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November/December 2018
Volume 39, Number 6

Evolution of Cabling Infrastructure Design and IoT Compatibility

PLUS:

- Multimode Optical Fiber Networks
- New Data Center Testing Methods
- NFPA 72 Updates

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From the President, Jeff Beavers, RCDD, OSP, CFHP

A Digital Moo and You: ICT Down on the Farm (I-C-T-E-I-E-I-O)

The opening keynote speaker at the recent 2018 BICSI Fall Conference was Jack Uldrich. He captivated our audience with his BIG AHA message, explaining how Awareness, Humility and Action interplay to help us confront a quickly changing world, including the exponential growth of emerging technologies. The closing keynote speaker was Patrick Sweeney who spoke about the power of fear to transform our lives and fuel innovation and growth as we take action.

On a recent trip, with teenagers in tow, to visit my wife's family in rural Iowa, my father-in-law mentioned that the electric cooperative (co-op) was planning to install fiber optic cable and that he "didn't know why we'd need fiber out here." Unaware of how quickly technology was changing, I began to explain to him that we were now accessing his wireless network, with broadband delivered to his house (an acreage) via fixed wireless with line-of-site connection to the water tower a few miles away. Undoubtedly, our mobile devices added new demands to his broadband connection.

I continued to explain that the co-op would utilize fiber for its own use, such as SCADA (supervisory control and data acquisition) and for its own corporate communications to substations and other facilities. With infrastructure already in place, electric co-ops are key players to deploy fiber-based services to the rural community and high-speed internet would provide access to information for education and connectivity for industry and healthcare. I emphasized that with this technology, the town might someday take advantage of telemedicine.

Our discussion about technology led us to a neighboring farm that had robotic cow milking machines. The first indicator of technology and mission critical operations was the pad mounted generator next to the driveway. Each of the cows had RFID tags, an early application of IoT. As a cow entered the milking stall, data on the cow was read by the machine. If the cow was not ready for milking, gates opened and the cow exited. If the cow was ready for milking, a specific portion of feed measured by the cow's data was dispensed into a bucket. As the cow began to eat, the robot quickly attached milking apparatus, guided by cameras and lasers, to each teat of the cow's udder. A computer screen showed the yield and flow of each teat. Upon completion of the milking, the robotic arms removed the apparatus, sprayed disinfectant, returned it to a holder, and opened the gate for the cow to exit. The cow's medical history is electronically shared with the veterinarian, who can coordinate a visit with any necessary medications.

Augmented with pliers and baling wire, the farmer showed me an app on his smart phone with IP addresses for the various pieces of equipment in the barn, which he affectionately referred to as a "wired barn." Later, I learned that robotic milking machines are a 20-year old technology, satellite-guided tractors (autonomous vehicles) have been used for decades, and GPS technology offered to the civilian market from the military has been a foundation of agricultural technology for the past 30 years. In 2016, 87% of farmers used a smart phone, greater than the national average.[1]

Clearly, managers at the co-op, the dairy farmer, and the military exhibited "Humility" as defined by Uldrich. Those with humility are leaders who realize that "what served us yesterday, won't serve us tomorrow." They pave the way to bigger and better technology solutions. In contrast, managers who lack humility see their industries from one perspective: their own. They do the same thing over and over, ultimately falling into complacency and inaction. They neither fear the future, inaction, or risk aversion. Rather, they embrace the status quo that stifles innovation and growth.

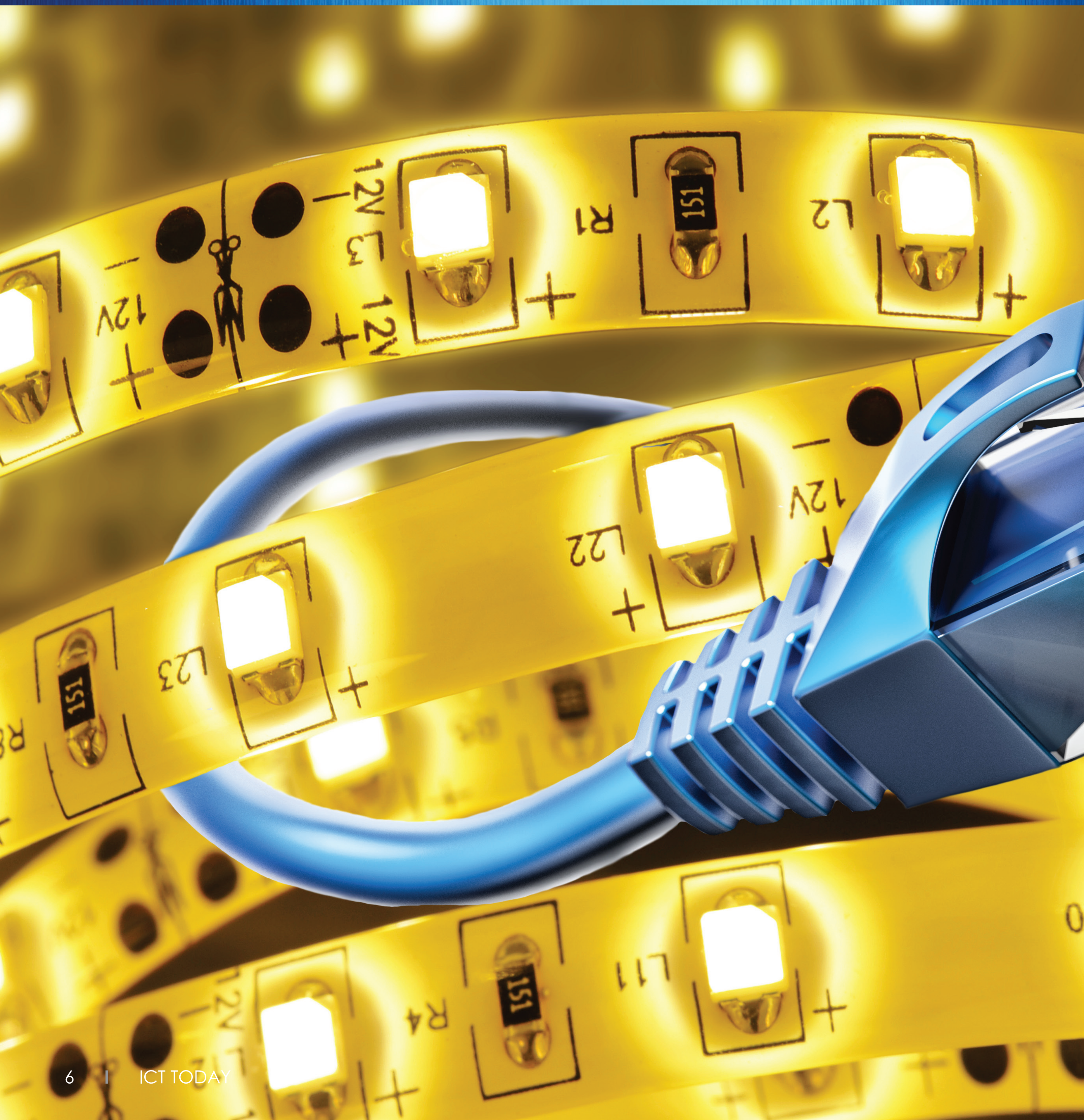
I wholeheartedly believe that BICSI, our members, and each person testing for a BICSI credential possesses the humility, like the dairy farmer, to reach beyond our comfort zones, face calculated risks head-on, and fearlessly reject the status quo. We are humble leaders who courageously embrace the future of ICT technology with transformational growth and innovation.

"The best way to predict the future is to create it yourself"
Peter Drucker

Be safe, someone is counting on you.

REFERENCE:[1] Powell, Alyson, *The Next Evolution of Agriculture Technology*, Georgia Institute of Technology, June 29, 2015

Evolution of Cabling and IoT Compatibility



Infrastructure Design

COVER ARTICLE
By Gautier Humbert, RCDD

Where from and where to?

Since the first TIA-568 standard ratified in 1990, structured cabling systems have been based on a star topology (Figure 1) composed of the backbone and horizontal link. This design has ensured reliability, flexibility, ease of management, and a stable base for developing multiple applications. Today, the North American ANSI/TIA 568, European EN 50173 and the international ISO 11801 series share the common basic design of two layers of backbone with a maximum 90 m horizontal link in a commercial environment.

From basic 10 Mb/s analog phones, ICT has progressed to 40 Gb on the horizontal, 400 Gb on the backbone, and added remote powering via PoE.

From basic 10 megabits per second (Mb/s) analog phones, information and communications technology (ICT) has progressed to 40 gigabit (Gb) on the horizontal, 400 Gb on the backbone and added remote powering via power over Ethernet (PoE). Structured cabling has integrated telephone, data, and video cameras, while building management has remained on a proprietary infrastructure. With the advent of the internet of things (IoT), LEDs needing far less power than previous lighting solutions, and USB, ZIGBEE and Bluetooth creating multiple bridges between networks, the time has come for structured cabling to provide the infrastructure for not only all communication in the building, but also a significant part of the power.

Standards

Standards are often viewed as fixed rules imposing drastic requirements, but historically standards have been very flexible. They evolve to adapt to new technologies, are sometimes subject to interpretation, but more importantly, they provide the minimum requirements for ICT applications. Therefore, it is possible to develop methods which outperform the standards, as long as the minimum standard requirements are met. All structured cabling standards comply with each other on the star topology, while also allowing topological variations.

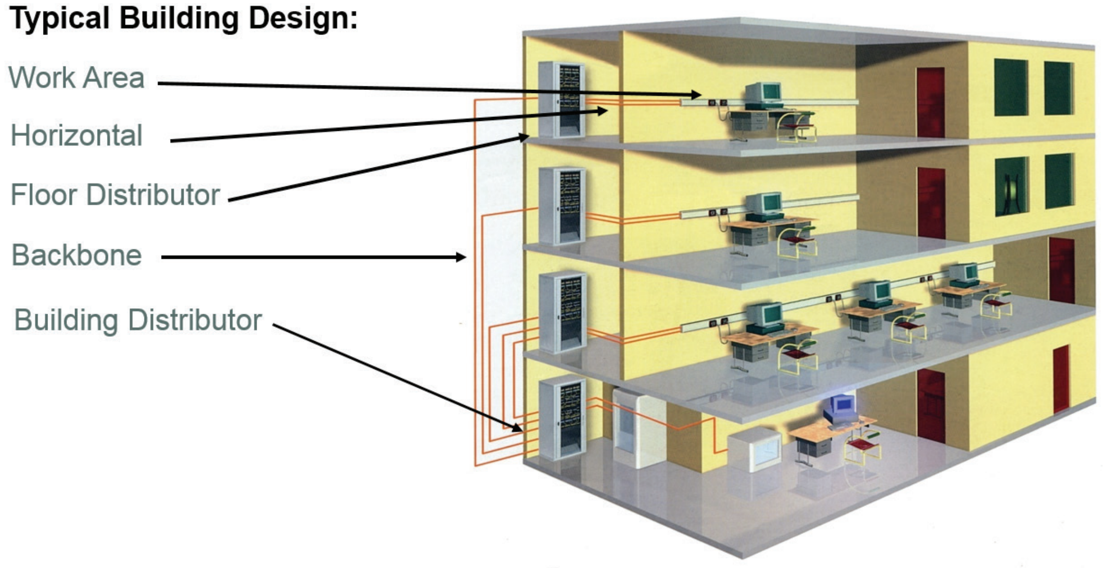


FIGURE 1: Traditional star topology

With increased cabling, PoE, and better performing topologies, the traditional star topology is beginning to reach its limits.

The Traditional Star Topology:

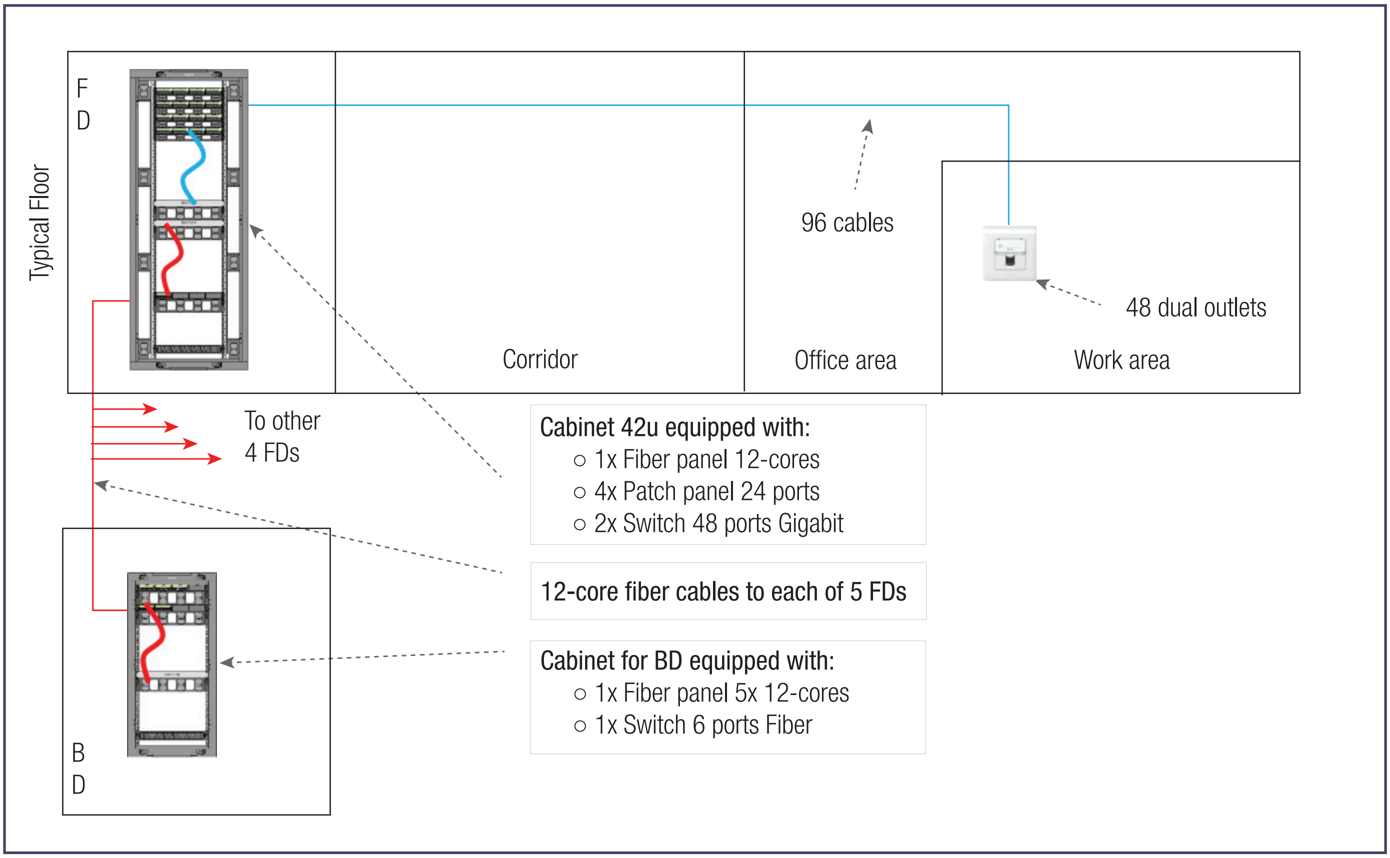


FIGURE 2: Traditional star topology designed with 5 floors, each with 48 dual outlets.

When thinking about a star topology, one imagines the usual building distributor (BD) on the ground floor and then a floor distributor (FD) on every floor. This is the case for most installations and has proven to be efficient and reliable, but it also has the following shortcomings:

- The telecommunications room (TR): when designed, it is always perfect, with plenty of space and perfect cord management in the racks. But after installation, due to various time and space constraints, the result can sometimes be far from expectations (e.g., the typical mess of spaghetti).
- The pathways: per standards and in theory, they are designed for maximum 40% fill ratio, but when changes are made, they rapidly fill.
- Changes: with long cables in the ceilings, moves, adds and changes (MACs) can lead to significant disruptions and costs. Consolidation points (CPs) and multi-user telecommunications outlet assemblies (MUTOAs) can improve this by providing local cabling management.
- Fire risks: more cables imply more plastic material and consequently more fuel in case of fire. The long cable lengths often crossing fire barriers require firestops, which risk being forgotten during MACs.
- Power efficiency: the maximum 90 m cable length is generally used to design a minimum of TRs that use up space and increase costs. However, with PoE applications, longer length also means higher resistance and lower power efficiency. The worst-case scenario with maximum power, maximum length and lowest category cable could imply up to 25% waste of energy!

- Performance: the applications are generally designed for the standard 100 m channel, but there are multiple grey areas where shorter links allow higher performance. The first standardized application for this was 10GBase-T. Although designed for Cat 6A, it could function on Cat 6 for limited distances depending on the quality of products and installation methods implemented. More recently, 2.5GBase-T and 5GBase-T both have similar testing methods to verify possible compliance on existing Cat 5e and Cat 6 for limited distances. And the latest Cat 8, although designed for data centers, could find a place in a commercial environment with a possible 25 Gb/s up to 50 m as shown in Figure 3.

With increased cabling, PoE, and better performing topologies, the traditional star topology is beginning to reach its limits.

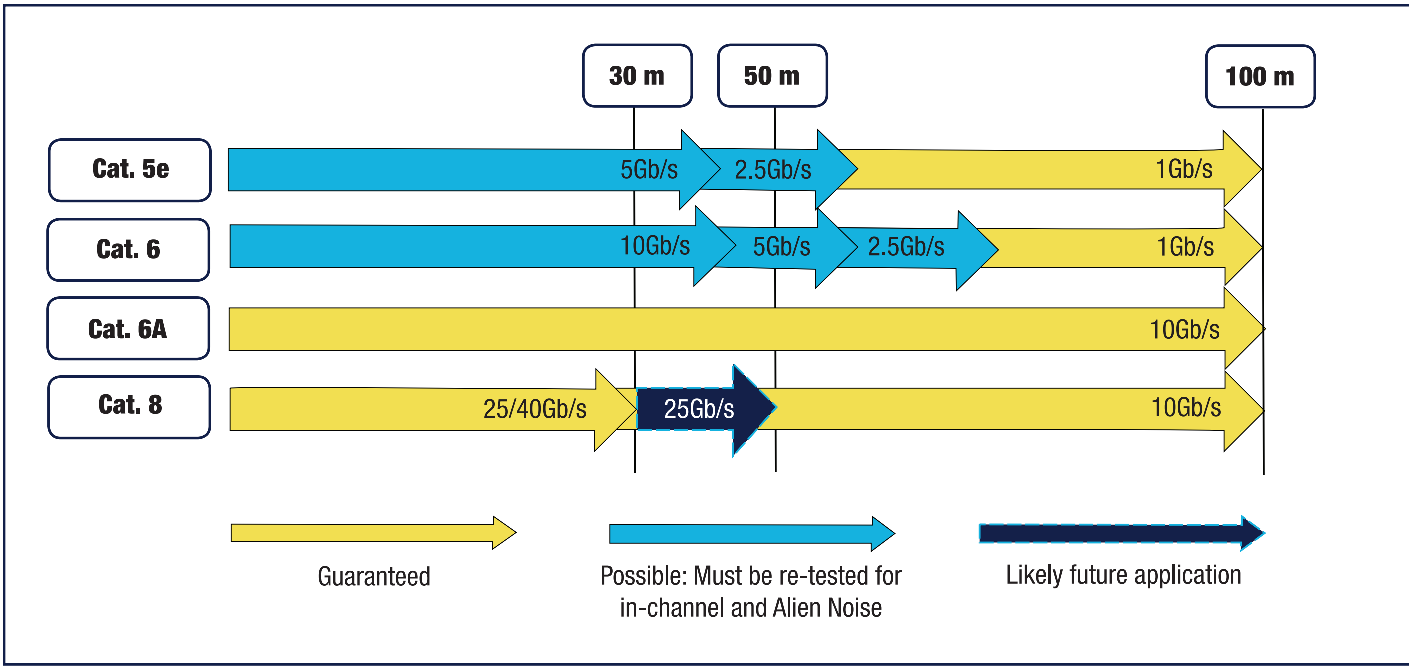


FIGURE 3: Performance in relation to distance for various cable categories.

