, and 100 Gb/s in the future.

Using a **24-fiber trunk cable backbone (Base24)** and LC patching, data centers can support 1 and 10 Gb/s up to 100 Gb/s in several current transceiver form factors, including SFP+, QSFP28, CFP, CFP2 and CPAK. This exact cabling design — including trunks, cassettes, and patch cords — also supports 40 and 100 Gb/s when using Wave Division Multiplexing (WDM) technology, such as Cisco or Arista QSFP+ Bi-Directional (BiDi) transceivers.

When migrating to a 40GBASE-SR4 or 100G-SR4 switch port, one only needs to make a simple change at the patching environment. The same 24-fiber backbone stays in place, and the MTP®-LC cassettes are swapped out for MTP-MTP conversion cassettes that break out to three 8-fiber MTP ports. This provides 100 percent fiber utilization and creates a higher return on cabling investment. It is an ideal strategy that minimizes costly and time-consuming "rip-and-replace" upgrades to trunk cables. The allowable link distances shorten to the 70-meter range over OM4 fiber. This distance still covers the majority of connections in an enterprise data center application.



## Cloud Network Migration Options

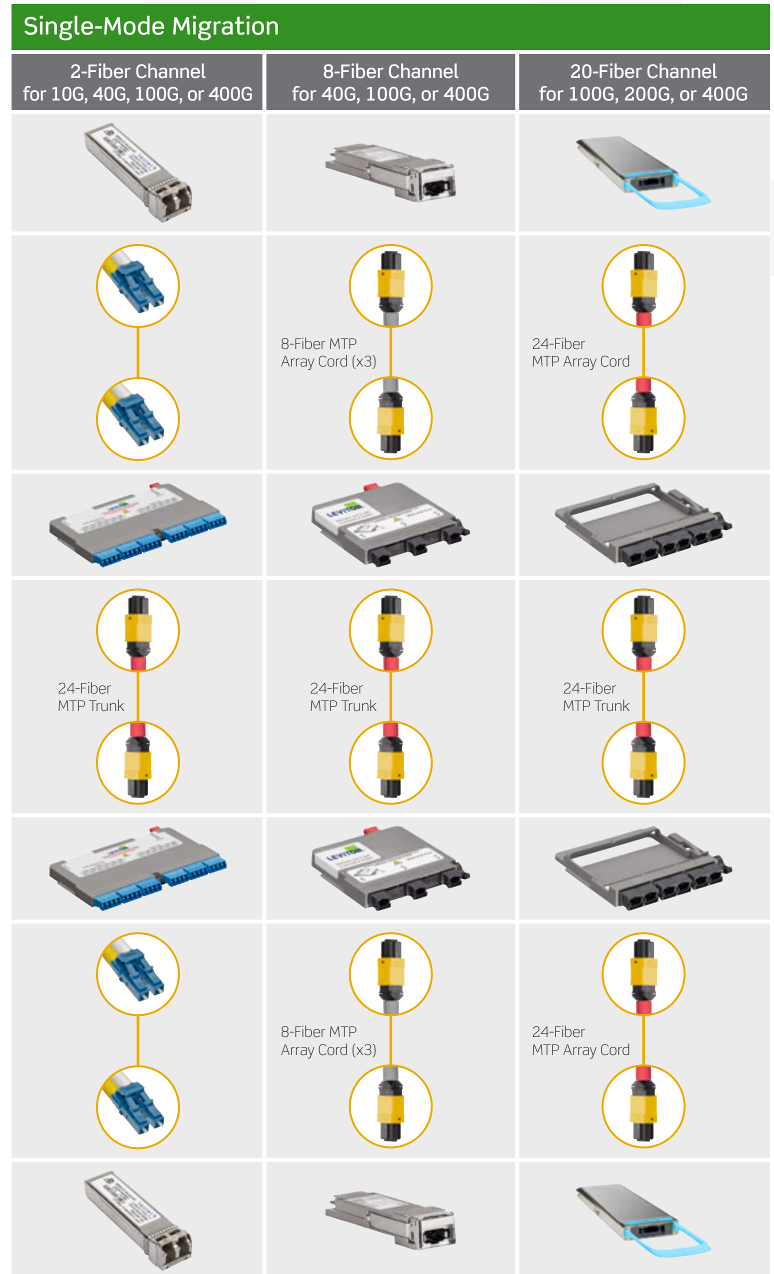
Most cloud data centers are already using single-mode or are planning to move to single-mode soon. Around 97 percent of single-mode links for these data centers are 350 meters or less. Based on this fact, there will be little need for a minimally extended multimode reach over OM5. The following cabling designs prepare networks for next-generation speeds while minimizing a rip-and-replace approach. Again, with so many transceiver options available and more on the horizon, data center managers should design their networks with the flexibility to support a range of upgrades and new technology.