The FTTZ Solution

The fiber-to-the-zone (FTTZ) solution is not new. It used to be referred to as fiber-to-the-enclosure (FTTE). The concept is simply to extend the fiber backbone further into the office space by removing the main rack or cabinet in the TR, and replacing it with multiple smaller enclosures in the zones around the users as shown in Figure 4.

Clearly, this will increase the cost of the enclosures and sometimes the active equipment due to lower port usage, but it also offers many advantages including:

- Saves real estate space with smaller and fewer FDs.
- Smaller patching zones, ensuring easier cord management.
- Smaller and less dense pathways. The largest change is on the main pathway out of the TR, previously supporting hundreds of copper cables; now filled with only a few fiber cables.
- MACs: adding or changing cables locally can be far simpler with shorter lengths. This can often make the difference between disrupting only one office rather than a complete floor of office space.
- Fire risks: there is less material to burn in case of fire. More importantly, the cables from the patching area to the outlets do not cross fire barriers. The need to firestop is eliminated, along with the risk of non-compliance.
- Improved efficiency: compared to an average 50 m length with the traditional solution (ranging from 15 m to 90 m), the cables are now reduced to average 15 m, lowering the resistance and loss while transmitting power. PoE is far more efficient on shorter lengths.
- Performance: shorter cables simply mean higher performance, increasing the likelihood of compliance for higher data-rate applications. It can also allow deployment of Category 8 in a commercial environment.

The FTTZ solution improves many aspects of the traditional star topology, while maintaining compliance

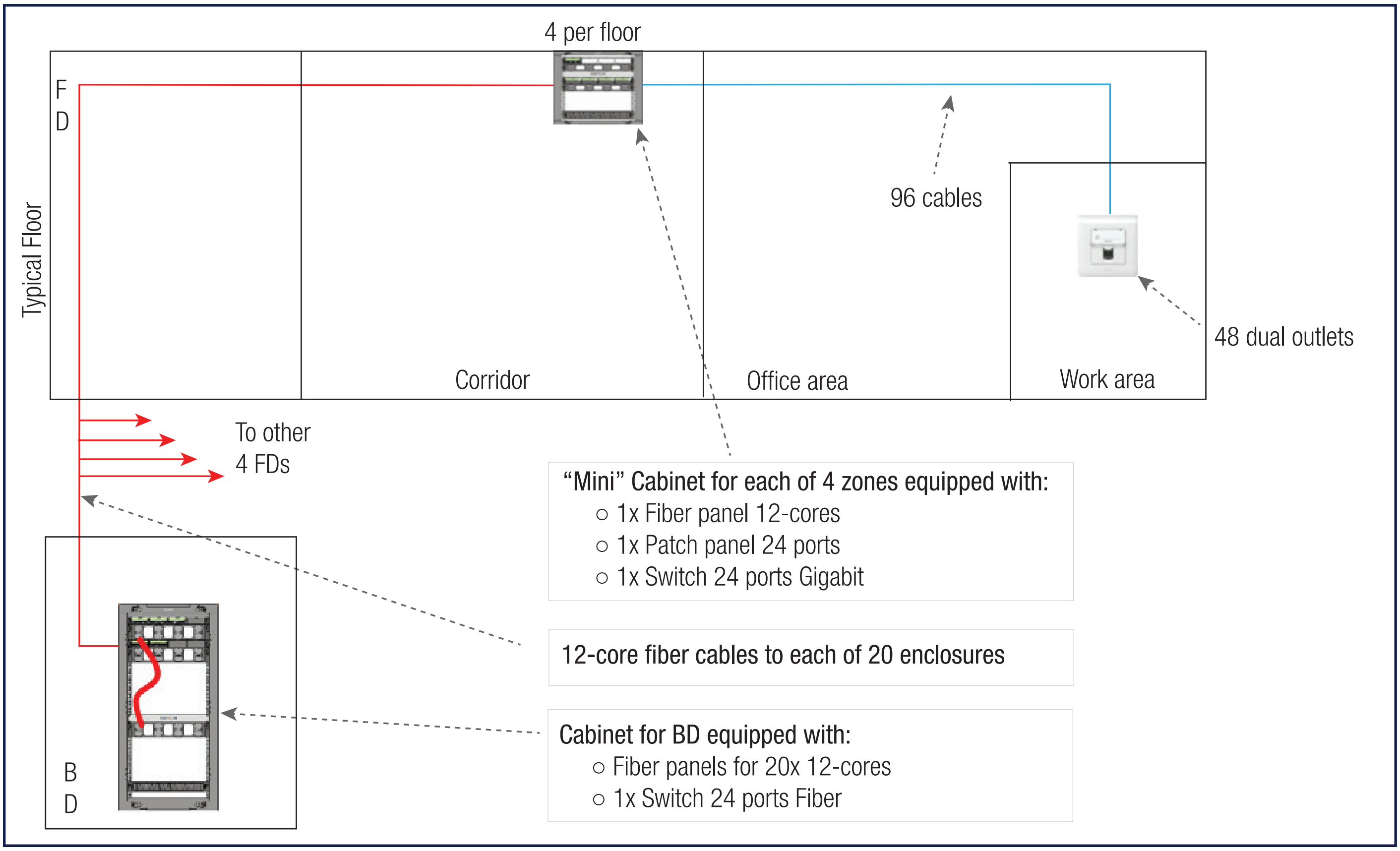


FIGURE 4: An example of an FTTZ design.

with standards. An often-overlooked aspect is that it also allows all standard applications, including Wi-Fi and PoE. It is also based on standard active equipment. The enclosures are available in a variety of options, including traditional wall mount, shallow vertical wall mount, and even ceiling and raised floor versions. Electrical and IT redundancy, if needed, can be easily provided to the zone enclosure.

Pushing to FTTO

Since we can bring fiber closer to the user and avoid placing equipment in the TR, why not go even further into the office space by going straight to the desk? However, fiber-to-the-desk (FTTD) has already been implemented many times. With the exception of very niche applications, such as security or protection from EMI, it has never really succeeded because all devices come with copper ports, not fiber. The fiber-to-the-outlet (FTTO) solution (Figure 5) simply uses a mini-switch in the outlet, connected to the fiber. This ensures that the user does not have access to the fiber and all equipment can be connected on copper.

In this solution, the mini-switch generally has one fiber connection on the side, and four or five copper ports (with sometimes PoE) in the front. It combines most advantages of the FTTZ with a few more including:

- No copper cabling.
- Even less cable management.
- No zone enclosures to manage.
- With a standard transceiver port, the solution can be based on either multimode or singlemode fiber depending on the transceiver chosen.

However, there are drawbacks:

- Dependence on local power supply for the mini switch.
- Standards compliance: unless to the floor directly above or below for low density, it is generally prohibited to extend the horizontal cabling into the backbone. Therefore, it is required that the horizontal fiber cables be spliced onto backbone cables in the TR. While this is not complicated, it can be overlooked and create fire risks.
- MACs: having placed the cabling so close to the user,

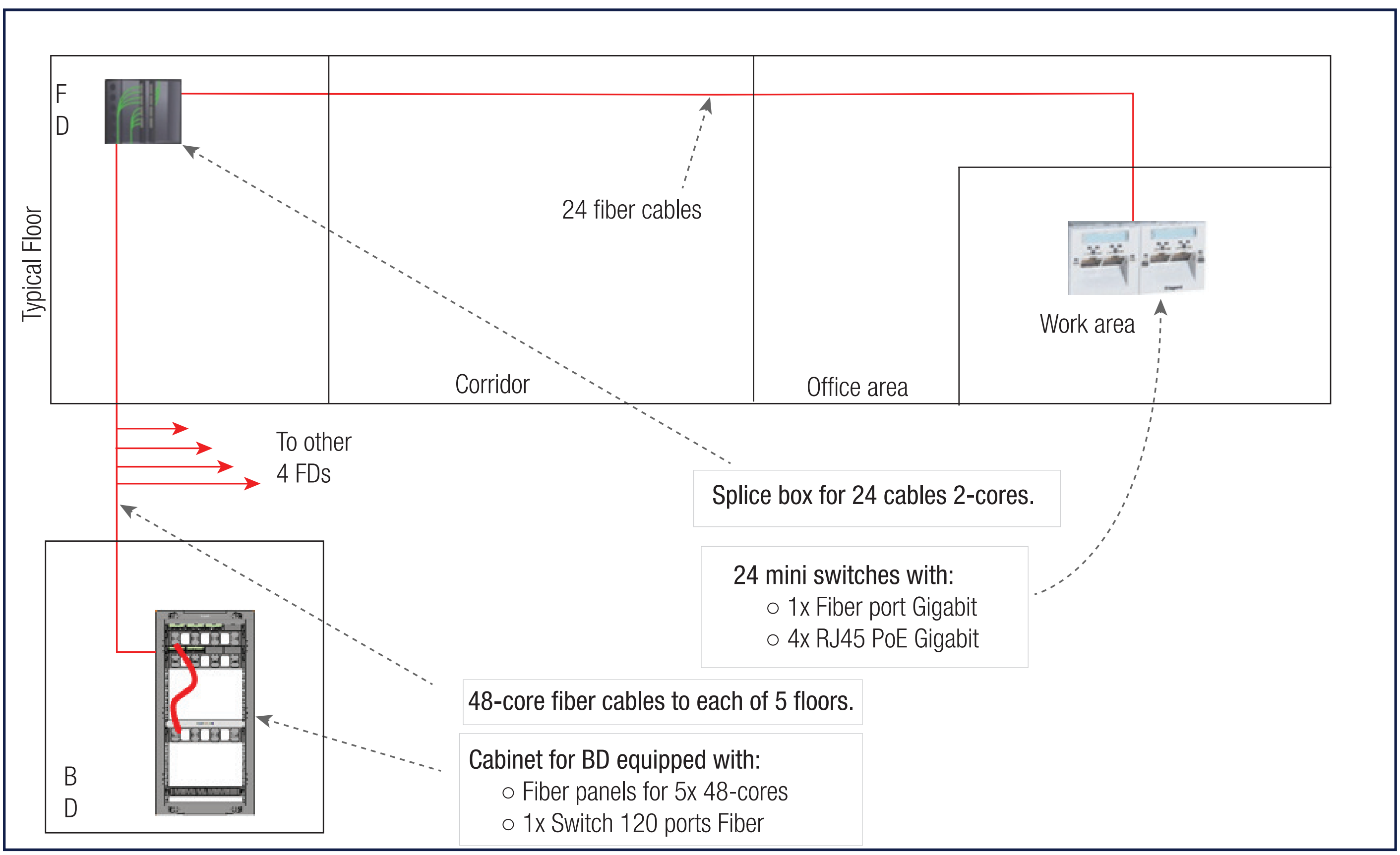


FIGURE 5: An example of an FTTO design.

it is necessary that extra fiber cores in the backbone are available. Otherwise, this solution requires even more effort to add backbone cables.

- Lack of redundancy: providing additional power to the mini-switches can be complex and costly. Sometimes, there is a lack of multiple paths.
- Heat management: most mini-switches are designed for installation in PVC trunking with heat evacuation on the side. Installing these products in narrow fit metal backboxes can impede the heat evacuation. Some models are available with front ventilation.
- Lack of choice: there are very few suppliers of such products; format and options are limited.
- Compatibility with local formats: with U.S., U.K., French, Italian, Japanese, and multiple other faceplate formats existing in the world, it can be quite challenging to find the right product for the right region.

The FTTO solution has certain advantages, but also some serious drawbacks that limit its use to niche applications.

The PON Alien

PON technology was introduced to support fiber-to-the-home (FTTH) applications. This architecture uses singlemode fiber, with only one strand to the home. Going back toward the service provider, multiple strands are spliced together with passive splitters, allowing connection of up to 32 homes on a single fiber. This clearly saves on cabling and provides a high data rate to the home compared to other solutions, such as ADSL or coaxial cable.

In the recent past, this technology has been introduced into the enterprise LAN environment as passive optical LAN (POL) and as a replacement of structured cabling. It has been ratified in some standards as a recognized alternative. POL provides some interesting advantages, including:

- Elimination of equipment in the FD, like the FTTO solution.
- Very reduced cabling, with sometimes only one strand to the floor with only passive splitters.

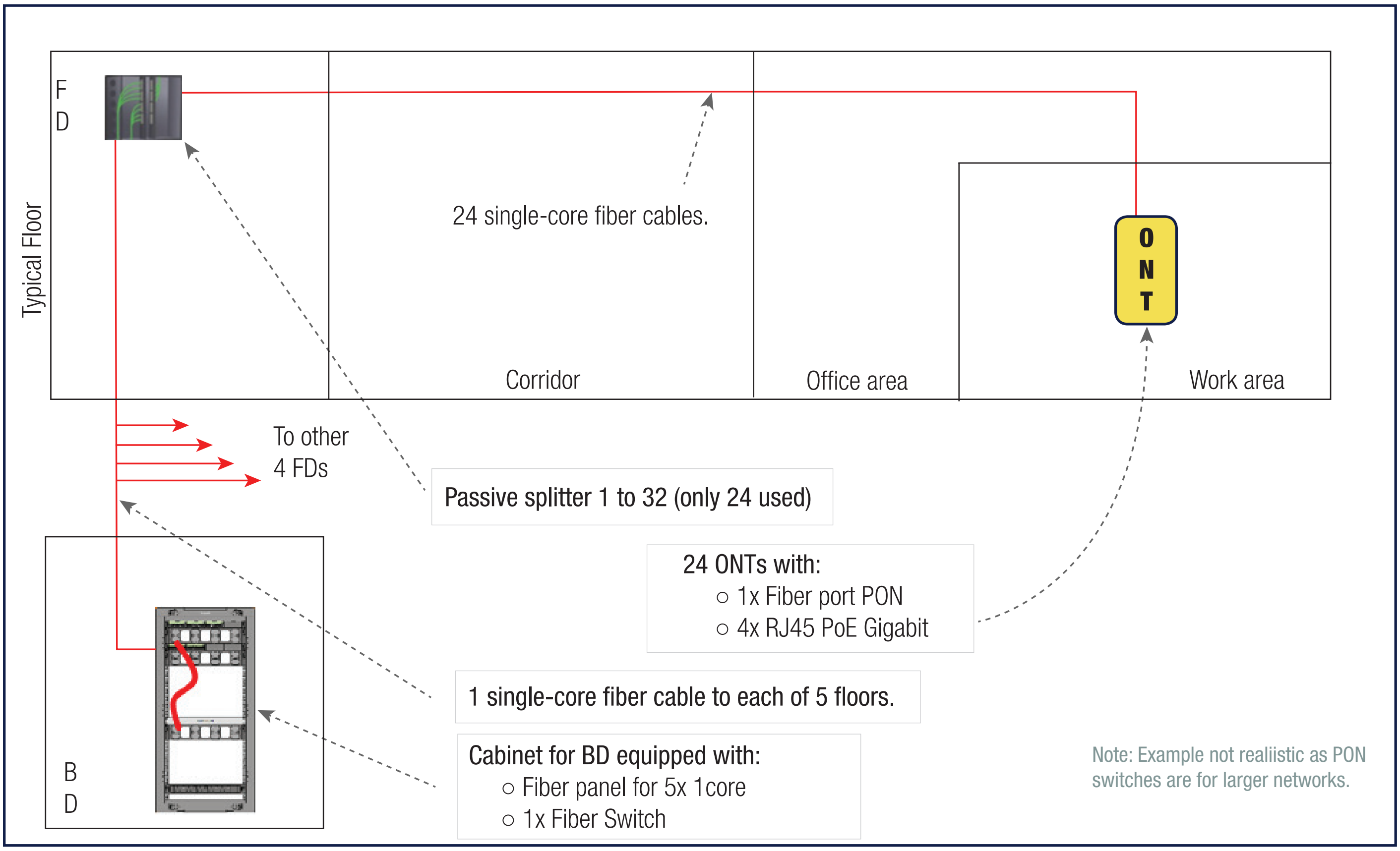


FIGURE 6: PON design example.

- Extremely reduced cable management.
- Possible flexibility for MACs, depending on the design.
- Immunity to EMI, like other fiber-based solutions.

However, this technology was not originally designed for the LAN environment, so it also has drawbacks:

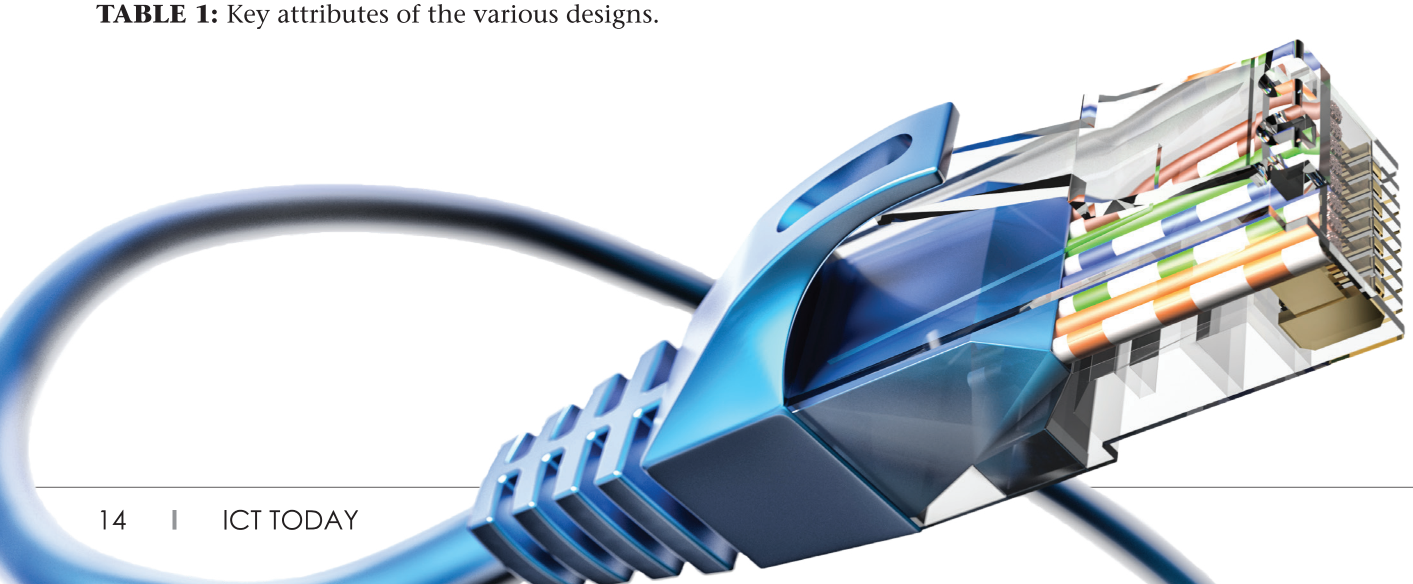
- Expensive network equipment, designed for sending signals for long distance.
- Lack of choice in the network equipment, as there are very few suppliers.
- Need for "electronic boxes" at the user level, called optical network terminals (ONTs). These must often be on desks, subject to risks, although newer models can now integrate into the walls, ceiling or furniture.
- Dependence on local power supply, and with difficulty to create redundancy.
- Low performance: one fiber port with 10G performance from the core switch can be divided into 32 strands each connected to a 4-port ONT, effectively providing an average of 78 Mb/s per port. For comparison, a 48-port gigabit switch connected on Cat 5e with a 10G backbone on OM3 provides more than 200 Mb/s on average.

PON technology provides a low-cost solution, immunity to EMI, while saving space and equipment in the FDs. It also allows longer distances than all other options. But it is not without drawbacks, limiting it also to niche applications. In fact, PON technology is very similar to FTTO, with less fiber cabling and longer distances, but with lower performance and equipment specific to a wireless area network (WAN) rather than a LAN environment.

	Traditional Star	FTTZ	FTTO	PON
Patching	Complicated	Simple	Simple	Extra simple
Cabling quantities and pathway sizes	High	Low	Extra low	Lowest
Ease of MACs	Difficult[1]	Easy	Difficult[1]	Difficult[2]
Data rate available to the user with typical installation	High	High	Low	Lowest
Compatible 10Gb/s to the user with technology	Yes	Yes	No	No
Compatible 40Gb/s to the user with current technology	No[3]	Yes	No	No
Implementation of power redundancy	Simple	Simple	Complex	Complex
Efficiency of PoE distribution	Inefficient	Efficient	Efficient (from mini-switch)	Efficient (from ONT)
Choice of compliant active equipment	Wide choice	Wide choice	Low choice	Low choice

[1] Unless using CPs or MUTOAs
[2] Unless splitters are placed strategically and have unused ports
[3] On most links, due to distance

TABLE 1: Key attributes of the various designs.



Cabling for Wireless Access Points

Until recently, cabling for wireless access points (WAPs) was done after the site survey, providing one cable for each device. With this method, the wireless infrastructure was effectively not considered part of structured cabling, since it did not follow the same standards. All it took was the addition of metal furniture in a room to impose relocation of the wireless device, requiring re-cabling of the complete cable length.

Standards have taken this into account and now propose specific cabling guidelines for the wireless infrastructure. Both TIA TSB-162 and ISO/IEC TR 24702 propose to install outlets in the ceiling at regular intervals. The American version is based on a square grid of 18.3 m side, while the international version is based on a honeycomb structure with 12 m radius cells. Both define a wireless service outlet (SO) with two ports Cat 6A minimum. The access points are connected to the closest SO with a patch cord after the site survey. In the future they can be easily moved. While not replacing traditional cabling, this addition is similar to a consolidation point or MUTOA. ANSI/BICSI 008-2018, *Wireless Local Area Network (WLAN) Systems Design and Implementation Best Practices* covers locations and placement of access points in greater detail.

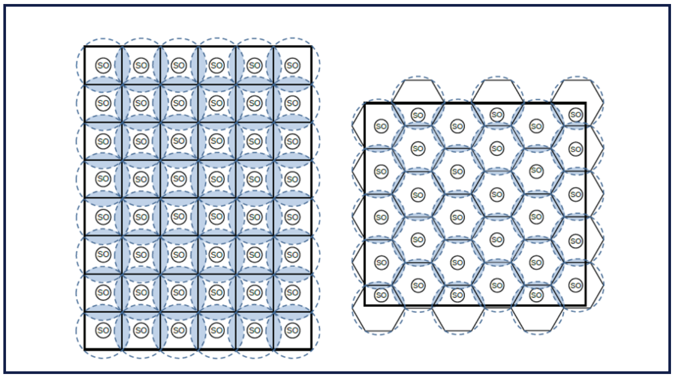
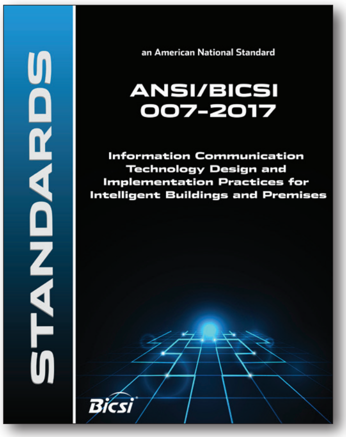


FIGURE 7: Example of grid and hexagonal SO coverage area patterns.

The basic design of FTTZ is not only extremely close to the HCP (SCP), but also to the wireless SO.

Intelligent Building Design for IoT

With the advent of IoT, ANSI/TIA-862-B and ISO 11801-6 offer solutions for the structured cabling of building management systems as an alternative to proprietary network solutions. The guidelines and best practices for a more global vision of the intelligent building design is covered in ANSI/BICSI 007-2017, *Information Communication Technology Design and Implementation Practices for Intelligent Buildings and Premises.*



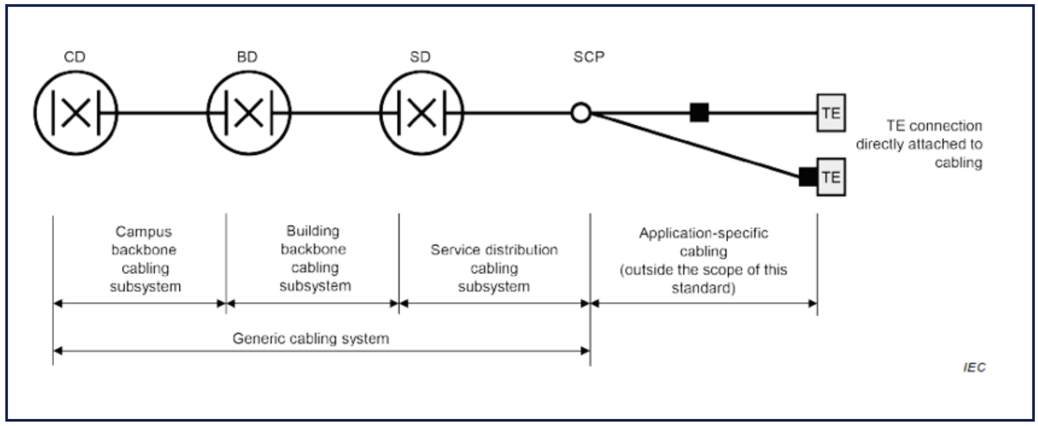


FIGURE 8: The service connection point according to ISO/IEC 11801-6. Source diagram-ISO/IEC.

These standards allow similar service outlets connected to a device called a horizontal connection point (HCP) according to TIA, and service connection point (SCP) per ISO/IEC. At first glance, the HCP is like a CP. However it has two specific distinguishing features:

- It allows direct connection to devices without an outlet; this part of the cabling being considered non-structured.
- It allows active equipment inside, something prohibited in a CP. In this manner, it resembles the cabinet in the FTTZ design.

Positioning of the HCPs and SOs is in a grid similar to the cabling for WAPs.This type of infrastructure is designed to replace all other cabling in the ceiling, allowing building management to implement sound systems, real-time location systems, surveillance cameras, HVAC, LED lighting, and many other operational technology (OT) functions.

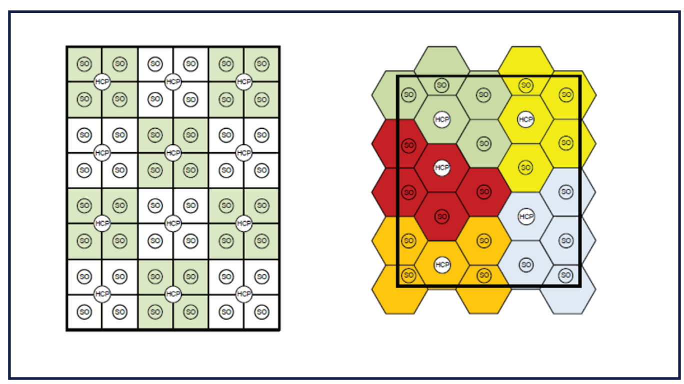


FIGURE 9: Possible patterns of HCPs with SOs.

It is important to consider the amount of cabling involved to understand that the active equipment inside the HCP is vital. Without it, there would be an increase of all the flaws in the traditional star topology, with one being most critical: the heat in the cable. Longer cables can cause lower efficiency in power delivery, the loss being energy transformed into heat, which can lead to lower performance. All calculations for structured cabling distances are based on a temperature of 20° Celsius. If cable temperature rises, then the cable distances must be reduced.

Calculation formulas can be found in both ANSI/TIA 568.2-D and ISO/IEC 11801-2. A worst-case scenario indicates that the 90 m permanent link can be reduced to 72 m at 60°C. Above 60°C, the system is non-compliant to standards and unable to provide any guaranteed performance, along with possible degradation of components. In North America, *NEC* can require a specific cable rating for power delivery and higher temperatures. In the rest of the world, ISO/IEC requires control of the PoE installation to maintain the temperature below 60°C.

Choosing the Optimum Design for Flexibility

For ICT infrastructure cabling, there are many options and any of them could be considered as the best solution depending on customer needs. For the building management infrastructure and, especially IoT, only a design according to ANSI/BICSI 007 (compliant to ANSI/TIA-862-B and/or ISO 11801-6) will provide the necessary flexibility. Because of the efficiency of PoE linked to the length of the cables, the use of HCP (SCP) with active equipment becomes inevitable as power density increases.

There is nothing wrong with the separation of networks; one for IT and the other for building management. It can sometimes be a strategic choice to separate responsibilities. In this case, a bridge between the two networks can be made in the TRs. To attain maximum flexibility, however, it seems logical to combine all infrastructures under one network. In this case, some architectures will not meet the requirements for optimum flexibility and efficiency.

	Traditional Star	FTTZ	FTTO	PON
Compatible with cabling for wireless access points ANSI/ BICSI 008	Yes	Yes	No[1]	No[1]
Compatible with cabling for Intelligent Building ANSI/BICSI 007	Yes	Yes[2]	No[1]	No[1]
Efficient for PoE delivery for IoT	No	Yes	N/A	N/A

[1] Must be separate cabling network [2] With additional copper links to dedicated cabinet

TABLE 2: Compatibility and efficency of the various designs.

- Traditional star, even with CP or MUTOA, generally has long horizontal cables that are too long for optimum efficiency.
- FTTO, with its fiber-only infrastructure, is incompatible. In fact, it is also incompatible with cabling for WAPs, which would need to be on a separate infrastructure.
- PON, for the same reasons, is also incompatible. It is also more complicated to bridge with a separate copper network, since the active equipment is completely unique.

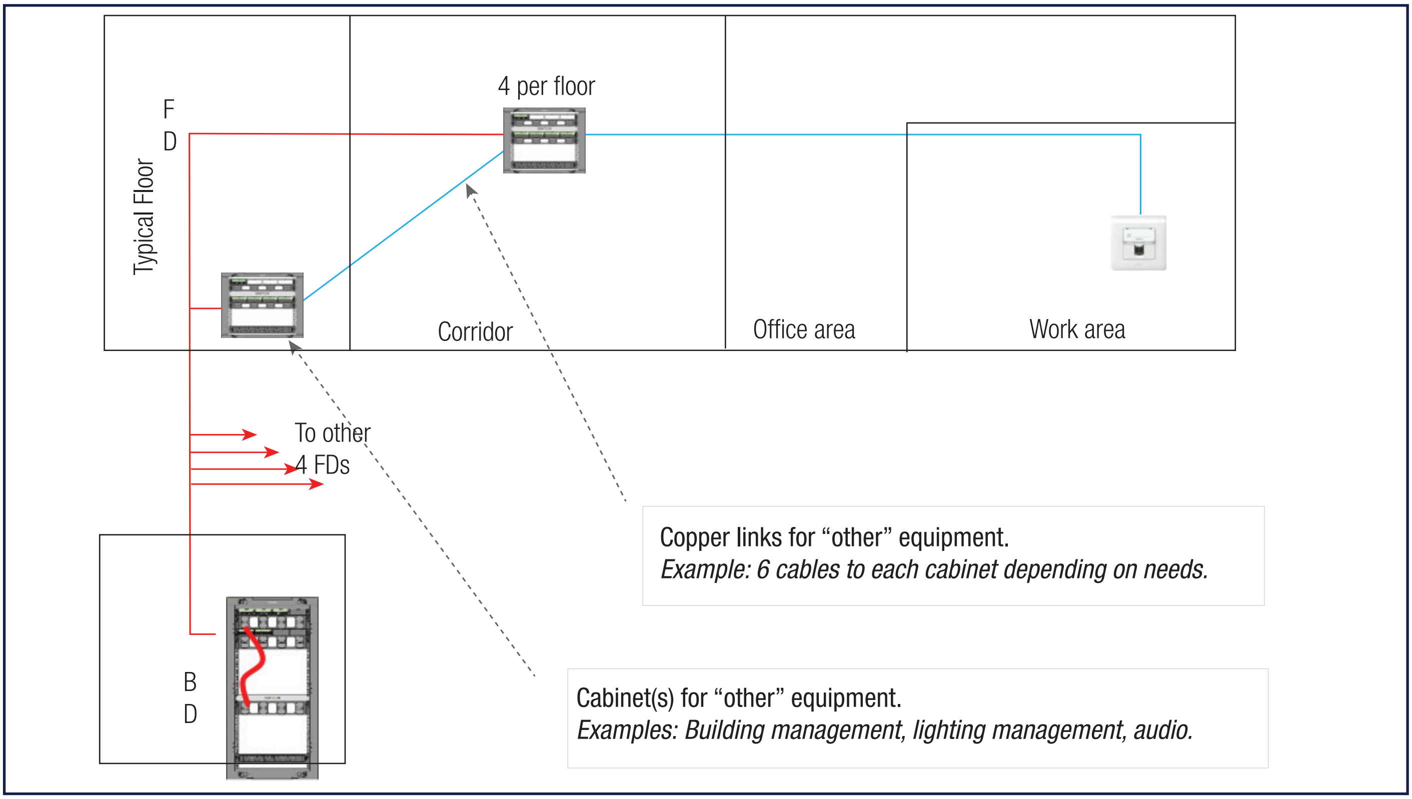


FIGURE 10: Combining the HCP (SCP) into the FTTZ design for optimum flexibility and IoT.

Having analyzed the various topologies, FTTZ emerges as the best option. The basic design of FTTZ is not only extremely close to the HCP (SCP), but also to the wireless SO. It is only missing some copper connections to a dedicated cabinet in either the TR or electrical room where building management equipment would be located. For an optimized design combining both ICT and building management for IoT networks, the most flexible solution is a modified FTTZ with extra copper links to another dedicated cabinet.

What is Coming Next?

Just like the telephone network was absorbed by the ICT network, now is the time for building management to also be combined. However, there are some radical changes, not only with IoT devices, but also with LED lighting that can now be powered with structured cabling. There is a big question in the industry whether 4-pair cable is really adaptable, since it is designed for high data rates. LEDs mainly require power, along with very low data rates for control, making the 4-pair cable somewhat of an overkill.

The standards are evolving with a new project called SPE (single-pair Ethernet). The ICT industry will soon discover new single-pair cables with new single-pair connectors designed to provide the correct power with low data rates for longer distances, and maybe even daisy-chain!

Look for IEEE 802.3cg, IEEE 802.3bw and IEEE 802.3bp for the data applications and IEEE 802.3bu for the power aspects. For cabling, TIA and ISO/IEC are both working to propose the right specifications. Also expected are advances in SPE switches, so that the integration of SPE in an existing network will be extremely easy in the modified FTTZ design. If working with a traditional star topology, FTTO, or PON, integration may be more difficult and complicated.

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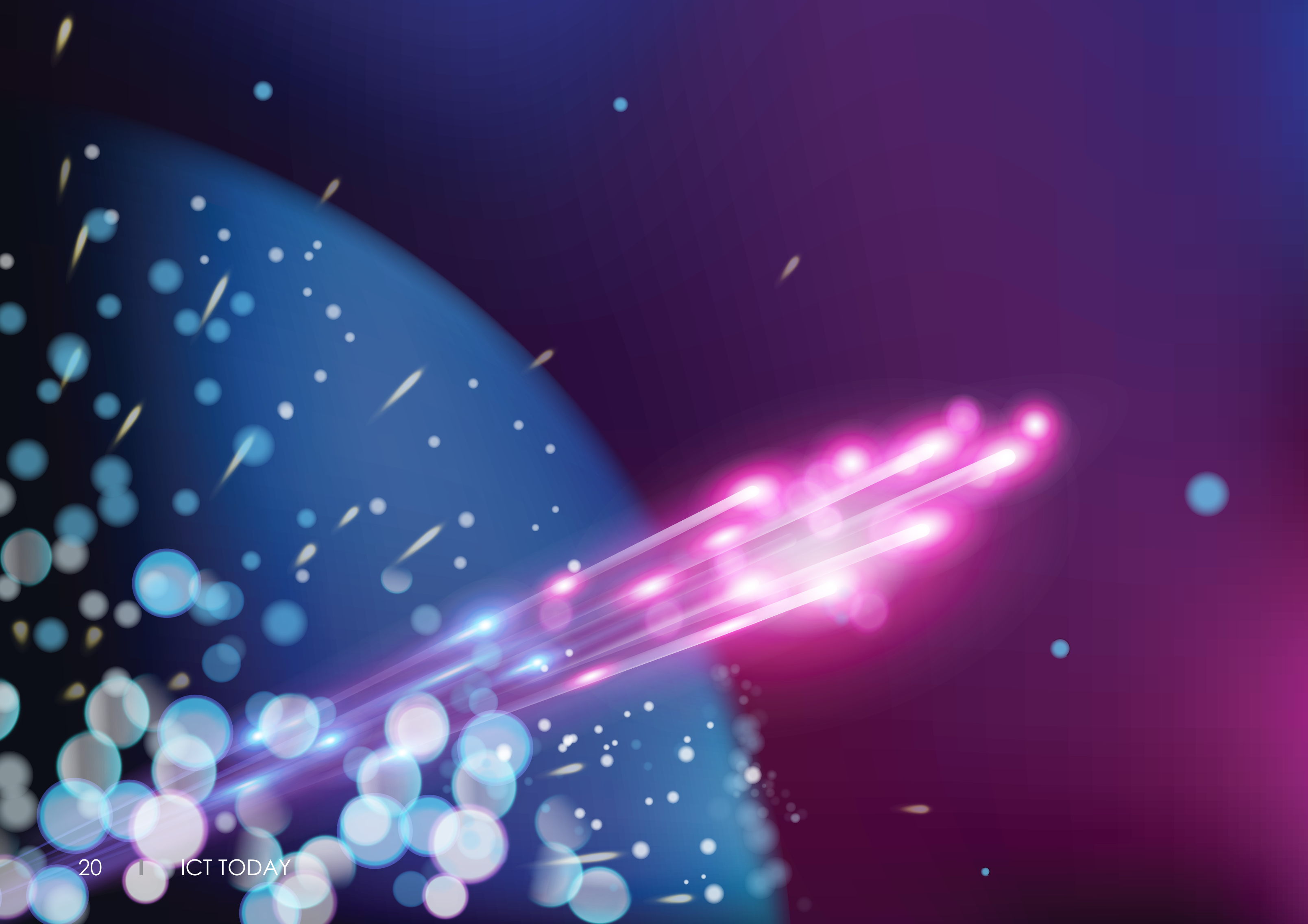
Enterprise Fiber Standards and Applications: What's New?

By John Kamino, RCDD

In enterprise and data center networks, cloud computing and web services continue to drive increased bandwidth demand, pushing data communications rates from 1 and 10 Gigabits per second (Gb/s) to 40 and 100 Gb/s and beyond. Multimode optical fiber easily supports most distances required for these applications and continues to evolve to meet greater demand for speed and capacity. This article outlines the latest developments in multimode fiber types and technology available for this market space and the standards that govern them.



Multimode Market Continues to Boom

According to the 2017 Cisco Visual Networking Index, the amount of IP traffic is growing at an annual rate of 24 percent worldwide. The 2018 Cisco Global Cloud Index shows that global data center traffic is expected to increase from 6.8 zettabytes (ZB) in 2016 to 20.6 ZB in 2021. While the most significant growth is expected in the Asia Pacific region, every segment of the globe shows significant growth. This demand drives the need for higher speed networks, and consequently higher optical fiber volume in all regions.

Among Cisco's other findings: there is almost five times more traffic inside the data center than from the data center to the user. When combined with data center interconnect traffic, this so-called "east-west traffic" accounts for more than 85 percent of total traffic. This helps to explain the demand for higher data center network speeds and more links between servers and switches.

It is a truism that the enterprise data center is moving to the cloud. But what exactly does that mean? An obvious answer is that some enterprises are migrating to public cloud services offered by hyperscale vendors, such as Google, Microsoft, Amazon and others, but there are other approaches. An enterprise private cloud can provision service for its users in similar fashion to one of the hyperscale providers, but with owned rather than leased facilities. A combination of the two approaches can also be used. Cisco projects that the enterprise cloud, now the majority of the market, will continue to grow throughout the study period, reflecting a migration from legacy enterprise data centers, and in some cases, a pull back to in-house control from hyperscale providers. The public cloud will grow at an even faster pace, while the legacy enterprise data center will decrease.

It is sometimes taken as fact that hyperscale data center customers only want singlemode fiber. However, Google, Alibaba and Baidu, for example, have deployed multimode fiber applications and continue to plan for its use in their roadmaps. The market is also seeing an increasing interest in multimode applications from other hyperscale players in the United States for 400G-SR4.2 (a standard to be discussed later) and 400G-SR8 for a variety of applications, including breakout.