When using 10G solutions today, you can deploy a 24-fiber backbone (Base24) trunking solution that will carry through multiple upgrades in the future. While duplex LC connections to SFP+ transceivers are the typical form factor for 10G data rates, there are 40G optics available today — and 100G solutions in the future — that can be supported by an LC interface. By selecting the right family of transceivers, you can use the cabling system below to support a range of optics, including 40GBASE-LR4/LRL4 and Arista 40G Universal QSFP+ options, as well as 100GBASE-LR4/LRL4 in CFP2/CPAK or QSFP28 form factors. The same infrastructure will support 100G-FR2, 200G-FR4, and 400G-FR8 in the future.

If data center managers want to take advantage of low-cost PSM4 optics mentioned earlier, they can migrate to 8 fibers per switch port. Upgrading from the previous 2-fiber channel means replacing MTP®-LC cassettes with MTP-MTP cassettes that break into three 8-fiber ports. The same 24-fiber trunk stays in place. For 40G speeds, this design supports 40GBASE-PLRL4 and 4x10G-LR/IR in the QSFP+ form factor. For 100G, it will support 100G-PSM4, and it will support future applications of 200G-DR4 and 400G-DR4.

One other option for delivering 100G is through the 10G ecosystem, creating 100G using 10 lanes of 10G. This design — using the same 24-fiber trunk but swapping in MTP passthrough cassettes and extending 20-fiber connections to the equipment — supports Cisco CPAK 10x10G-LR modules.

While a 24-fiber backbone is used in all the channels above, it is not required to support next-generation upgrades; 12-fiber MTP trunk cables are also available. However, the 24-fiber solution is a key piece in establishing the most flexibility when migrating to 400 Gb/s.



# 13. Network Monitoring with Passive Optical TAPs

Network visibility is a top priority for many data center managers. When networks become larger and more complex, monitoring for performance and security is no longer optional, it becomes critical. Industries such as financial, medical, and telecom markets need visibility tools to manage their networks and handle troubleshooting quickly and efficiently. And it needs to be done without adding any disruptions to the network.

That's why more data center managers are using fiber optic TAPs to monitor network links.

## What is a TAP?

A traffic analysis point (TAP) is designed to allow traffic being sent over a fiber optic path to be monitored for security or network performance. The tap is positioned in the passive cabling system between a host and recipient device.

TAPs create greater visibility into a network. They provide a window into your data for security or surveillance. But they also make it possible to look at data packets and advise the network administrator on how the network is performing in real time.

Analyzing data in real time can be as simple as viewing a bank transaction or seeing if a health care record was placed in the correct file. And when there are millions of transactions happening constantly, TAPs will help find any bottlenecks in your network.

## Two Types of TAPs

There are two primary TAP types available: active solutions and passive solutions. Active optical TAPs are primarily used for specialized applications that require manipulation of the signal sent to the monitoring port. TAPs require power to generate the signals, and any power disruptions would impact the functionality of any of the active solutions in your network.

Passive optical TAPs are much more common in enterprise data centers, as they offer a number of distinct advantages:

- TAPs pass all link traffic for monitoring. Even corrupt data will not be rejected, so users are able to see everything in real time.
- Unlike SPAN ports, there is no programming or switch configuring required with a passive TAP.
- They are invisible to the network: they place no burden on the network or any changes to packets or data transmitted through the link.
- They offer full duplex port monitoring with a transmit and receive path that is scalable at data rates. This means you won't encounter oversubscription when using a passive TAP.
- TAPs that are built into the existing patching environment reduce the number of connections required in the structured cabling, taking at least two connections out of the link.