Given the distance advantages offered by singlemode fiber, why is multimode fiber still a preferred media? The reasons have to do with cable size, design and cost.

How Multimode Fiber Stacks Up

Until about 2010, copper had been used for data center server links. However, as server speeds increased, the link distance supported by copper twinaxial cable (twinax) and UTP Category5/6 cables significantly decreased, in some cases to as short as five to seven meters (m). For 40 Gb/s links, an 8-pair twinax cable is often used. However, a twinax cable is three or four times the diameter of a fiber cable (Figure 1). When large numbers of these cables are used, it significantly affects airflow around the rack, making it much more difficult to cool. By comparison, optical fiber cables, with their much smaller diameter, demand far less cable management space and are easier to manage.

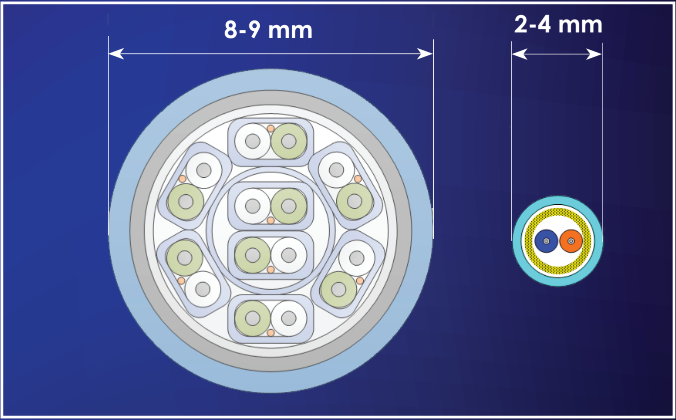


FIGURE 1: Size difference between copper twinax (8 pair) and duplex fiber solutions for 40 Gb/s.

Among optical fiber types, multimode continues to be more cost-effective than singlemode for these shorter reach applications. While the cost of multimode fiber is greater than that of singlemode, it is the optics and connection costs that dominate the total cost of a network system, dwarfing variations in cable costs.[1]

On average, singlemode transceivers continue to cost from one-and-a-half to five times more than multimode transceivers, depending on data rate. As faster optoelectronic technology matures and volumes increase, prices come down for both, and the cost gap between multimode and singlemode can decrease. However, singlemode optics have traditionally been more expensive than their equivalent multimode counterparts.[2]

Multimode fiber is the default choice of transmission media for data centers and other high-speed enterprise applications over copper and singlemode fiber. The reasons have to do with cable size, design and cost.

Multimode transceivers also consume less power than singlemode transceivers, an important consideration especially when assessing the cost of powering and cooling a data center. In a large data center with thousands of links, a multimode solution can provide substantial cost savings from transceiver and power/cooling perspectives. Finally, the fact that multimode optical fiber is easier to install and terminate in the field than singlemode is an important consideration for enterprise environments where frequent moves, adds and changes are required. This advantage extends to cleaning, where a small amount of dust or contamination could create significant attenuation on a singlemode connector, but only slightly increase the loss of a multimode link.

The Evolution of Multimode Fiber

As shown in Table 1, there are five types of multimode fiber currently on the market.

OM1 and OM2, the original 62.5 micron (µm) and 50 µm-diameter types, respectively, are considered obsolete in the ISO/IEC 11801 and TIA 568 standards, and no longer included in the main text of the documents. They are, however, allowed as grandfathered fiber types and may be used to extend legacy networks. New installations should use OM3, OM4 or OM5 multimode fiber types.

OM3 multimode, introduced in 2003, was the first fiber designed for use with laser light sources at 850 nanometers (nm), primarily to support 1 and 10 Gb/s operation. OM4, standardized in 2009, offers longer link lengths supporting 10 Gb/s operation to 400 m in the standard, and up to 550 m using some engineering rules.

	*(described in the industry using primarily the **ISO/IEC 11801** Designations)*							**BANDWIDTH** (MHz-km)			
	Industry Standards					**Attenuation—** Typical Cabled Max. (dB/km)		**Overfilled Launch (OFLc)**		**Effective Modal Bandwith (EMB)** (also known as Laser BW)	
Fiber Type	**ISO/IEC 11801-1 Nov. 2017**	**IEC 60793-2-10 Aug. 2017**	**TIA-568.3-D Oct. 2016**	**TIA/EIA 492AAAx various**	**ITU-T Dec. 2008**	**850nm**	**1300nm**	**850nm**	**1300nm**	**850nm**	**953nm**
62.5/125	~~OM1[1]~~	A1b	~~TIA 492AAAA (OM1)~~	492AAAA	---	3.5	1.5	200	500	---	---
50/125	~~OM2[2]~~	A1a.1b[3]	~~TIA 492AAAB (OM2)~~	492AAAB	G.651.1	3.5	1.5	500	500	---	---
50/125	OM3	A1a.2b[3]	TIA 492AAAC (OM3)	492AAAC	---	3.0[4]	1.5	1500	500	2000	---
50/125	OM4	A1a.3b[3]	TIA 492AAAD (OM4)	492AAAD	---	3.0[4]	1.5	3500	500	4700	---
50/125	OM5	A1a.4b[3]	TIA 492AAAE (OM5)	492AAAE	---	3.0	1.5	3500	500	4700	2470

(1) OM1 is typically a 62.5µm fiber, but can also be a 50µm fiber.
(2) OM2 is typically a 50µm fiber, but can also be a 62.5µm fiber.
(3) "b" designates Bend-Insensitive
(4) ISO/IEC 11801 has a max. cabled attenuation of 3.5dB/km

TABLE 1: Multimode fiber types.

An even more recent innovation was the introduction in 2017 of OM5, known as wideband multimode fiber. Traditionally, multimode fiber has operated at a single wavelength. When higher network speeds were needed, lasers were developed that would operate at these speeds. This approach worked very well up to 10 Gb/s and, later, 25 Gb/s. To increase speeds further, however, parallel fiber systems were introduced; first for 40 Gb/s, then for 100 Gb/s. Four fibers, or lanes, were used to support these higher speed links.

OM5 fiber is the first multimode fiber designed to support multiple wavelengths. It enables duplex transmission of 100 Gb/s using either two or four wavelengths between 850 and 950 nm. This is done while taking advantage of multimode fiber's longer wavelength transmission properties. The fiber's lower chromatic dispersion at longer wavelengths means that modal bandwidth requirements could be relaxed at those longer wavelengths.

Commercial transceivers are available to support either technology. In fact, several large transceiver manufacturers were key contributors to the wideband multimode fiber standard. They provided guidance on the wavelength spacing needed for the most cost-effective wavelength division multiplexing (WDM). This resulted in a transmission window that went from the current 850 nm up to 953 nm.

Other than some limited application in service provider central offices, 100GBASE-SR10 has been less widely deployed, in large part because newer standards requiring fewer fiber pairs have been developed.

An additional requirement was the support of all existing OM4 applications and reaches. In other words, OM5 fiber is completely backward compatible with all OM4 requirements and supports applications to the same link distances.

Table 2 indicates where the OM5 specifications were tightened in order to support WDM applications. Notice that the 850 nm laser bandwidth (also called effective modal bandwidth, or EMB) remains the same at 4700 Megahertz over one kilometer (MHZ-km). Transmission reach at 850 nm matches all OM4 applications. The additional bandwidth requirement is at 953 nm, the long or "far" end of the wavelength range, where a laser bandwidth of 2470 MHz-km is specified. The window between these two wavelengths is the space designed for multimode WDM applications.

	OM4 Multimode Fiber	OM5 (Wideband) Multimode Fiber
Zero Dispersion Wavelength	$1295 \leq \lambda_o \leq 1340$ nm	$1297 < \lambda_o < 1328$ nm
Zero Dispersion Slope	$S_0 \leq 0.105$ ps/nm^2·km for $1295 \leq \lambda_o \leq 1310$ nm, and $\leq 0.000375(1590-\lambda_o)$ ps/nm^2·km for $1310 \leq \lambda_o \leq 1340$ nm	$S_0 \leq 4(-103)/(840(1-(\lambda_o/840)^4))$ ps/nm^2·km
850 nm Effective Modal Bandwidth (EMB)	4700 MHz-km	4700 MHz-km
953 EMB	N/A	2470 MHz-km

TABLE 2: Specification comparison between OM4 and OM5 wideband multimode fiber.

OM5 multimode fiber and cable standards are fully mature and complete. TIA completed fiber standard TIA-492AAAE in June 2016, and IEC published IEC 60793-2-10 in August 2017. TIA published its structured cabling standard, ANSI/TIA-568.3-D, in October 2016, and ISO/IEC published ISO/IEC 11801-1 in October 2017. The 11801 standard defines the OM5 designation for multimode wideband fiber. That designation will also be included, with reference to 11801, in future TIA and IEC fiber standards.

Equipment Trends Follow Suit

What equipment can be used with OM5 multimode fiber? Table 3 shows currently available short wavelength division multiplexing (SWDM) transceivers, along with one announced solution. It is clear that, while OM3 and OM4 still support short-reach applications, OM5 gives added reach to the full range of applications.

The first widely deployed application for OM5 fiber was 40 Gb/s bidirectional (BiDi) transceivers. Duplex (BiDi and SWDM4) 40 Gb/s links are widely deployed; as 100 Gb/s solutions become more commonplace, similar trends can be expected in that space. The introduction of an extended-reach SWDM (eSWDM4) solution will further expand the market for multimode fiber with its ability to support 400-m duplex 100 Gb/s links.

To encourage these developments, an SWDM alliance was formed in 2015. This industry-based organization, which includes OFS and other optical fiber and cable suppliers as well as transceiver and switching equipment suppliers, was created to promote the use of SWDM technology for short-reach applications. An SWDM multi-source agreement (MSA) has also been created to develop interoperable SWDM devices. Specifications for both 40 Gb/s and 100 Gb/s transceivers were released and are available on the swdm.org website.

Recently, a 400 Gb/s BiDi MSA was announced. This MSA will continue to build on the advantages of multi-wavelength solutions with a four-pair 400 Gb/s link. The goals of this MSA include the development of a specification that will support up links up to 150 m over OM5 fiber.

It should be pointed out that these are not standards-based solutions; they are either MSA-based or proprietary offerings from switch and/or transceiver suppliers. However, the transceivers do fit into the standard quad small form-factor pluggable (QSFP+ or QSFP28) footprint, and as long as they are paired with a like transceiver, no problems should be encountered.

While these applications can operate over legacy OM3 and OM4 fiber, OM5 fiber offers a significant reach advantage over the older fiber types.

New Developments in Multimode Signal Transmission

Another technical achievement not tied specifically to wideband transmission is the use of four-level pulse amplitude modulation (PAM-4) signaling, which is a more complex signaling method than the simple

				Link Distance (m)		
Speed (Gb/s)	Transceiver	Form Factor	λ	OM3	OM4	OM5
40	BiDi	QSFP+	2	100	150	200
40	SWDM4	QSFP+	4	240	350	440
100	BiDi	QSFP28	2	70	100	150
100	SWDM4	QSFP28	4	75	100	150
100	eSWDM4	QSFP28	4	200	300	400

TABLE 3: LC Duplex SWDM transceivers (non-standards based).

on-off keying (OOK) previously used in optical transmission. Instead of simply transmitting a 1 or 0, PAM-4 transmission doubles the amount of information that can be sent in a single time period by using four signal levels. PAM-4 signaling will be incorporated into new Ethernet and Fibre Channel standards, as well as MSAs and proprietary solutions as speeds increase. It will allow for 50 Gb/s per lane transmission using today's 25 Gbaud/s lasers, and as laser speeds increase further, will allow even higher lane speeds.

Of course, nothing is free. PAM-4 signaling will require better receiver sensitivity than OOK in order to detect the different levels. As seen in Figure 2, four "eyes" will need to be detected, rather than the single eye found in OOK. The sensitivity requirements can be reduced using several compensation methods, including equalization and/or forward error correction.

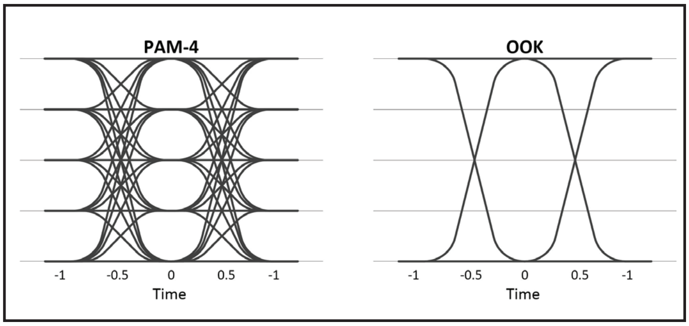


FIGURE 2: Comparison of OOK sensitivity to PAM-4.

Latest Ethernet Standards

The first Ethernet standards for 40 Gb/s (40GBASE-SR4) and 100 Gb/s (100GBASE-SR10) were adopted in 2010. Both used parallel fibers to support higher bit rates on short reach (SR) links (the "4" or "10" following the "SR" designates the number of fiber pairs in the link). Each fiber pair carried 10 Gb/s bi-directionally, so four pairs were needed to support 40 Gb/s and 10 pairs were used to support 100 Gb/s. Typically, a 12-fiber multi-fiber push on (MPO) connector was used as the interface for 40 Gb/s, while a 24-fiber MPO connector was used for 100 Gb/s (two 12-fiber MPOs could also be used).

The second PMD is 400GBASE4.2. This will be the first standards-based application that will exhibit the reach advantage of wideband OM5 fiber.

40GBASE-SR4 has been widely deployed. Initially very popular for server breakout applications where one 40 Gb/s switch port was used to support four 10 Gb/s servers, native 40 Gb/s switch-to-switch links quickly followed. 40GBASE-eSR4 modules are also available to support longer distance links. While not defined in the standard, transceiver manufacturers are increasingly developing "beyond the standards" products that can support longer link distances found in some data centers.

Other than some limited application in service provider central offices, 100GBASE-SR10 has been less widely deployed, in large part because newer standards requiring fewer fiber pairs have been developed.

Both PMDs support up to 150 m link lengths on OM4, but as noted previously, 40 Gb/s transceivers are available that can support longer links.

Soon after its introduction, it became obvious that 100GBASE-SR4 could be used in breakout situations similar to early 40 Gb/s installations, and a single-pair 25GBASE-SR standard was written in 2016. The application space is similar to that for 40 Gb/s breakout, with four 25 Gb/s servers supported by a single 100GBASE-SR4 switch port.

Additional 200 and 400 Gb/s Ethernet solutions were introduced in 2017. Here, only one multimode PMD was included. 400GBASE-SR16 uses 16 fiber pairs, each transmitting at 25 Gb/s. This PMD is not expected to be widely deployed as there is reluctance on the part of end users to deploy 32 fiber cables to support a single link. Newer multimode Ethernet standards being developed will use fewer fiber pairs by incorporating PAM-4 technology and WDM.

What's Ahead for Ethernet?

Table 4 highlights Ethernet standards under development for multimode fiber. IEEE802.3cd is working on a 50/100/200 Gb/s standard, which is expected to be published in the second half of 2018.

PMD	Link Distance	Fiber Count (f) and Media Type	Technology	
50GBASE-SR	100 m OM4/OM5	2-f multimode	1x50G PAM-4 850 nm	**Active – Publication expected in 2018**
50GBASE-FR	2 km	2-f singlemode	1x50G PAM-4 1300 nm	
50GBASE-LR	10 km	2-f singlemode	1x50G PAM-4 1300 nm	
100GBASE-SR2	100 km	4-f multimode	2x50G PAM-4 850 nm	
100GBASE-DR	500 km	2-f singlemode	1x100G PAM-4 1300 nm	
200GBASE-SR4	100 km	8-f multimode	4x50G parallel PAM-4 850 nm	

TABLE 4: Standards under development for 50/100/200 Gb/s Ethernet (IEEE 802.3cd).

The multimode standards are all based on 50GBASE-SR, a 50 Gb/s PAM-4 lane that can support up to 100 m on both OM4 and OM5 fiber. Since the 802.3cd PMDs operate only at 850 nm, there is no advantage to the multi-wavelength support offered by OM5 fiber. 100GBASE-SR2 is a two-pair solution, while 200G BASE-SR4 is a four-pair solution for 200 Gb/s.

The latest IEEE task force to be formed is IEEE 802.3cm. This group has approval to develop two new 400 Gb/s multimode standards. The first PMD, 400GBASE-SR8, will use eight pairs of multimode fiber, each pair carrying 50 Gb/s. This was driven by a hyperscale customer who wanted the flexibility this solution offered, including breakout of 50, 100, and 200 Gb/s, as well as 400 Gb/s switch-to-switch links. There will be two different media interfaces for 400GBASE-SR8: the new 16-fiber MPO that was recently standardized in TIA and the older 24-fiber MPO connector that has two rows of 12 fibers.

The second PMD is 400GBASE4.2. This will be the first standards-based application that will exhibit the reach advantage of wideband OM5 fiber. The task force has established several important parameters, including that the second wavelength (910 nm) and transmission will be bi-directional (BiDi). 400GBASE-SR4.2 plans to introduce a new naming scheme to clearly define the lanes used in the PMD: SRx.y, in which "x" indicates the number of fibers and "y" is the number of wavelengths.

Conclusion

Bandwidth demands in all parts of the enterprise continue to grow and application speeds are increasing to support those needs. Enterprise cloud, hybrid and hyperscale data centers will continue to deploy multimode optical fiber links, and multimode transceivers are evolving to support higher speed links needed in the newest data centers, including the hyperscale market.

Multimode links continue to have cost and operational advantages over competing media types. Through the standards organizations and groups, such as the SWDM Multi-Source Agreement, the industry continues to develop new technological solutions to meet this explosive market demand.

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2. *Relative Link Costs for 100G Applications*, NGMMF Study Group, January 2018.

DATA CENTER CABLE INFRASTRUCTURE

New Methods for Testing and Installing AOC and DAC

By Guylain Barlow

Global IP traffic will increase nearly threefold over the next five years.[1] Furthermore, data-rich and high-bandwidth applications are likely to accelerate at a furious pace with the proliferation of quickly evolving technologies, such as IoT, 4k Ultra HD video streaming, and 5G wireless.

At the heart of this changing ICT landscape is the data center. A massive amount of information is exchanged within data centers and a key requirement to meet the application needs of today and tomorrow is the capacity to scale. Beyond the need for power, cooling, storage and switching inside the data center is the necessity for practical and efficient cabling.

Data centers can roughly be divided between hyperscale, multi-tenant and private. The use of cables as described in this article, namely active optical cables (AOC) and direct attach copper (DAC), applies to all three categories, although this topic is especially applicable to hyperscale data centers. This article addresses practical operational considerations, such as the validation of AOC and DAC to save time and reduce costs in data centers.

DATA CENTER ARCHITECTURES

Figure 1 provides an example of a data center and its interconnectivity to the external world.