"**no programming** or **switch configuring** required with a passive TAP"

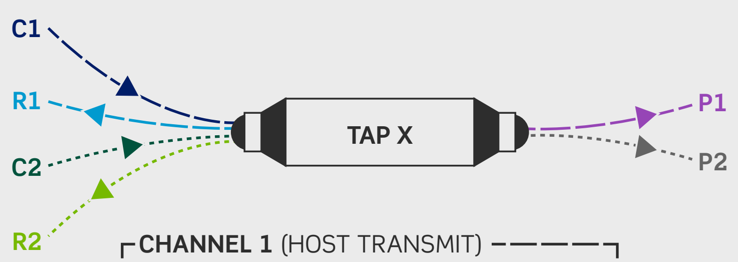
Standards 1
Applications 2
Architecture 3
Edge Data Centers 4
Fiber Selection 5
Category-Rated Copper 6
Patching 7
Field Termination 8
Pre-Terminated Cable 9
Multi-Fiber Connectors 10
Polarity 11
Migration Tactics 12
Network Monitoring 13
Data Center Terms 14

## How a Passive TAP Works

An optical TAP is essentially a splitter that divides the light into two or more outputs. It can also combine two or more inputs into a single output. For example, in the figure below, the input in Channel 1 (C1) from the host is passed through the TAP to the recipient (P1). The transmit not only pushes through the live traffic to the recipient, it also transmits through the TAP to the monitoring tool (R1).

There are two primary technology options for creating a TAP splitter: a fused biconical taper, or thin film filters, as shown at right. The fused biconical taper is the older of the two technologies, and while it is easier to produce than thin film filters, it creates a higher insertion loss. The thin film filters — which are made up of a stack of layers of refraction which both reflect and transmit light — is the preferred method and is used in Leviton TAP cassettes. It provides a lower loss that is critical for a TAP solution, since that loss can impact the power budget in the link.

### TAP Inputs and Outputs



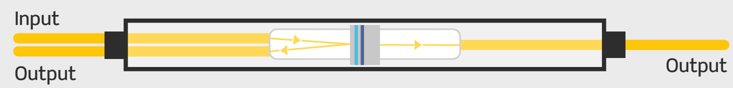

**CHANNEL 1** (HOST TRANSMIT)
- **C1** = COM 1 (INPUT FROM HOST)
- **R1** = REFLECT 1 (OUTPUT HOST Tx TO MONITOR)
- **P1** = PASS 1 (OUTPUT TO RECIPIENT)

**CHANNEL 2** (RECIPIENT TRANSMIT)
- **C2** = COM 2 (INPUT FROM RECIPIENT)
- **R2** = REFLECT 2 (OUTPUT RECIPIENT Tx TO MONITOR)
- **P2** = PASS 2 (OUTPUT TO HOST)

### TAP Splitter Types

Fused Bioconical Taper


Thin Film Filter




The construction of a splitter makes the flow of data directionally specific. The monitoring outputs (reflect fibers) only receive traffic. In each TAP, one monitoring/reflect output receives transmitted traffic from the original host device and the other receives response transmission from the recipient device.

Each TAP cassette has multiple tap splitters based on the number of designed outputs. Each signal (per TAP splitter) is split to “live” and “monitoring” output signals at a pre-determined ratio — typically 50/50 or 70/30 (70 live and 30 monitoring).

A 70/30 split ratio is generally the preferred method, as it dedicates a higher percentage for network traffic, avoiding any dropped packets. The 70/30 split is most commonly used in 1 Gb/s and 10 Gb/s networks. However, at higher speeds such as 40 Gb/s and 100 Gb/s, the 50/50 ratio is more commonly used in order to meet power budgets.

continued

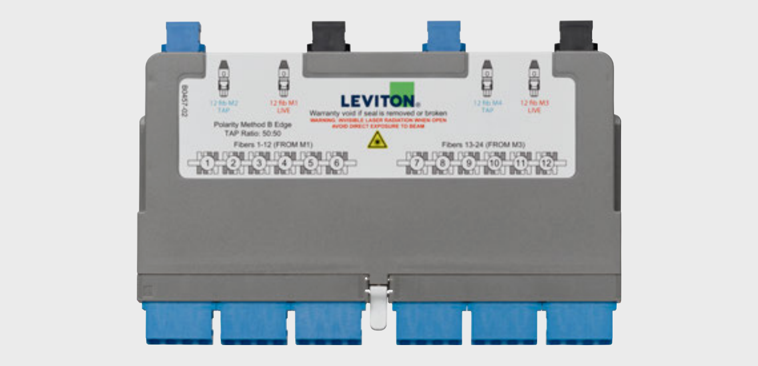
## How a Passive TAP Works Continued

The chart below lists the maximum insertion loss for TAP cassettes in both 50/50 and 70/30 split ratios. The numbers listed include the loss from the splitter inside, as well as the connections on the rear and front. TAP cassettes on the monitoring side can become much lossier than conventional network cassettes, so it is important to consider low-loss solutions for these connections.

| Maximum Insertion Loss for TAPs | | MTP®-LC | | MTP-MTP | |
|---|---|---|---|---|---|
| Multimode Optical TAPs | Split Ratio | 50/50 | 70/30 | 50/50 | 70/30 |
| | Max Insertion Loss (Network) | 4.3 dB | 2.3 dB | 4.3 dB | 2.3 dB |
| | Max Insertion Loss (Monitor) | 4.3 dB | 6.3 dB | 4.5 dB | 6.5 dB |
| Single-Mode Optical TAPs | Split Ratio | 50/50 | 70/30 | 50/50 | 70/30 |
| | Max Insertion Loss (Network) | 4.4 dB | 2.9 dB | 4.6 dB | 3.0 dB |
| | Max Insertion Loss (Monitor) | 4.4 dB | 6.6 dB | 4.6 dB | 7.0 dB |

Traditionally, when installing a passive TAP, one would add a dedicated TAP panel and extend a patch cord from the TAP panel to the network patching environment. In contrast, Leviton has built TAP technology into its existing cassette footprint so it can be part of the patching environment instead of an additional element added to the network. This integration eliminates the need for a dedicated TAP panel and therefore removes two additional connections from the channel.

The integrated design also conserves rack space, since no additional TAP panel is required. With TAP ports on the rear of the cassette instead of front, no patching density is lost. In the image below, the HDX TAP cassette includes blue MTP Taps ports on the rear. This design allows for monitoring of all 72 ports in a 1RU HDX panel.




Passive optical TAPs have become a popular choice for creating network visibility and enhancing network security. They place no burden on the network, and don't contribute to dropped packets. The Leviton HDX2 makes adding TAPs easy, as it can be built into the existing patching environment, reducing the number of connections required in the structured cabling infrastructure, and in turn lowering channel insertion loss. These passive TAPs also include low-loss connectivity that will contribute to the best channel performance for your network.

You can learn more about HDX2 TAP cassettes and the HDX patching platform at Leviton.com/HDX.

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14.

# Definition of Terms

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## Definition of Terms

**Access floor**: A system consisting of completely removable and interchangeable floor panels that are supported on adjustable pedestals or stringers (or both) to allow access to the area beneath.

**Access provider**: The operator of any facility that is used to convey telecommunications signals to and from a customer premises.

**Administration**: The method for labeling, identification, documentation and usage needed to implement moves, additions and changes of the telecommunications infrastructure.

**Backbone**: A facility (e.g., pathway, cable or bonding conductor for Cabling Subsystem 2 and Cabling Subsystem 3.

**Backbone cable**: See backbone.

**Base8**: Refers to the fiber count (8 fibers) used in the MPO/MTP® connections of the structured cabling (fiber trunk).

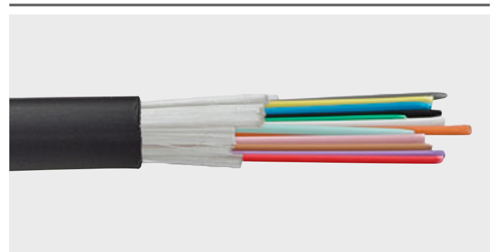
**Base12**: Refers to the fiber count (12 fibers) used in the MPO/MTP® connections of the structured cabling (fiber trunk).