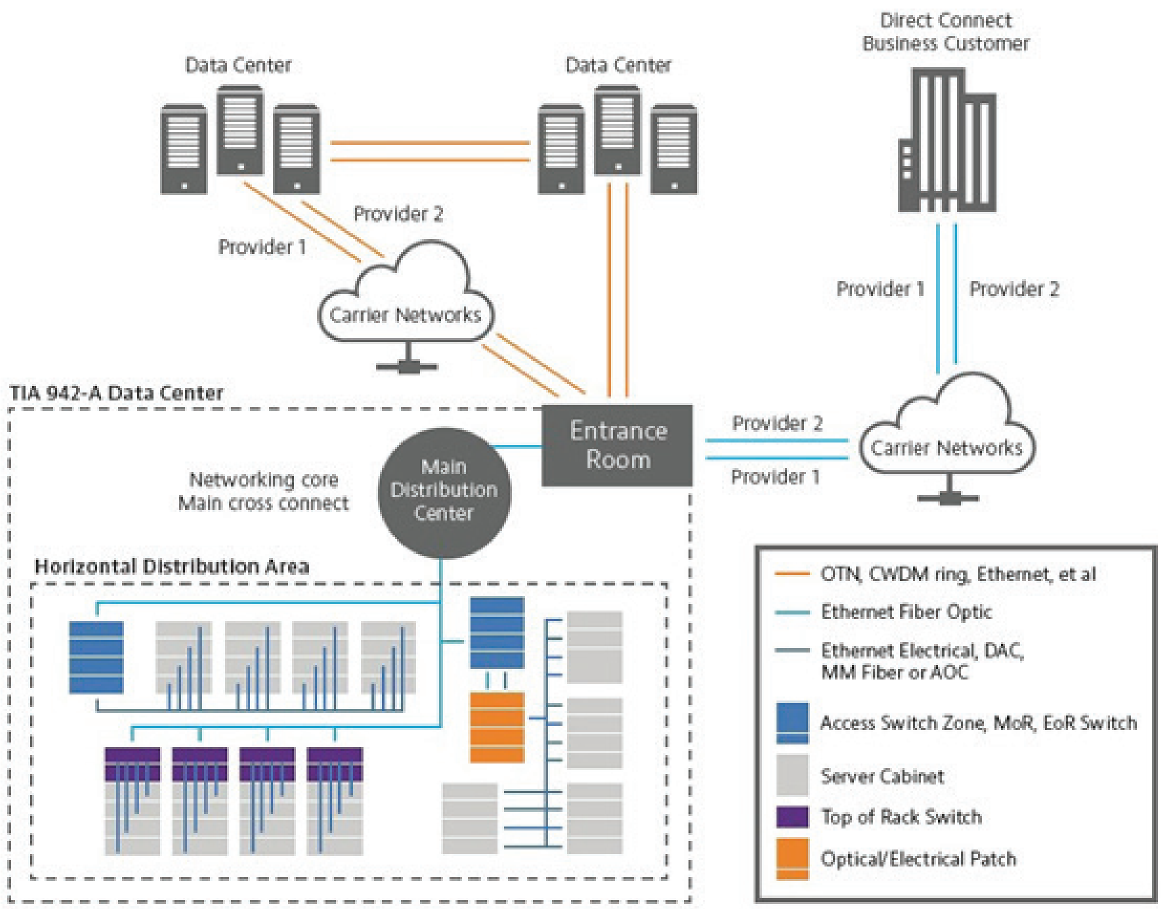


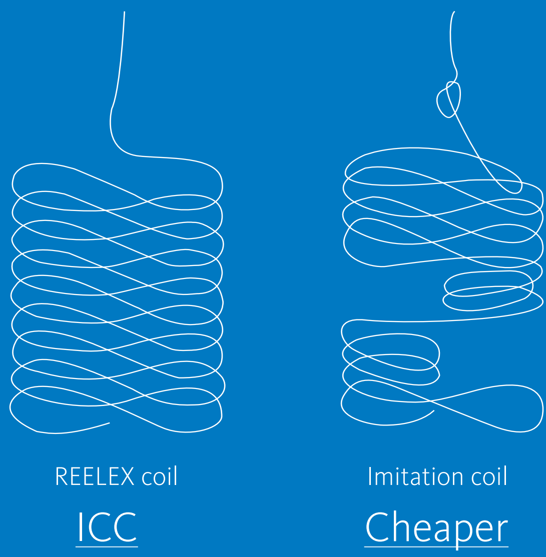
FIGURE 1: Data center architecture.

Within the data center, there are a few potential architectures:

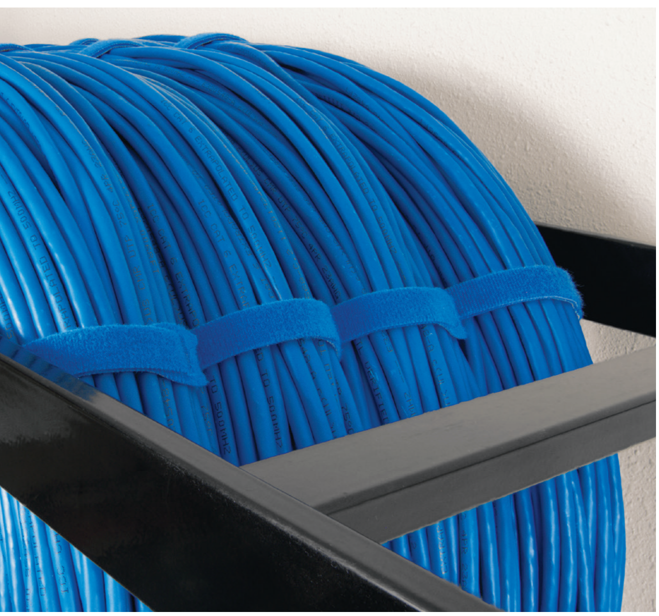
Top of Rack architecture is where the cabling between switch and server stays within a rack. This has the benefit of reducing the overall amount of cabling with the downside of reduced efficiency in the usage of Ethernet switch ports that are limited within a rack.

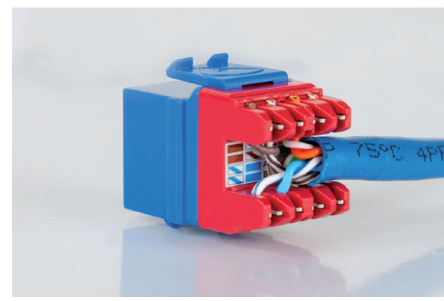
End of Row/Middle of Row (EOR/MOR) configuration is where switch ports are grouped together leading to longer cables. There are two EOR/MOR examples where, in one case, cables connect directly between servers and switch ports. In the second case, physical connectivity goes through a patch panel which provides the benefit of greater connection flexibility with the disadvantage of a higher number of cables.

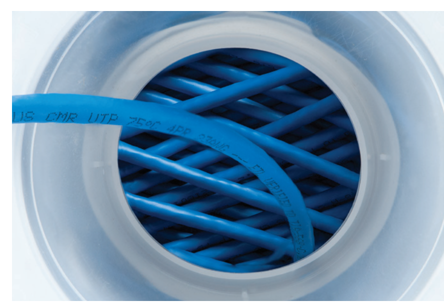
Further information about architectural and cabling design considerations, as well as all major systems within a data center, can be found in ANSI/BICSI 002-2014, *Data Center Design and Implementation Best Practices.*



Cheaper is Better, Right?







Wrong! An installer had to rip out the entire cabling system because the cheap cables failed the test and customer refused to pay. One of the six pull-box kinked, so the installer had to cut the entire bundle. I am sure you heard these horror stories and more. You may think you are saving money using cheap cables. The truth is, you lose thousands of dollars in the long run!

At ICC, we do not believe in "Min. (minimum) Compliance", cheap cables; we only manufacture full compliance cables with REELEX II™ tangle-free, full gauge copper, UL®, RoHS and more. Even with all these features, ICC cables are still 20%-40% less than big brands and ICC Elite Installers are winning projects left and right.

If you want to sleep better at night, and you want a manufacturer-supported warranty, you need ICC cables. Ask your distributor to stop selling you the cheap cables and ask for ICC!

Target Distributing	Jenne	Beach wire and cable	TeleDynamics	Coleman's Telecom	Fontel
888.792.7463 Maryland	800.422.6191 Ohio	800.309.2322 California	800.847.5629 Texas	801.484.5238 Utah	800.238.0787 Nebraska

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ACTIVE OPTICAL CABLES

Active optical cables, as shown in Figure 2, are used in limited range interconnect applications in data centers. For high-speed links at 40 Gigabit Ethernet (GbE) and 100 GbE, this means using multiple lanes of data over ribbon cables. Ribbon cables also facilitate mass fusion splicing that can splice up to twelve fibers at a time, thereby saving time and labor cost dollars. At 10 GbE or 25 GbE, a single lane or optical fiber per direction is enough. An AOC is often based on multimode optical fibers while some (e.g., parallel singlemode 4) is on singlemode optical fiber. A key attribute is that AOC employs the same connectors as pluggable optics and performs electrical-to-optical conversions at each cable end. In practice, this means quad small form-factor pluggable (QSFP) terminations for 40 GbE and 100 GbE and small form-factor pluggable (SFP) terminations for 10 GbE and 25 GbE. The AOC is therefore active and includes transceivers, control chips and modules, in addition to the fiber optic cable. AOC cables are of fixed length, starting at just a few meters (m) with possibilities up to 100 m or more.

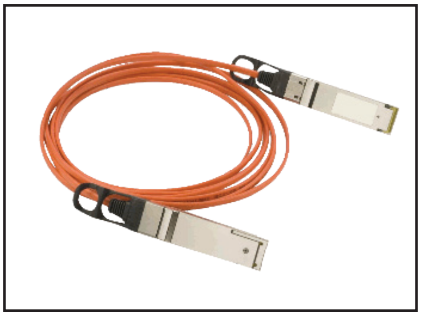


FIGURE 2: AOC cable.

Technically, an AOC does not have to comply with an Ethernet interface type although many advertise a certain type in their coded information. Table 1 provides a list of potential Ethernet interface types. In the table, RS-FEC refers to the Reed-Solomon

Ethernet Rate	Interface Type	Maximum Reach	Medium	No. of fibers/ wavelengths	Wavelength Range	RS-FEC	Pluggable Type
100 GbE	CWDM4 MSA	2 km	SMF	4 λ / dir	1310 nm	Yes	QSFP28
	CLR4 Alliance	2 km	SMF	4 λ / dir	1310 nm	Optional	QSFP28
	PSM4 MSA	500 m	SMF	4 fibers / dir	1310 nm	Yes	QSFP28
	SWDM4 Alliance	75 m 100 m 150 m	OM3 MMF OM4 MMF OM5 MMF	4 λ / dir	850 nm	Yes	QSFP28
	100GBASE-SR4	70 m 100 m	OM3 MMF OM4 MMF	4 fibers / dir	850 nm	Yes	QSFP28
	100GBASE CR4	5 m	Twinaxial	4 cables / dir	N/A	Yes	QSFP28
40 GbE	SWDM4 Alliance	240 m 350 m 440 m	OM3 MMF OM4 MMF OM5 MMF	4 λ / dir	850 nm	No	QSFP+
	40GBASE-SR4	100 m 150 m	OM3 MMF OM4 MMF	4 fibers / dir	850 nm	No	QSFP+
	40GBASE CR4	7 m	Twinaxial	4 cables / dir	N/A	No	QSFP+
25 GbE	25GBASE-SR	70 m 100 m	OM3 MMF OM4 MMF	1 fiber / dir	850 nm	Yes	SFP28
	25GBASE CR	5 m	Twinaxial	1 cable/ dir	N/A	Yes	SFP28
	25GBASE CR-S	3 m	Twinaxial	1 cable / dir	N/A	No	SFP28
10 GbE	10GBASE-SR	33 m 400 m	62.5 µm MMF 50 µm MMF	1 fiber / dir	850 nm	No	SFP+
	10GBASE- CR	15 m	Twinaxial	1 cable / dir	N/A	No	SFP+

TABLE 1: Potential Ethernet interface types.

FEC (forward error correction). Introduced in the 1960s, RS-FEC is still one of the most prevalent channel coding techniques used today. It is a digital mechanism designed to extend transmission distance by adding redundancy to a signal which enables code word self-correction at the far-end. The RS-FEC algorithm, when specified for use with a cable, runs on the Ethernet switches and servers found at each end of the physical connection.

DIRECT ATTACH COPPER CABLES

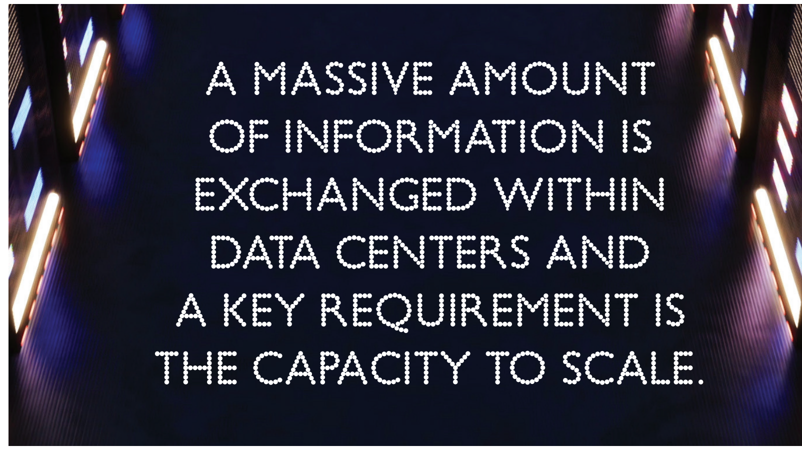
Shown in Figure 3, DAC cables are an alternative when the cable itself is made of copper instead of optical fiber. A DAC may be passive to provide a direct electrical connection or active when signal processing circuitry is integrated in the DAC built-in connectors.

FIGURE 3: DAC cable.

As with an AOC, a DAC will be terminated by SFP or QSFP depending on the line rate. As a comparison, AOC cables support longer transmission distances, use less power, and are more lightweight than DAC cables. However, AOC cables cost more. When comparing AOC cables to traditional fiber optic cables connected to pluggable optics, AOCs provide simplicity of installation without the need to consider interconnection loss, and they eliminate the need to clean and inspect fiber end-faces before making a connection. However, AOC cables cannot be used in EOR/MOR configurations that use patch panels as explained earlier.

ANSI/TIA-942-B addresses the use of direct attach cabling in clause 7.3.4 and recommends the following:

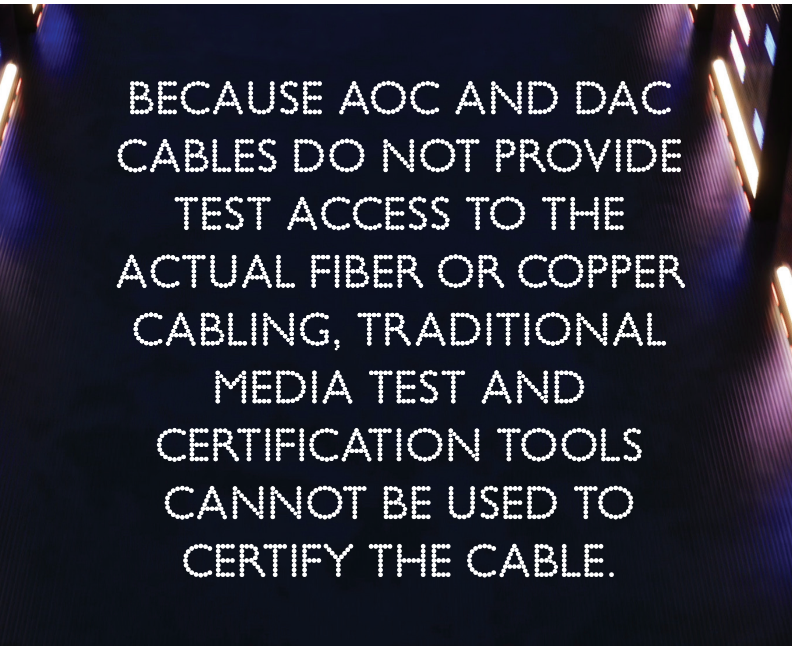
- Cable lengths for direct attach cabling between equipment in the EDA should be no greater than 7 m and should be between equipment in immediately (i.e., not multiple) adjacent racks or cabinets in the same row.
- Direct attach cabling within distributors (MDs, IDs, HDs) and entrance spaces should be constrained within the distributor or entrance space and within a contiguous row.



The corresponding ISO/IEC data center standard, ISO/IEC 11801-5, restricts the use of direct-attach cords within a distributor, within a single cabinet, frame or rack, and between adjacent cabinets, frames, or racks in the same row.

OPERATIONAL CHALLENGES

Because AOC and DAC cables do not provide test access to the actual fiber or copper cabling, traditional media test and certification tools cannot be used to certify the cable. Experience indicates a fairly high rate of failure for AOC and DAC cables to the extent that if a user suspects that a faulty cable has been installed, it is thrown away without the technician knowing whether it was really the source of the problem. At up to $1000 per cable, the cumulative cost to the user or data center can potentially be budget draining. Therefore, a test tool that can accept dual SFP/QSFP transceivers and generate and analyze traffic must be used. Testing AOC and DAC is a critical step to ensure that any issues with network performance are not due to the AOC/DAC cable or its installation. Consider that it is costlier to troubleshoot a faulty cable once installed than to test it upfront (e.g., it is necessary to trace and locate the far end). Causes of AOC/DAC cable failure include simple

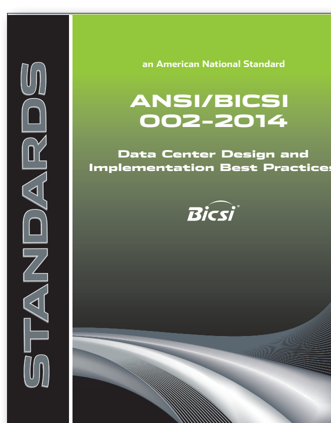


manufacturing defects with wrong or reversed polarities, mislabeling, or damage during shipment. For AOCs, they may get excessively bent, causing high loss, or the optical fibers may get crushed. In the case of DAC, there can be EMI degradation resulting in excessive bit errors. Prior to installation, a technician can choose to test all AOC/DAC cables using a test device equipped with dual-port SFP/QSFP or simply sample test a subset of the cables received from a batch. Troubleshooting cables that are already installed requires two devices because of the distance between the two cable connector endings.

BIT ERROR RATE TESTING

The simplest and most effective way to test cables is to run a test pattern where the results can be compared to a bit error rate (BER) threshold. AOC and DAC cables usually have a BER rating on their datasheets, especially when they are meant to be used with devices implementing the RS-FEC algorithm. This BER rating depends on the type of cable, line rate and type of Ethernet interface. In the case of a cable meant for use with RS-FEC encoded traffic, which is typical at 100 GbE and 25 GbE, there may even be both a pre-FEC rating, which is before error correction, and post-FEC rating after error correction. In this case, it is recommended to perform a cable test using a pre-FEC BER threshold close to the cable BER rating and ensure the measured BER is smaller than the threshold for a successful test. For 40 GbE and 10 GbE cables where RS-FEC is not used, the expected BER threshold needs to be quite a bit smaller as there is no error correction on those circuits. In such cases, if there is no BER rating for the AOC or DAC, the recommended BER threshold is 10^{-12}. Test times of one minute per cable are more than sufficient to obtain meaningful BER results with line rates of 10 gigabits per second or higher. Best practice procedures for cable tests will result in the generation of test reports including a cable identifier, such as the serial number, which can be read from an AOC or DAC cable. In summary, ensuring AOC or DAC cables are tested against their target BER thresholds is a meaningful method to ensure cables will be functional when connected to switches and servers in the data center.

CONCLUSION: OPTIMUM TESTING OF AOC AND DAC CABLES



ANSI/BICSI 002-2014 section 9.11 covers Testing and Quality Assurance, as well as many testing best practice procedures that should be followed.

From a test unit and optimum testing of AOC and DAC cable perspective, technicians should seek a complete test and measurement solution in an all-in-one testing unit that provides line rates up to 112 Gbps. For contractors and installation companies, there are many considerations when evaluating their inventory of testing units for performance, reliability and long-term investment cost savings. The testing units should include the following:

- Support for all Ethernet rates with dual-port capabilities, including 10/100/1000BASE-T, optical GbE, 10 GbE, 25 GbE, 40 GbE, and 100 GbE.
- Multi-functionality to test numerous applications, such as AOC/DAC cables, metro, backbone, and data center interconnectivity.
- Testing capabilities from DS1/E1 to OTU4, including CPRI, Fiber Channel, PDH, SONET/SDH, OTN, and Ethernet.
- Expansion to support optical time domain reflectometer modules, fiber inspection with auto-focus, and advanced timing and synchronization capabilities.
- Cloud-based asset management, configuration, and reporting for easy management and sharing.
- 5G-readiness.

THE SIMPLEST AND MOST EFFECTIVE WAY TO TEST CABLES IS TO RUN A TEST PATTERN WHERE THE RESULTS CAN BE COMPARED TO A BIT ERROR RATE (BER) THRESHOLD.

Like the data center, an all-in-one testing unit needs to be scalable and future-proofed to support both legacy and emerging technologies with the lowest cost of ownership possible.

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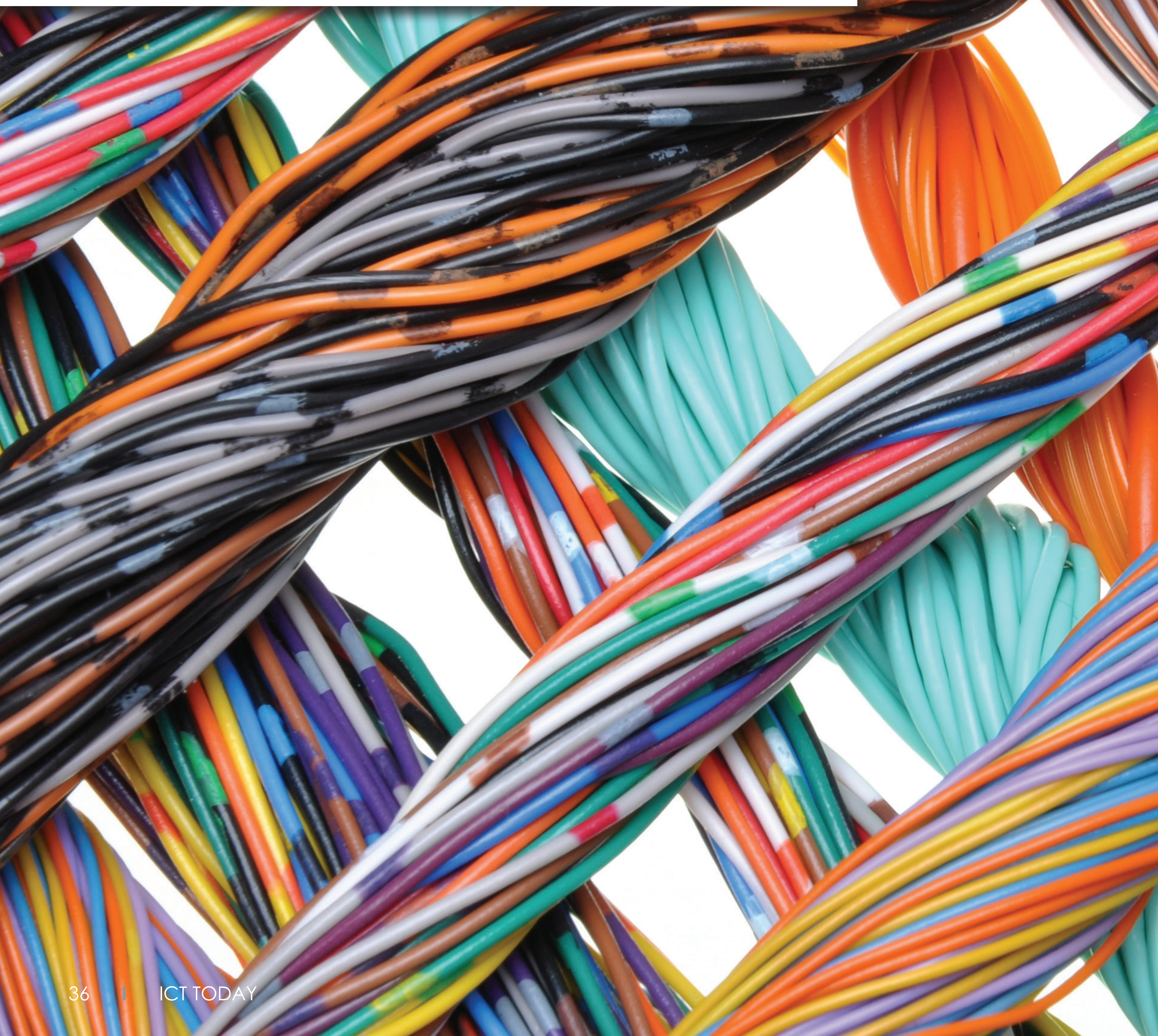
Everything You Need to Know about Multimode Optical Fiber Networks

By Adrian Young



Enterprise optical fiber networks are often viewed as being complex with numerous choices and methods to consider. For those information and communications technology (ICT) industry professionals who are new to installing fiber optic cabling systems, this article sheds some light on today's enterprise fiber infrastructures to help gain a better understanding of available options covering the range of fiber types, connector and termination choices, and multimode applications.

Multimode Optical Fiber

Multimode optical fiber is the most common media choice for both backbone and horizontal distribution within the LAN including campuses, buildings, and data centers.

With multimode, there are many modes of light, rather than one beam of light traveling down the cable as with singlemode. These modes travel down the cable at different speeds. As depicted in Figure 1, the white area in the middle is the fiber core surrounded by cladding. When light is sent into multimode cable, it is going to hit the cladding and then reflect up until reaching the point of the critical angle. As these modes advance at different angles, they will arrive at different times at the other end. The pulse of light placed at the front end is going to spread as it travels down the cable. The longer the fiber, the more spreading occurs. This is called dispersion. Inherently, dispersion is the effect of different delay times of the individual modes.

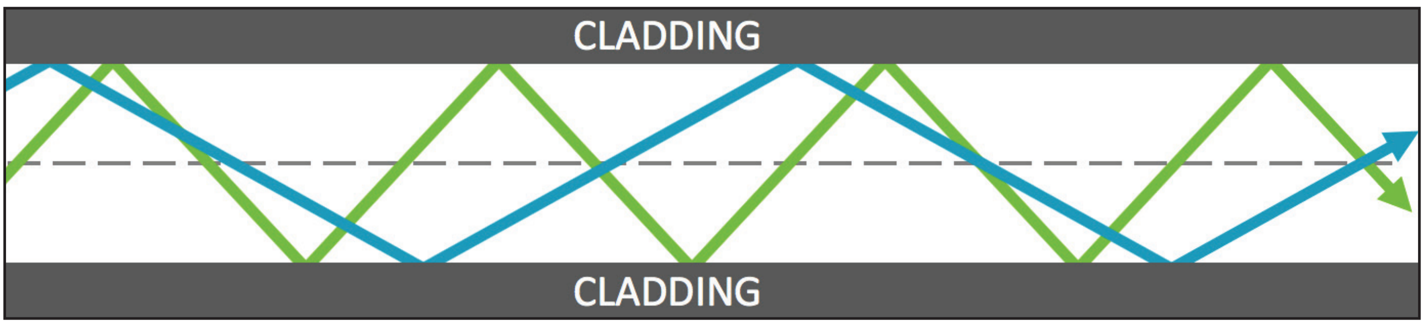


FIGURE 1: Multiple modes of light, characteristic of multimode optical fiber cable.

Cable manufacturers over the years have been able to reduce this dispersion, enabling increased distance or higher speeds over multimode cable.

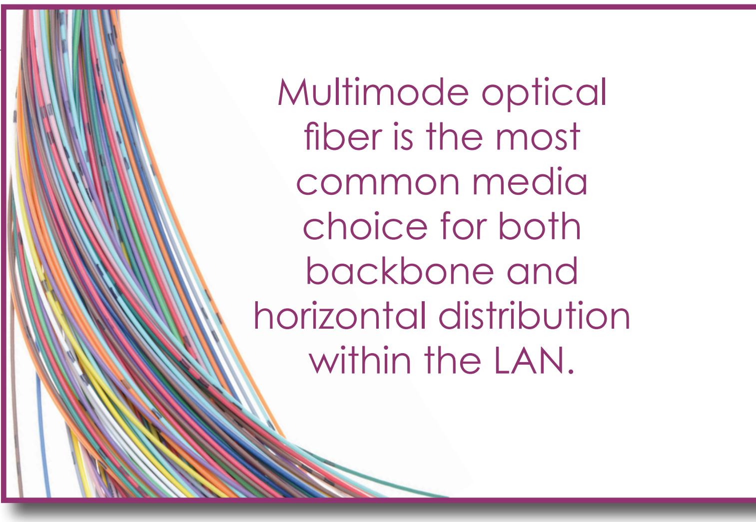
Designation	Modal Bandwidth @ 850 nm (MHz.km)	1000BASE-SX (Duplex LC) Meters	Feet	10GBASE-SR (Duplex LC) Meters	Feet	40GBASE-SR4 (MPO) Meters	Feet	100GBASE-SR4 (MPO) Meters	Feet
—	160	225	738	26	85				
OM1	200	275	902	33	82	—	—	—	—
OM2	500	550	1,808	82	269				
OM3	2,000	860	2,822	300	984	100	328	100	328
OM4	4,700	860	2,822	400	1,312	150	492	150	492
OM5									

FIGURE 2: Multimode optical fiber types and distances.

Review of Multimode Optical Fiber Types

- **OM1**
  Standards designate OM1 (62.5/125 µm) cable as orange. However, 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 nanometers (nm), as opposed to 200 MHz/km for OM1. If an orange cable is encountered that is not marked OM1, the technician may need to assume the cable is 160 MHz/km.
- **OM2**
  OM2 (50/125 µm) provides a much better modal bandwidth than OM1, 500 MHz/km @ 850 nm. The industry standard color for OM2 is gray. However, there are some early OM2 cable installed that is orange, so always check the markings to make sure.
- **OM3/OM4**
  Both laser-optimized OM3 and OM4 cable share the color aqua, since TIA and ISO have not introduced a new color for OM4. However, some manufacturers introduced the color Erika (heather) violet to designate OM4. 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**
  The color lime for OM5 cable was approved by TIA and ISO in 2017. Note in Figure 2 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, which transmits four channels on one duplex multimode optical fiber pair between 850 nm and 953 nm. However, for all existing IEEE applications, there is no current advantage of OM5 over OM4.

While multimode optical fiber comes in either 50 micron or 62.5 micron core size, the ANSI/TIA-568.0-D standard recommends 850 nm laser-optimized 50/125 micron be installed for new structured cabling designs.



This includes both OM3 and OM4 classifications to support 10 Gigabit Ethernet (10 GbE) and possibly provide a migration plan to support future 40 and 100 GbE applications. Both OM1 (62.5/125 micron) and OM2 (50/125 micron) classifications are now considered legacy fiber types.

Understanding Distance Limits

- **1 GbE/s**
  The majority of enterprise optical fiber networks today still run 1000BASE-SX, delivering up to 1 GbE/s over multimode. OM1 cable supports 1000BASE-SX out to 275 meters (m) and that distance jumps to 550 m with OM2 cable. OM3, OM4 and OM5 came after the 1000BASE-SX standard was written, so the distances up to 860 m listed in Figure 2 are based on the gigabit fiber channel values. When ICT managers require distances upwards of 860 m, they will likely want to consider singlemode cable instead of multimode.
- **10 GbE/s**
  Many enterprise networks are moving beyond 1000BASE-SX and transitioning to 10 Gigabit Ethernet networks, such as 10GBASE-SR. This is where distance considerations really come into play. A network using OM1 has a maximum distance of 275 m for 1000BASE-SX, but it would see a distance limit of only 33 m for 10GBASE-SR. Similarly, OM2 fiber for 1000BASE-SX has a 550 m limit, but drops down to 82 m for 10GBASE-SR. The introduction of OM3 increased that distance to a more usable 300 m in the enterprise.

Distance limits for 10 GbE/s over OM4 and OM5 are listed at 400 m in Figure 2. This limit is set by TIA and IEEE standards based on worse case assumptions. However, these distances can likely extend out to 500 or 550 m. The 400 meter limit is based on the transceiver having a spectral width of 0.65 nm, but most of these transceivers today are 0.47 nm, so the distance can typically extend farther than 400 m. That is a conversation to have with the cabling manufacturer.

- **40 and 100 GbE/s**
  When considering multimode for 40 Gigabit Ethernet—namely 40GBASE-SR4 using four transmitters and four receivers—an MPO-style connector is needed. Older OM1 or OM2 fiber cannot be used to support 40 and 100 GbE/s. Also, the distance limits will drop to 100 m for OM3 and 150 m for OM4/OM5. The original intent of 40GBASE-SR4 was for the data center where the vast majority of the links are less than 100 m. In contrast, enterprise links are typically much longer than 100 m. These networks will likely deploy 10GBASE-SR throughout the campus, and then 40GBASE-SR4 in server rooms or telecommunications rooms. Moving to 100GBASE-SR4 reduces the supported length further to 70 m over OM3 and 100 m over OM4/OM5, which is why there is an increase in the deployment of OM4 fiber and the growing consideration of singlemode, which is not so distance limited.

There are two IEEE Ethernet compliant options for 100 GbE/s over multimode: 100GBASE-SR10 and 100GBASE-SR4. The 100GBASE-SR10 standard was introduced in 2010 and delivers 100 GbE/s over 10 lanes at 10 GbE/s per lane, requiring 20 fibers in total and the use of a 24 fiber MPO connector. With most installations at the time utilizing 12 fiber MPO connectors, its adoption was not nearly as successful as 100GBASE-SR4, introduced in 2015. 100GBASE-SR4 reduced the lane count to four lanes at 25 GbE/s each, requiring only eight fibers in total, supported over the existing 12 fiber MPO installations.

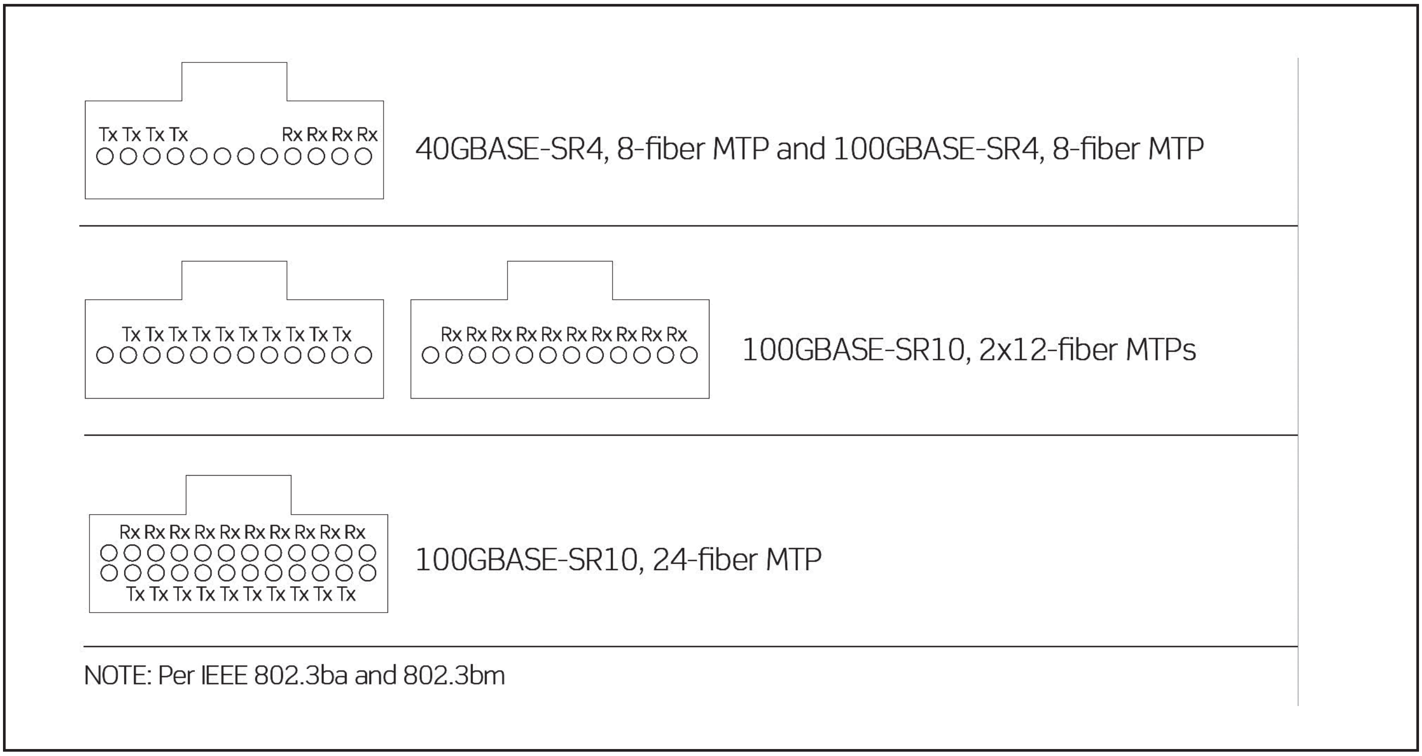


FIGURE 3: MPO lane assignments for 40 and 100 GbE/s. MTP® is a registered trademark of USConec Ltd.

If looking beyond 100GBASE-SR4, IEEE 802.3cd (when published) will support 200GBASE-SR4 using the same number of fibers as 100GBASE-SR4 to again provide an easy transition. Looking even further ahead and targeted for data centers only, 400GBASE-SR4.2, found in draft IEEE 802.3cm, will also use the same number of fibers in a four-pair scheme that will leverage two wavelengths per fiber.

When looking for a migration path with fewer connectivity components to be replaced or added when upgrading, a 24-fiber MPO system can simplify migration and reduces costs for both components and installation. For example, when a 24-fiber backbone trunk cable is installed in a 10GBASE-SR network, that backbone stays in place when upgrading to either a 40GBASE-SR4 or 100GBASE-SR4 network. A single 24-fiber MPO terminated cable with an appropriate cassette at each end can support 12 x 1000BASE-SX or 10GBASE-SR links, or 3 x 40GBASE-SR4 / 100GBASE-SR4 links, simplifying network upgrades immensely. When equipment is upgraded, only cassettes and patch cords are exchanged for the appropriate new MPO/MTP components.

Non-IEEE-Based Applications

Consider a scenario where there is duplex (two strand) multimode fiber in a network. If wanting to upgrade to a higher bandwidth, such as 40 and 100 GbE/s, the technician or installer would likely need MPO/MTP connections at some point. However, if not in the position to do that today, then there are some non-IEEE options available.

The proprietary QSFP 40 Gb/s Bidirectional (Bidi) Transceiver, QSFP-40G-SR-BD, has a duplex LC connector interface using multimode fiber. Each BiDi transceiver consists of two 20 Gb/s transmit and receive channels, enabling an aggregated 40 Gb/s link over a two-strand multimode fiber connection using two wavelengths as shown in Figure 4. This transceiver transmits 850 nm at 20 Gb/s on one fiber, and then receives on that same fiber at 900 nm. This allows customers to reuse their existing duplex 10GBASE-SR infrastructure for migration to 40 Gb/s connectivity.

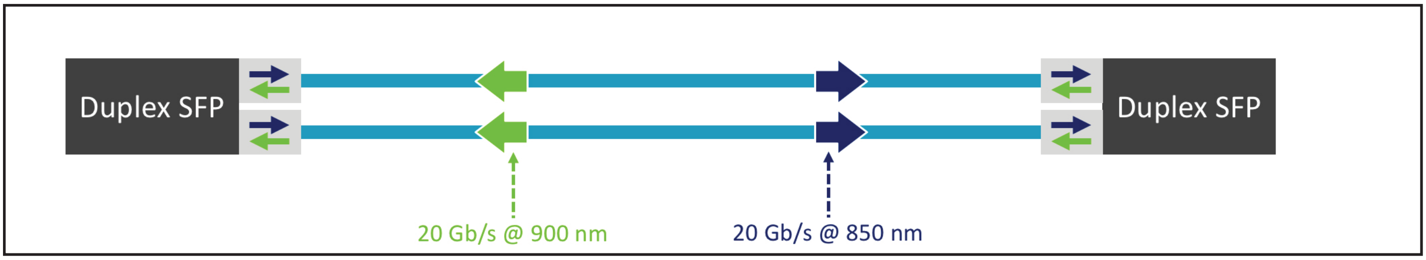


FIGURE 4: Cisco 40 Gb/s BiDi, Bi-directional transmission over two wavelengths.

In addition, non-IEEE versions defining 100 Gb/s over duplex have been released (Figure 5), extending the life of those older duplex installations. Support is only stated for OM3, OM4 and OM5.