**Base24**: Refers to the fiber count (24 fibers) used in the MPO/MTP® connections of the structured cabling (fiber trunk).

**Bonding**: The joining of metallic parts to form an electrically conductive path.

**Cabinet**: A container that may enclose connection devices, terminations, apparatus, wiring, and equipment.

**Cable**: An assembly of one or more insulated conductors or optical fibers, within an enveloping sheath.

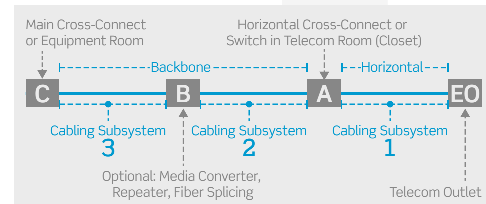


**Cabling**: A combination of all cables, jumpers, cords, and connecting hardware.

**Cabling Subsystem 1**: Cabling from the equipment outlet to Distributor A, Distributor B, or Distributor C. See Horizontal Cabling.

**Cabling Subsystem 2**: Cabling between Distributor A and either Distributor B or Distributor C (if Distributor B is not implemented).

**Cabling Subsystem 3**: Cabling between Distributor B and Distributor C.



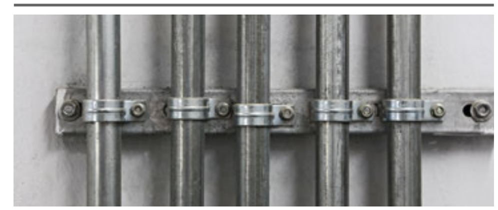

**Centralized cabling**: A cabling configuration from an equipment outlet to a centralized cross-connect using a continuous cable, an interconnection, or a splice.

**Channel**: The end-to-end transmission path between two points connected to application-specific equipment.

**Common equipment room**: An enclosed space used for equipment and backbone interconnections (telecommunications) for more than one tenant in a building or campus.

**Computer room**: An architectural space whose primary function is to accommodate data processing equipment.

**Conduit**: 1) A raceway of circular cross-section. 2) A structure containing one or more ducts.



**Conduit sizes**: For the purposes of this Standard, conduit sizes are designated according to metric designator and trade size as shown below:

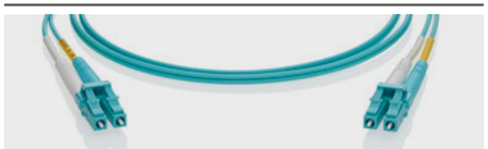
| Metric Designator | Trade Size |
|---|---|
| 16 | 1/2 |
| 21 | 3/4 |
| 27 | 1 |
| 35 | 1 1/4 |
| 41 | 1 1/2 |
| 53 | 2 |
| 63 | 2 1/2 |
| 78 | 3 |
| 91 | 3 1/2 |
| 103 | 4 |
| 129 | 5 |
| 155 | 6 |

**Connecting hardware**: A device providing mechanical cable terminations.

**Consolidation point**: A connection facility within cabling subsystem 1 for interconnection of cables extending from building pathways to the equipment outlet.

**Converged Network Adapter (CNA)**: a computer input/output device that combines the functionality of a host bus adapter (HBA) with a network interface controller (NIC).

**Cord (telecommunications)**: An assembly of cord cable with a plug on one or both ends.



**Cross-connect**: A facility enabling the termination of cable elements and their interconnection or cross- connection.

**Cross-connection**: A connection scheme between cabling runs, subsystems, and equipment using patch cords or jumpers that attach to connecting hardware on each end.

**Data center**: A building or portion of a building whose primary function is to house a computer room and its support areas.