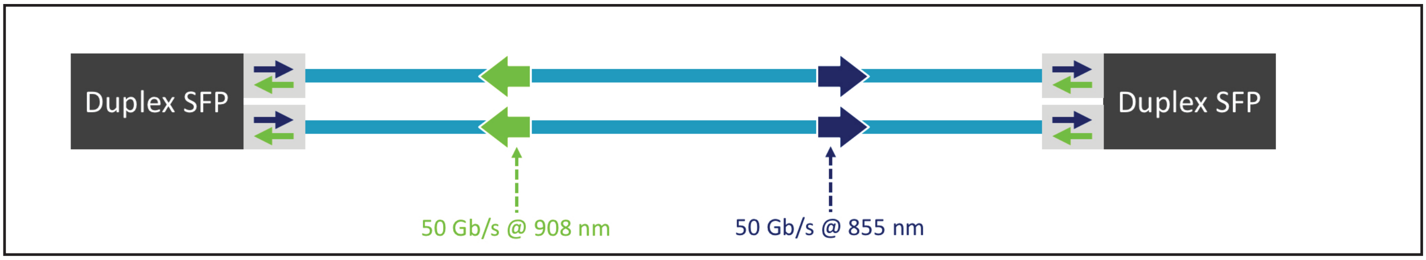


FIGURE 5: Cisco 100 Gb/s Bi-directional transmission over two wavelengths.


BICSI
RCDD

Connector Options

The type of optical fiber connector chosen ultimately is influenced by the fiber transceiver interface. There are quite a few connector types available, including LC, SC, MPO, ST, and FC. However, this list has been consolidated recently based on trends in transceivers. While technicians/installers may encounter more legacy connectors in existing enterprise networks, such as ST or FC, they will likely choose an LC or MPO connector moving forward.

LC

The Lucent connector or "little connector" is a small form factor latching connector and is keyed for standard A/B duplex polarity. It has a 1.25 mm ferrule and is half the size of an ST or SC connector. It is also available in duplex.

MPO / MTP

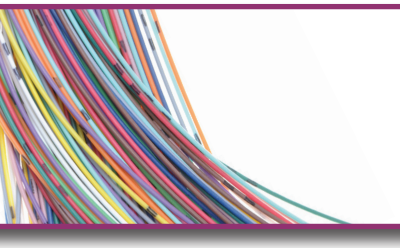
The MPO or multi-fiber push-on connector can accommodate up to 32 fibers and is keyed for array polarity. MTP is a high performance MPO connector, trademarked by USConec Ltd.

SC

The Subscriber connector is a push-pull connector with a 2.5 mm ferrule and is keyed for standard A/B duplex polarity.

ST

The Straight Tip connector uses a twist lock coupling and a 2.5 mm ferrule. While it was once the most popular connector for multimode networks, it is now a legacy connector and is difficult to use in high density duplex applications. It is no longer recommended by TIA.



The type of optical fiber connector chosen ultimately is influenced by the fiber transceiver interface.

Installing Optical Fiber Connectors

There are four basic approaches to terminating optical fiber connections in the field: adhesive connection and field polishing, mechanical connectors with no polishing, splice on connectors and fusion splicing using pigtail assemblies:

1. Field polish / adhesive terminations
Adhesive connectors are a very common option. With these terminations, 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 to purchase. However, they are very craft sensitive, so labor costs are a consideration. Also, a word of caution: TIA has tightened its requirements for singlemode return loss (reflectance) at 35 dB. Meeting those requirements become much more challenging with field polish connections. Concerns over return loss are typically limited to singlemode deployments. If planning to install singlemode, the technician/installer may wish to consider one of the other three options.

2. Factory polish / mechanical connections
With mechanical connectors, the end-faces are factory-polished and highly controlled, leading to better insertion loss and return loss. However, these connectors do cost more than field polished connectors and will require a precision cleaver. The upside to that investment is that labor savings can be considerable.

3. Splice-on connectors
Mechanical connections have proven to be reliable over the years, but there are still skeptics in the ICT industry. Still relatively new to many, splice-on connectors are pre-polished with a very short fiber tail that is spliced directly onto the trunk cable, eliminating the need for a splice tray. It requires the investment of a fusion splicer and often the use of a specific type of fusion splicer and holder for compatibility.

4. Fusion splicing pigtails
Typically found in long haul singlemode applications, but now making its way into the enterprise, fusion splicing pigtails are pre-terminated fiber connectors with typically a three-foot fiber tail that is fusion spliced onto the trunk cable. If this sounds similar to the splice-on connectors, it is. However, the advantage over splice on connectors is that it can be cut and re-fused. With the splice-on connectors, there is one shot only. Any problematic issues require a new connector assembly.

Making Forward-Looking Choices For the Network

Fiber optic network infrastructures and the many options available may seem overwhelming, so it is important to get assistance from ICT experts who understand the evolution of fiber for enterprise and data center networks. Be sure to reach out to network consultants or the cabling system manufacturer to help with the best possible multimode or singlemode migration strategy that meets the specific goals and requirements of each data center and enterprise project.

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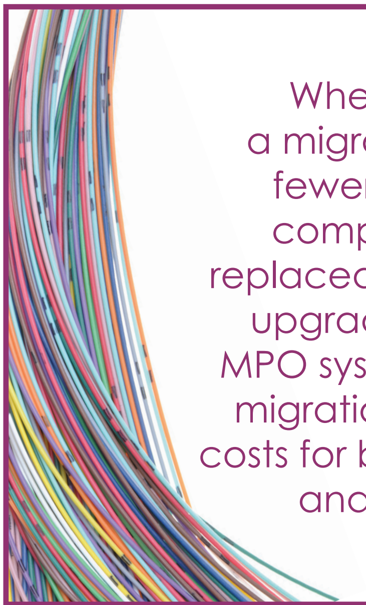
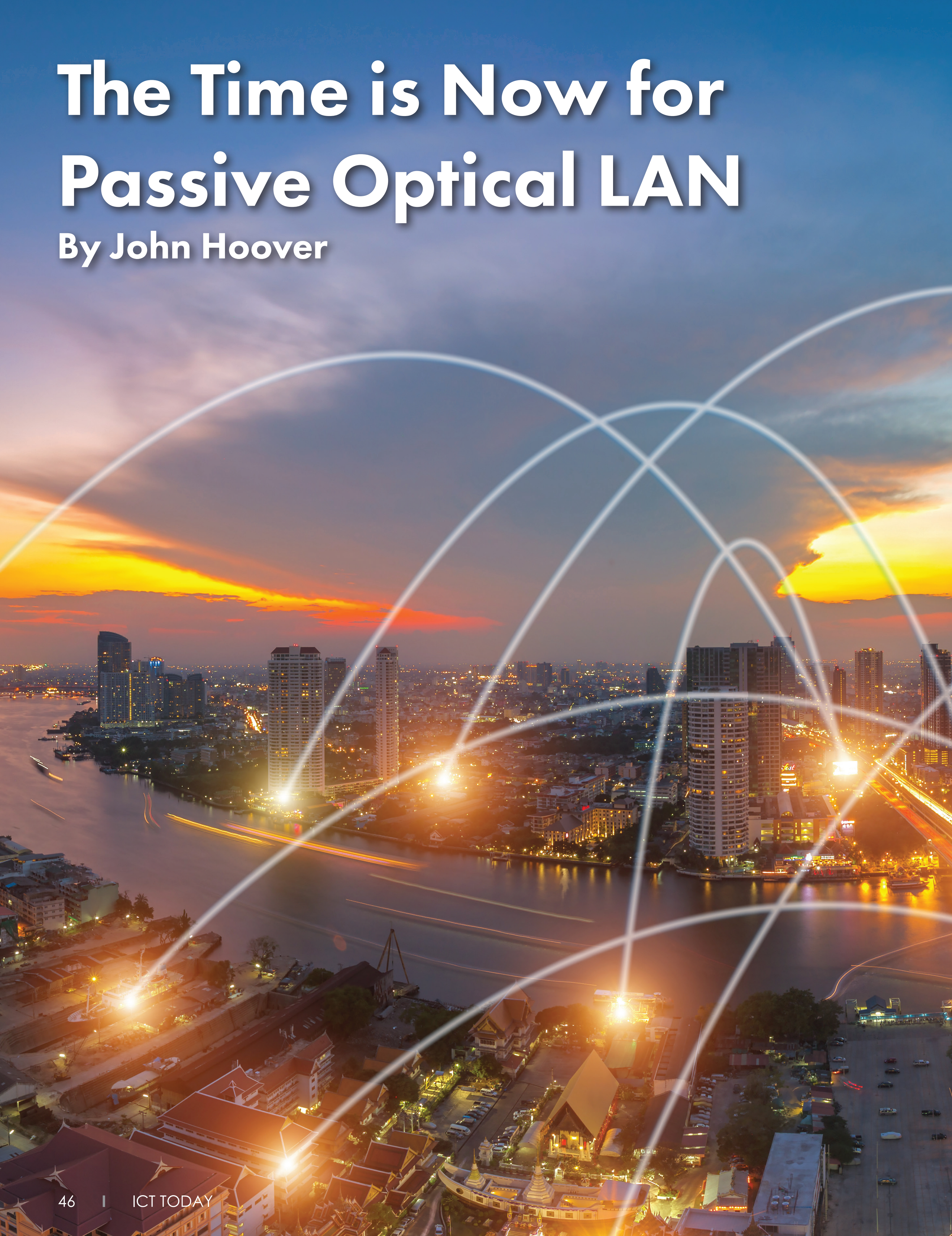


When looking for a migration path with fewer connectivity components to be replaced or added when upgrading, a 24-fiber MPO system can simplify migration and reduces costs for both components and installation.

The Time is Now for Passive Optical LAN

By John Hoover



2018 is winding to a close, which makes it the ideal time to pause and take stock of the year's technical advancements in ICT, such as passive optical LAN (POL). There are many recent positive data points indicating that enterprise-based POL has experienced accelerated growth in 2018 for commercial and federal government markets — not only in an increase in new customers, but also in the maturity of the POL industry as measured by factors such as:

- Greater industry awareness
- Increased players and customers
- Industry trends driving fiber-based enterprise LAN growth (e.g., wireless network infrastructures, IoT and smart buildings, LAN security).

Greater Industry Awareness

New technology adoption starts with an awareness of a new idea that offers some improvement to the greater industry. It was more than 10 years ago when Verizon launched its fiber-to-the-home (FTTH) service called FIOS, which was based on passive optical network (PON) technology. With the success of this residential offering of voice, data and video over a passive optical fiber infrastructure, Verizon began to explore adjacent market verticals, such as downtown high-rise apartment buildings and multi-tenant units (MTUs). Then came large federal government campuses. When businesses, whether government or commercial enterprises, adopted PON technology, it began to serve the ICT needs of the enterprise LAN. That meant the PON optical line terminals (OLTs) in the enterprise's main data center and optical network terminals (ONTs) at workers' desks or work stations were required to support advanced Ethernet, IP, security, controlled access, and power over Ethernet (PoE) applications.

Industry-wide awareness of the success of PON, FTTH and Verizon FIOS is well known, while awareness about enterprise-POL has been steadily growing over the years [Figure 1].

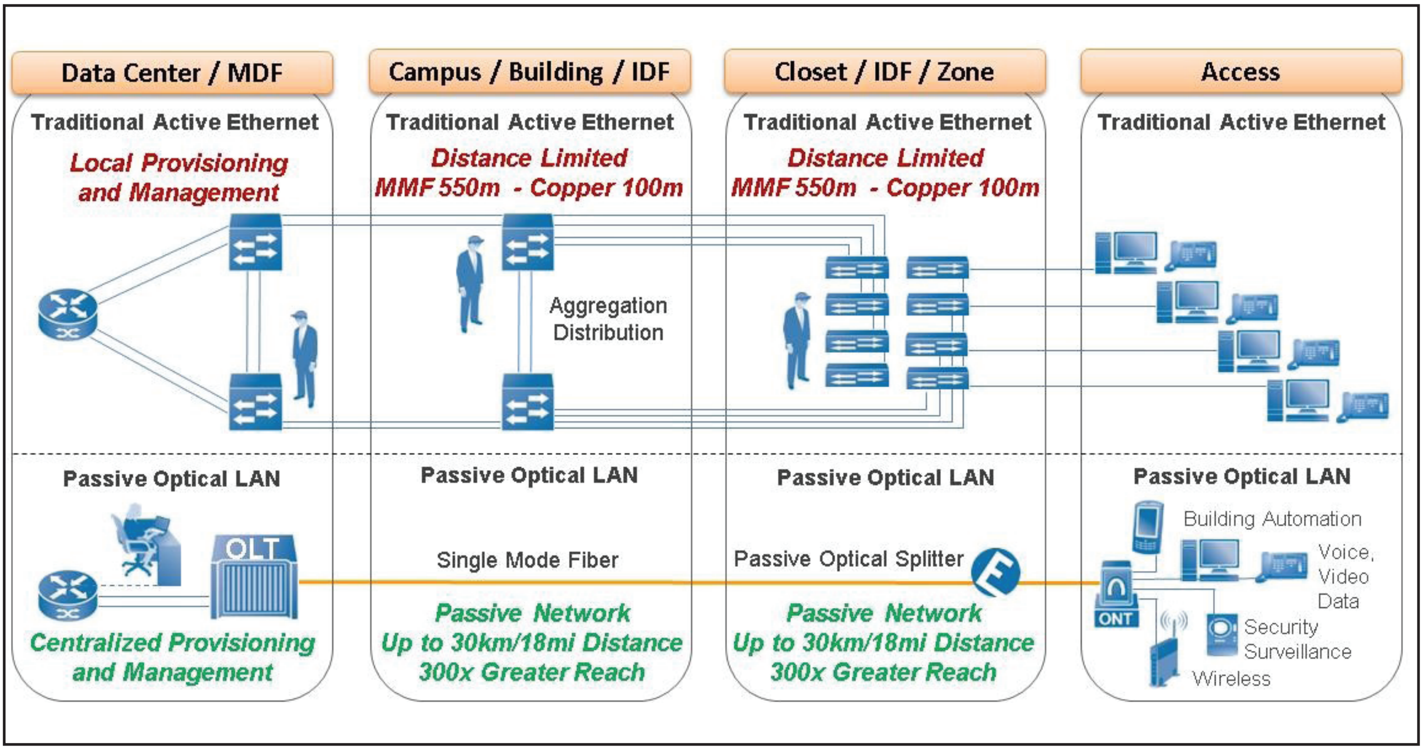


FIGURE 1: Comparing the configurations of a passive optical LAN to a traditional copper-based active Ethernet LAN.

Industry-wide awareness of the success of PON, FTTH and Verizon FIOS is well known, while awareness about enterprise-POL has been steadily growing over the years.

In late 2017, APOLAN, a non-profit association advocating the education and global adoption of POL, commissioned Hanover Research to provide a custom study on the technology's awareness and adoption. The survey revealed that 44 percent of the ICT professionals they spoke with heard of POL and were familiar with it. 59 percent found fiber-based LAN solutions very appealing.[1] The findings from the POL survey showcased how the industry perception of POL evolved very quickly over the last few years. Hanover Research went on to identify POL's most appealing benefits driving its growth (see Figure 2). According to survey participants, the most appealing benefits included product quality, reliability, longevity and POL's centralized management capabilities.

Increased Players and Customers

Gartner, a global research and advisory firm, has been actively tracking the market adoption for POL since its inception. Over the years, it has published several studies

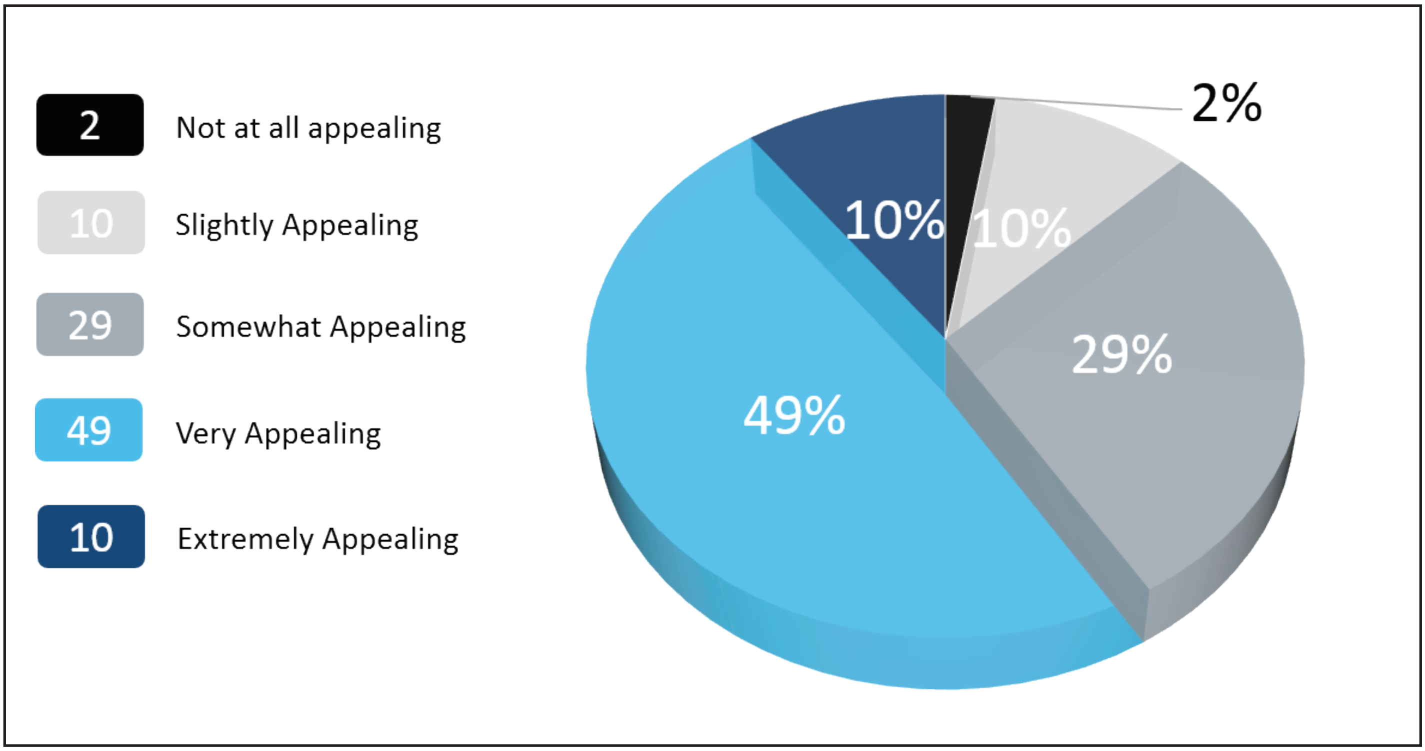


FIGURE 2: Hanover Research survey showing 59% of respondents find fiber "very" and "extremely" appealing.

The latest BSRIA global POL study, Passive Optical Local Area Networks (POL) 2018, calculated that the POL market is ramping at a 46% compound annual growth rate (CAGR).

on the topic. In March 2018, Gartner updated its ongoing POL research with a new study titled, *Does POL Have a Future in Your Access Network?* [2] In this study, it cited a growing number of Gartner client inquiries investigating POL and that the number of network integrators offering the POL solution continues to increase. Gartner's position was that POL is a mature technology, since it has been deployed by many large service providers for years. It also considers the technology an alternative to the traditional copper-based LANs, especially when new cabling infrastructure is required. Finally, Gartner recommends POL as an option when customers need extended Ethernet connectivity, experience talent shortage, or when network security is a top concern.

Building Services Research and Information Association (BSRIA) is a research and consultancy organization, providing specialist services in construction and building services. BSRIA tracks new trends in building construction and enterprise workplace design that are driving innovation in enterprise networks inside buildings and across campuses. BSRIA also has been tracking POL adoption over the past couple of years. Its reports highlight how building owners, developers and ICT decision-makers must reprioritize upgrades to the in-building technology backbone infrastructure to make the necessary changes to meet growing connectivity needs. The latest BSRIA global POL study, *Passive Optical Local Area Networks (POL) 2018* [3], calculated that the POL market has a 46% compound annual growth rate (CAGR). BSRIA's growth projection for new POL projects is influenced by the overall maturing of the POL industry and the growing number of POL manufacturers and integrators both in North America and globally.

"BSRIA's previous network cabling market brief cited that POL will experience significant growth, gaining market share and awareness in the LAN market, solidifying its position as a disruptive technology," said Martin Chiesa, BSRIA senior researcher. "Two years later, we have released the third edition of our POL report and found that POL has evolved faster than our most optimistic expectations."