**Demarcation point**: A point where the operational control or ownership changes.

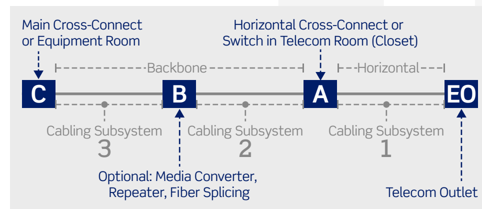
**Dew point**: The temperature to which air must be cooled (assuming constant air pressure and moisture content) to reach a relative humidity of 100% (i.e. saturation).

**Disk storage**: a general category of storage mechanisms where data are recorded by various electronic, magnetic, optical, or mechanical changes to a surface layer of one or more rotating disks.

**Distributor A**: Optional connection facility in a hierarchical star topology that is cabled between the equipment outlet and Distributor B or Distributor C.

**Distributor B**: Optional intermediate connection facility in a hierarchical star topology that is cabled to Distributor C.

**Distributor C**: Central connection facility in a hierarchical star topology.




**Dry-bulb temperature**: The temperature of air measured by a thermometer freely exposed to the air but shielded from radiation (e.g. sunlight, radiant heat) and moisture.

**Earthing**: See grounding.

**Electromagnetic interference**: Radiated or conducted electromagnetic energy that has an undesirable effect on electronic equipment or signal transmissions.

**Entrance point (telecommunications)**: The point of emergence for telecommunications cabling through an exterior wall, a floor, or from a conduit.

**Entrance room or space (telecommunications)**: A space in which the joining of inter or intra building telecommunications cabling takes place.

**Equipment cord**: See cord.

**Equipment distribution area**: The computer room space occupied by equipment racks or cabinets.

**Equipment outlet**: Outermost connection facility in a hierarchical star topology.


**Equipment room (telecommunications)**: An environmentally controlled centralized space for telecommunications equipment that usually houses Distributor B or Distributor C.

**Ethernet:** A system for connecting a number of computer systems to form a local area network, with protocols to control the passing of information and to avoid simultaneous transmission by multiple systems.

**External network interface**: Interface between the computer room cabling and external cabling.

**Fiber optic**: See optical fiber.

**Fibre Channel**: high-speed network technology (commonly running at 2, 4, 8, 16, and 34-gigabit per second rates) primarily used to connect computer data storage.

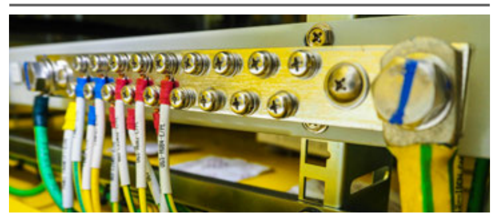
**Fibre Channel over Ethernet (FCoE)**: a computer network technology that encapsulates Fibre Channel frames over Ethernet networks. This allows Fibre Channel to use 10 Gigabit Ethernet networks (or higher speeds) while preserving the Fibre Channel protocol.

**FICON (Fibre Connection)**: high-speed input/output (I/O) interface for mainframe computer connections to storage devices.

**Ground**: A conducting connection, whether intentional or accidental, between an electrical circuit (e.g., telecommunications) or equipment and the earth, or to some conducting body that serves in place of earth.

**Grounding**: The act of creating a ground.

**Grounding conductor**: A conductor used to connect the grounding electrode to the building's main grounding busbar.



**Horizontal cabling**: Cabling Subsystem 1.

**Horizontal cross-connect**: Distributor A.

**Horizontal distribution area**: A space in a data center where a horizontal cross-connect is located.

**Identifier**: An item of information that links a specific element of the telecommunications infrastructure with its corresponding record.

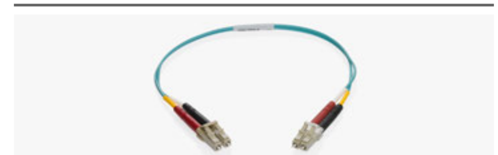
**Infrastructure (telecommunications)**: A collection of those telecommunications components, excluding equipment, that together provide the basic support for the distribution of information within a building or campus.

**Interconnection**: A connection scheme that employs connecting hardware for the direct connection of a cable to another cable without a patch cord or jumper.

**Intermediate cross-connect**: Distributor B.

**Intermediate distribution area**: A space in a data center where an intermediate cross-connect is located.

**Jumper**: 1) An assembly of twisted-pairs without connectors, used to join telecommunications circuits/links at the cross-connect. 2) A length of optical fiber cable with a connector plug on each end.



**Link**: A transmission path between two points, not including equipment and cords. Liquidtight: Impervious to moisture ingress.

**Mainframe**: a very large computer capable of handling and processing very large amounts of data quickly. They are used by large institutions, such as government agencies and large corporations.

**Main cross-connect**: Distributor C.

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**Main distribution area**: The space in a data center where the main cross-connect is located.

**Mechanical room**: An enclosed space serving the needs of mechanical building systems.

**Media (telecommunications)**: Wire, cable, or conductors used for telecommunications.

**Modular jack**: A female telecommunications connector that may be keyed or unkeyed and may have 6 or 8 contact positions, but not all the positions need be equipped with jack contacts.

**Multimode optical fiber**: An optical fiber that carries many paths of light.

**Network convergence**: the efficient coexistence of telephone, video and data communication within a single network. (LAN and SAN on the same switch)

**Optical fiber**: Any filament made of dielectric materials that guides light. Optical fiber cable: An assembly consisting of one or more optical fibers.

**Parallel Sysplex**: a cluster of IBM mainframes acting together as a single system image.

**Patch cord**: 1) A length of cable with a plug on one or both ends. 2) A length of optical fiber cable with a connector on each end.

**Patch panel**: A connecting hardware system that facilitates cable termination and cabling administration using patch cords.

**Pathway**: A facility for the placement of telecommunications cable.

**Plenum**: A compartment or chamber to which one or more air ducts are connected and that forms part of the air distribution system.

**Port**: A connection point for one or more conductors or fibers.

**Post-tensioned concrete**: A technique for reinforcing concrete. Post-tensioning tendons, which are prestressing steel cables inside plastic ducts or sleeves, are positioned in the forms before the concrete is placed. Afterwards, once the concrete has gained strength but before the service loads are applied, the cables are pulled tight, or tensioned, and anchored against the outer edges of the concrete.

**Post-tension floor**: A floor that is constructed of post-tensioned concrete.

**Private branch exchange**: A private telecommunications switching system.

**Pull box**: A housing located in a pathway run used to facilitate the placing of wire or cables.

**Rack**: Supporting frame equipped with side mounting rails to which equipment and hardware are mounted.

**Radio frequency interference**: Electromagnetic interference within the frequency band for radio transmission.

**Return loss**: A ratio expressed in dB of the power of the outgoing signal to the power of the reflected signal.

**SAN (Storage Area Network)**: high-speed network of storage devices that also connects those storage devices with servers. SAN storage devices can include tape libraries, and, more commonly, disk-based devices.

**Screen**: An element of a cable formed by a shield.

**Service provider**: The operator of any service that furnishes telecommunications content (transmissions) delivered over access provider facilities.

**Sheath**: See cable sheath.

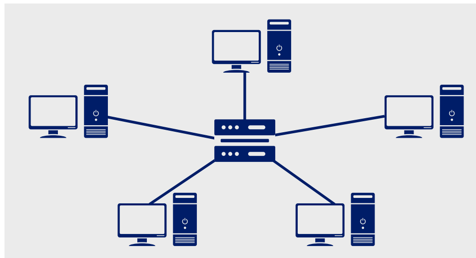
**Shield**: 1) A metallic layer placed around a conductor or group of conductors. 2) The cylindrical outer conductor with the same axis as the center conductor that together form a coaxial transmission line.

**Single-mode optical fiber**: An optical fiber that carries only one path of light.

**Space (telecommunications)**: An area used for housing the installation and termination of telecommunications equipment and cable.

**Splice**: A joining of conductors, meant to be permanent.

**Star topology**: A topology in which telecommunications cables are distributed from a central point.



**Tape Data Storage**: a system for storing digital information on magnetic tape using digital recording. Modern magnetic tape is most commonly packaged in cartridges and cassettes.

**Telecommunications**: Any transmission, emission, and reception of signs, signals, writings, images, and sounds, that is, information of any nature by cable, radio, optical, or other electromagnetic systems.

**Telecommunications entrance point**: See entrance point (telecommunications).

**Telecommunications entrance room or space**: See entrance room or space (telecommunications).

**Telecommunications equipment room**: See equipment room (telecommunications).

**Telecommunications infrastructure**: See infrastructure (telecommunications).

**Telecommunications media**: See media (telecommunications).

**Telecommunications room**: An enclosed architectural space for housing telecommunications equipment, cable terminations, or cross-connect cabling.

**Telecommunications space**: See space (telecommunications).

**Termination block**: A connecting hardware system that facilitates cable termination and cabling administration using jumpers.

**Topology**: The physical or logical arrangement of a telecommunications system.

**Uninterruptible power supply**: A buffer between utility power or other power source and a load that requires continuous precise power.

**Wire**: An individually insulated solid or stranded metallic conductor.

**Wireless**: The use of radiated electromagnetic energy (e.g., radio frequency and microwave signals, light) traveling through free space to transport information.

**Zone distribution area**: A space in a data center where an equipment outlet or a consolidation point is located.

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14.

## Acronyms and Abbreviations

**AHJ**: authority having jurisdiction

**ANSI**: American National Standards Institute

**ASHRAE**: American Society of Heating, Refrigerating, and Air-Conditioning Engineers

**BICSI**: Building Industry Consulting Service International

**BNC**: bayonet Neill-Concelman

**CCTV**: closed-circuit television

**CER**: common equipment room

**CP**: consolidation point

**CPU**: central processing unit

**CSA**: Canadian Standards Association International

**DSX**: digital signal cross-connect

**ECA**: Electronic Components Association

**EDA**: equipment distribution area

**EIA**: Electronic Industries Alliance (Note: ceased operation December 31, 2010. EIA standards are managed by ECA)

**EMI**: electromagnetic interference

**EMS**: energy management system

**ENI**: external network interface

**EO**: equipment outlet

**HC**: horizontal cross-connect

**HDA**: horizontal distribution area

**HVAC**: heating, ventilation and air conditioning

**IC**: intermediate cross-connect

**IDA**: intermediate distribution area

**IDC**: insulation displacement contact

**IEEE** - Institute of Electrical and Electronics Engineers

**ISO** - International Organization for Standardizations

**KVM**: keyboard, video, mouse

**LAN**: local area network

**LFMC**: liquidtight flexible metallic conduit

**LFNC**: liquidtight flexible non-metallic conduit

**MC**: main cross-connect

**MDA**: main distribution area

**NEC®**: National Electrical Code®

**NEMA**: National Electrical Manufacturers Association

**NFPA**: National Fire Protection Association

**OSHA**: Occupational Safety and Health Administration

**PBX**: private branch exchange

**PDU**: power distribution unit

**RFI**: radio frequency interference

**SAN**: storage area network

**SDH**: synchronous digital hierarchy

**SONET**: synchronous optical network

**STM**: synchronous transport model

**TIA**: Telecommunications Industry Association

**TNC**: threaded Neill-Concelman

**TR**: telecommunications room

**UL**: Underwriters Laboratories Inc

**UPS**: uninterruptible power supply

**WAN**: wide area network

**ZDA**: zone distribution area

## Units of Measure

**A**: ampere

**dB**: decibel

**°C**: degrees Celsius

**°F**: degrees Fahrenheit

**ft**: feet, foot

**in**: inch

**kb/s**: kilobit per second

**km**: kilometer

**kPa**: kilopascal

**kVA**: kilovoltamp

**kW**: kilowatt

**lbf**: pound-force

**m**: meter

**MHz**: megahertz

**mm**: millimeter

**nm**: nanometer

**µm**: micrometer (micron)

LEVITON®

Today's networks must be fast and reliable, with the flexibility to handle ever-increasing data demands. Leviton can help expand your network possibilities and prepare you for the future. Our end-to-end cabling systems feature robust construction that reduces downtime, and performance that exceeds standards. We offer quick-ship make-to-order solutions from our US and UK factories. We even invent new products for customers when the product they need is not available. All of this adds up to the **highest return** on **infrastructure investment**.


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