APOLAN has witnessed international expansion for POL in the past two years. This has come in the form of adding more international member companies to the organization. In fact, one of the factors for BSRIA's impressive CAGR growth projections is due to the entry of network equipment manufacturer heavyweights and the global scale that they can bring to a technology like POL. Furthermore, as a result of this increased demand for POL worldwide, APOLAN established committees covering the European and Asia Pacific regions.

Industry Trends Driving Fiber-Based Enterprise LAN Growth

In early summer of 2018, APOLAN conducted a survey among its members to solicit feedback about which industry trends POL could have the greatest positive impact. The top three responses were:

- Wireless network infrastructure
- Internet of Things (IoT)
- LAN security

Wireless Network Infrastructure

POL can be deployed for wireless backhaul transport of access points traffic. It can do so via two architectures. First, there is the standalone static Wi-Fi architecture with no robust controller functionality. In this scenario, POL can provide the benefits of lower equipment cost, reduced energy and collapsed cabling infrastructure. There are also wireless access point (WAP) features and functionality integration that can be accomplished with POL via the centralized management platform. POL provides a greater system reach for improved performance and coverage for Wi-Fi service. When POL interoperates with established Wi-Fi vendors, it allows for Wi-Fi controller functionality to be provided by best of breed Wi-Fi manufacturers without limiting customer options. The controller functionality adds dynamic provisioning, interference correction, load balancing and coverage optimization as is required in a true enterprise deployment.

There are also synergies between POL, distributed antenna systems (DAS), small cell, future 5G cellular readiness and fiber optic cabling as illustrated in Figure 3. The cellular traffic does not necessarily traverse the POL equipment, but it can leverage the same fiber infrastructure that POL utilizes. Indoor enterprise cellular networks have a challenging return-on-investment (ROI) analysis. They are relatively expensive, perform only one function, and end customers believe they should not have to pay for them. Conversely, POL

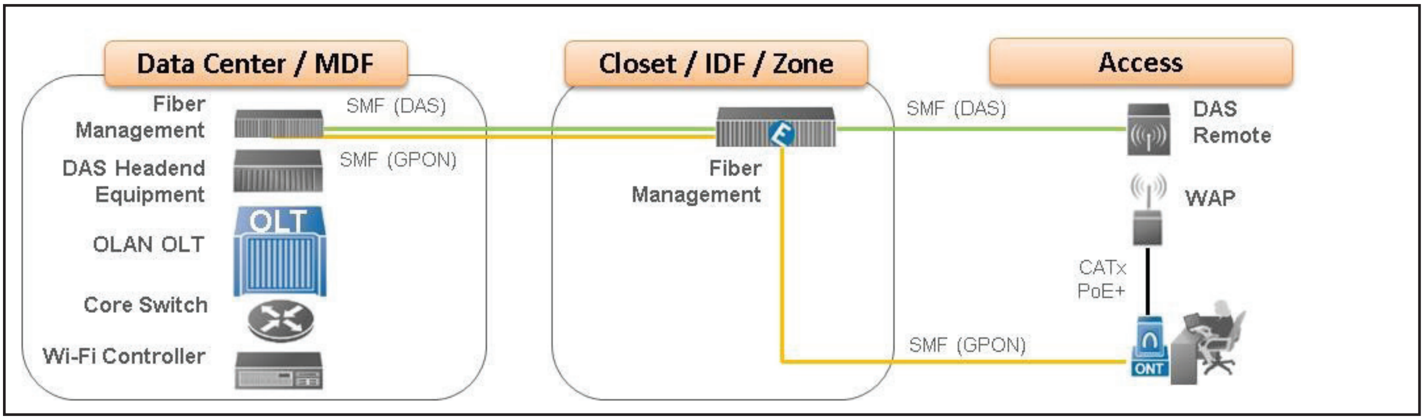


FIGURE 3: An example of indoor enterprise cellular network over fiber with synergies with optical LAN architecture.

has an excellent ROI that can justify the deployment of indoor cellular over existing fiber plant inside buildings and across a campus. Next-generation enterprise cellular network solutions are not going to be supported or their traffic backhauled over copper-based CATx cabling. Thus, investments in fiber optic cabling are protected relative to future demands of indoor enterprise cellular network advancements.

It should be noted that the ONTs support IEEE standards for 802.3af PoE, 802.3at PoE+, and 802.3bt 4PPoE (PoE++) to power the Wi-Fi WAPs. The ONTs also provide powered device (PD) management, monitoring and configuration using link layer discovery protocol (LLDP). The ONT detects the actual power requirements of a PD and then adjusts the power allocation for that PoE port. There are also mechanisms for providing reports on power consumption so that ICT managers may adjust deployment configurations to low-power modes for devices like WAPs and IP phones.

Internet of Things and Smart Buildings

There is a recognized need to design and build a network infrastructure that supports thousands of digital services and connectivity. That same LAN also needs to have the flexibility to expand as thousands of additional gigabit Ethernet (Gbe) connections are added over time and as the sheer number of digital devices grows exponentially. This is the same problem faced by ICT professionals around the world as they prepare to support the network demands of smart/intelligent buildings and the inevitable impact of IoT. In a traditional network design, this rapid connection growth requires racking and stacking Ethernet switches in telecommunications rooms (TRs) and running point-to-point copper cabling 100 meters to every connected device. Each time more electronic switches and copper cables are added, it negatively impacts energy, thermals, reliability, security, and especially environmental green programs. This is neither a sustainable business nor a sustainable green approach.

POL architecture, on the other hand, is a simple, scalable, stable and secure fiber-based network architecture that is ideal to handle the digital transformation of enterprise businesses and their buildings (see Figure 4). POL network design ensures ICT professionals a graceful and cost-effective means with which to grow their network connectivity in response to smart building IoT demand by leveraging the optical LAN system and superior cabling capacity. POL relies on singlemode (SMF) cabling from the main data center through the cable risers, through the horizontal pathways, and as close to the digital devices as possible. SMF cable bandwidth is tremendous and is measured in terabits today, far greater than copper cables' capacity measured in Gbs. With this greater capacity, the lifespan of SMF is expected to exceed twenty-five years, whereas copper cables historically have been ripped and replaced every five to seven years. Similarly, the optical LAN system and its components, such as passive optical splitters, already provide a graceful and conflict-free migration to 10Gb, 40Gb and 100Gb capacity. Optical LAN has greater gigabit Ethernet density in a smaller footprint and scalability to support thousands of future smart intelligent building IoT applications. Finally, POL has centralized intelligence and management to control the thousands of IoT connected devices in a more machine-to-machine (M2M) and plug-and-play approach.

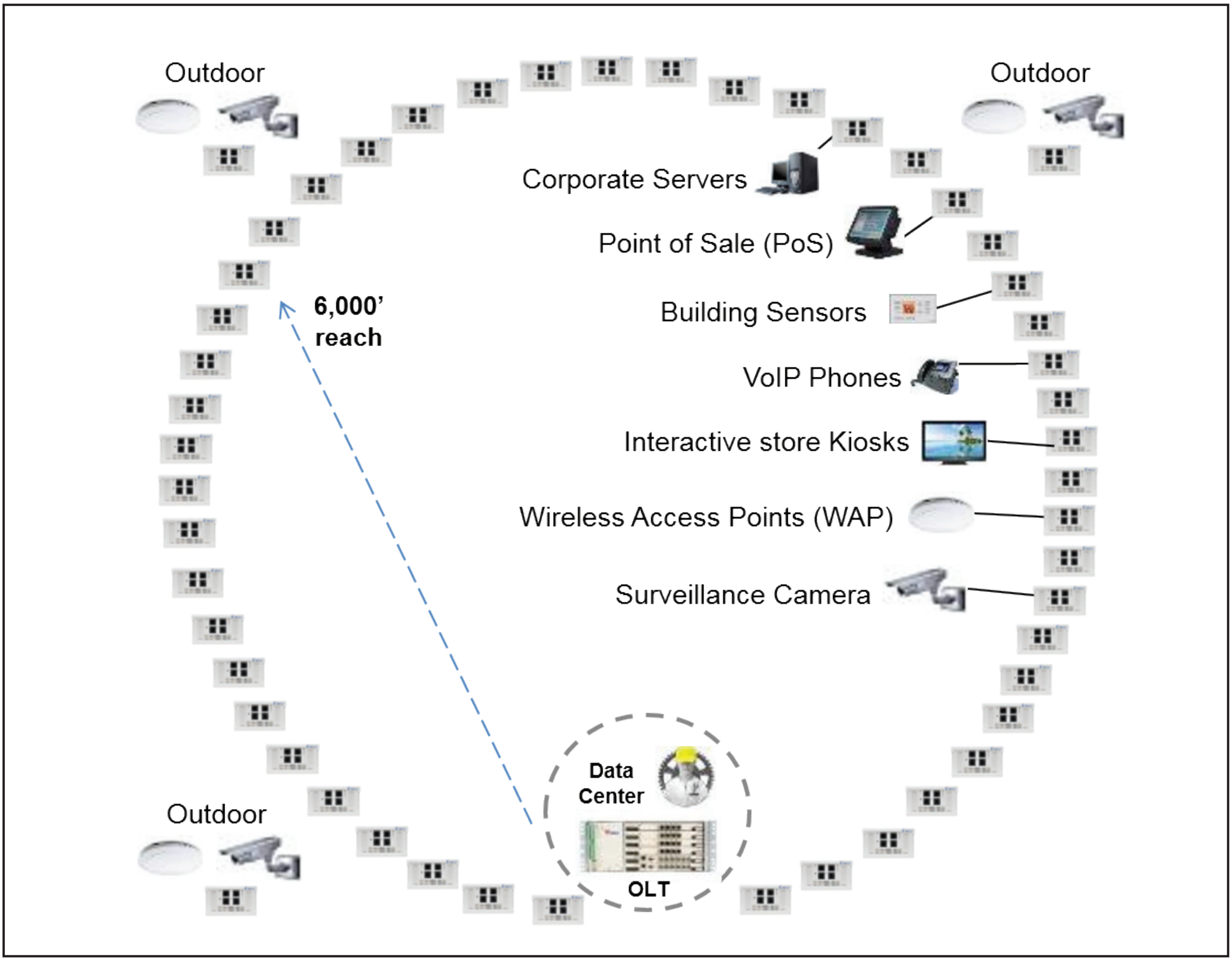


FIGURE 4: An example of better scalability for IoT and smart buildings with the optical LAN architecture.

Building management systems (BMS) and building automation systems (BAS) are extremely important for any new high-performance buildings and are key to reducing operating costs. Building monitoring devices, system reporting, and analysis tools require IP/Ethernet connectivity. In recent years, POL has taken on the responsibility of integrating these functions. Since most BMS/BAS monitoring devices today are IP/Ethernet-based, the connectivity into an existing or new POL is seamless. The POL can ensure adequate bandwidth, security, authentication, and quality of service specific to each monitoring and management device.

LAN Security

A secure LAN begins with system-wide centralized intelligence, control, automation, and management. Within the POL element management system (EMS), role-based access for users is established through strict authentication and authorization. This is where secure passwords are assigned and managed. Based on staff credentials, privileges are defined for what a user can view and modify. Then the activity of enterprise staff can be tracked, which helps root cause analyses during troubleshooting and can help with junior IT staff training. User management is very important for achieving the highest levels of security, stability and operational efficiencies. The POL EMS is where secure global profiles are created for ONTs, ports, connections and other network elements. Within these secure global profiles consistent policies and procedures can be ensured. Information managed within these global profiles include the ONT identifier and name, Ethernet port configuration, PoE, link layer discovery protocol (LLDP), network access control (NAC), IEEE 802.1x, and other settings that are configured as autonomous rules-based provisioning.

The optical fiber cabling infrastructure can make significant contributions to overall security. Optical fiber cabling is more secure than copper cabling and is not susceptible to interference nor does it introduce interference. With optical fiber, there is no cross-talk, electromagnetic interference (EMI), radio frequency interference (RFI), or interference with electromagnetic pulse (EMP). The opposite is true of copper cabling, which radiates emissions that can be eavesdropped without physical access. A person cannot "listen to" fiber from any distance, and one would need to physically access fiber to gain entry to fiber-based communications. Physically tapping fiber is tremendously difficult, taking into consideration the expertise and equipment that would be needed. POL also uses stateful protocols that can detect all abnormal, rogue and intrusion events, so the physical tapping event can be thwarted.

The POL ONTs are inherently secure as well. Optical LAN ONTs are designed with no local management access because there are few needs for human touch. The ONTs are basically simple optical-to-electrical terminals that are highly secure and reliable. Furthermore, optical LAN has centralized intelligence and management. Therefore, no information, such as user and provisioning data, is stored at the ONTs. User/device policies are managed solely at the OLT. Thus, ONTs can move freely around the LAN and be sent back to the manufacturer for repair or return without the risk of compromising network-user data.

Optical LAN has greater gigabit Ethernet density in a smaller footprint and scalability to support thousands of future smart intelligent building IoT applications.

Flourishing POL Market Poised for Expansion

Time certainly cannot be decelerated, and perhaps POL has hit a point where its adoption rate cannot be slowed either. POL experienced healthy growth in 2018 due, in part, to its appealing characteristics shown in Figure 5 and by attaining greater awareness, increased players, and more North American and global customers. Leading industry indicators point toward POL as a mature and flourishing technology poised for expansion in the future, since it can directly help the ICT industry overcome challenges with wireless, IoT and security.

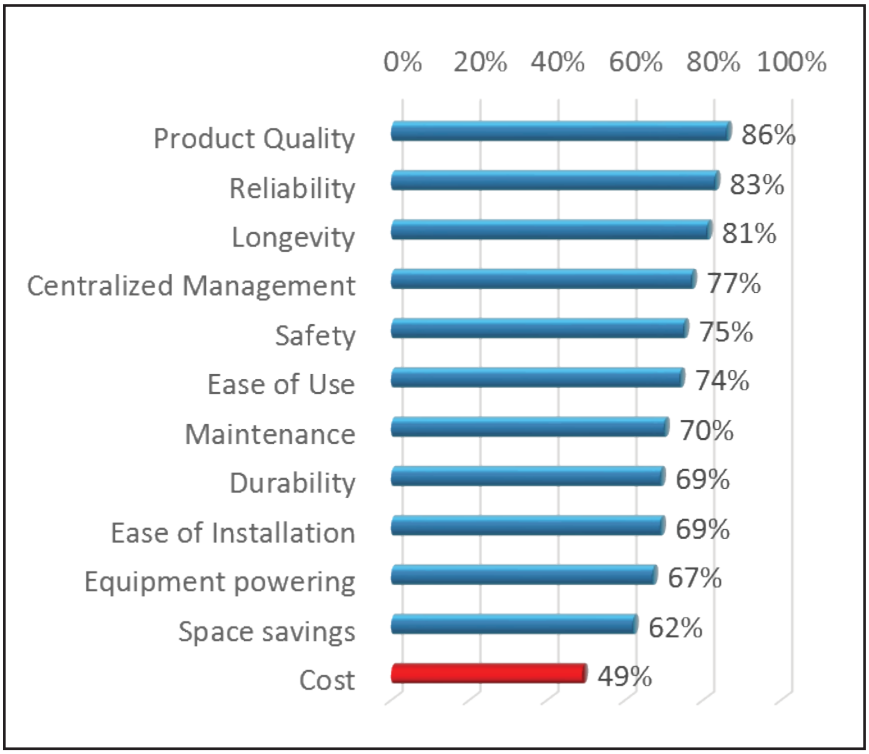


FIGURE 5: Hanover Research survey showing appealing characteristics of POL.

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Looking Ahead to 2019 – NFPA 72

By Denise Pappas

The 2019 Edition of *NFPA 72* promises to improve the code, making it easier for the user.

In June 2018, the National Fire Protection Association (NFPA) held its annual technical meeting. The 2019 Edition of NFPA 72 *National Fire Alarm and Signaling Code* was voted on and passed. The final step to approval is through the NFPA Standards Council meeting where this edition is expected to pass without reservation. This article is a brief overview of some of the significant changes in the 2019 edition, including communication paths, Class N, fire access elevators, occupant evacuation elevators, and the inclusion of NFPA 720, *Installation of Carbon Monoxide (CO) Detection and Warning Equipment,* into *NFPA 72.*

With each new edition of *NFPA 72*, members of the technical committees try to improve the code to make it easier for the user. This edition is no exception, with global changes to standardize a variety of terms and offer a clear and concise understanding to the reader.

Communication paths and Class N take on a new look in 2019. For years, the traditional digital alarm communicator transmitter (DACT) was deployed and required a primary and a secondary line with the DACT to be connected to a public switched telephone network (PTSN). In the 2007 code, the secondary line could be a cellular telephone connection, one-way radio system, one-way private radio alarm system, private microwave radio system, two-way radio system, one-way private radio alarm system, private microwave radio system, two-way radio frequency (RF) multiplex system, or another type of transmission that complied with the requirements.

With the evolution of newer communication technologies over the past decade, these requirements have changed. In an effort to include newer technologies and address the lack of PTSN, the 2010 edition allowed for managed facilities-based voice network (MFVN) as a subset to the PTSN. The MFVN is defined as a physical facilities-based network capable of transmitting real-time signals with their formats unchanged. During the next code cycle in 2013, the code kept the primary line, but made changes to the secondary line with reduced choices to a one-way private radio alarm system, two-way RF multiplex system, or a transmission method complying with the code. Recognizing that the world is getting further and further away from the PTSN and becoming more converged in their communications technology, the 2019 code eliminates the term PTSN and replaces it with MFVN.

For years, the fire alarm components on a system were connected using two-connector cable. With this design, there were three basic circuits: signaling line, initiating device, and notification device, all connected to the fire alarm control unit. With the continued advancements of newer communication technologies and the ever-increasing availability of computer networks, Class N was introduced into the 2016 code to allow for connecting to IP networks. A Class N network is required to have two or more pathways with the operational

By far, the most significant change made in the 2019 edition of NFPA 72 *National Fire Alarm and Signaling Code,* involved the integration of NFPA 720, *Installation of Carbon Monoxide (CO) Detection and Warning Equipment.*


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Look for the 2019 edition of *NFPA 72* to be released in the 4th quarter 2018.

capability verified through end-to-end communication. Since Ethernet wiring cannot meet all the fault monitoring requirements that normally apply to traditional wiring methods used for fire alarm circuits, the redundant path in this case is intended to compensate for it. In the 2019 edition of *NFPA 72*, work was done to make changes to Class N that gives the authority having jurisdiction (AHJ) greater influence. This greater influence pertains to the design and installation, specific testing criteria, and design considerations where a device failure resulting from a multiple ground-fault pathway failure could disable an entire area or zone incapable of initiating or receiving signals, additional marking and access considerations for the Class N Life Safety Networking Cable, equipment and associated infrastructure, and additional detailed requirements on the required risk analysis.

Chapter 21, *Emergency Control Function Interfaces*, contains significant changes with a complete rewrite of the Fire Service Access Elevators section. The Occupant Evacuation Elevators (OEE) section is overhauled as well. While the majority of these changes pertain to the programming and interface between the fire alarm control unit and the elevator controller, some pertain to in-building fire emergency voice/alarm communications systems messaging during elevator operation scenarios.

By far, the most significant change in the 2019 edition of *NFPA 72* involves the integration of NFPA 720, *Installation of Carbon Monoxide (CO) Detection and Warning Equipment*. With this change comes the important date of January 1, 2022. On this date, all newly installed household smoke alarms must meet listing specifications to distinguish between smoke generated by routine cooking and smoke generated by potentially more serious sources (e.g., furniture, flooring). This distinction is made to help eliminate nuisance alarms. Incorporating *NFPA 720* into *NFPA 72* allows the user to easily find requirements for smoke alarms, carbon monoxide alarms, smoke detectors, and carbon monoxide detectors all in the same document. Most of these changes will reside in Chapter 29, *Single-and Multiple-Station Alarms and Household Fire Alarm Systems.* For those occupancies other than household, the requirements for carbon monoxide detection systems are found in Chapter 23, *Protected Premises Fire Alarm Systems.*

While this article covers many significant changes, refer to the 2019 edition of *NFPA 72* for a deeper dive into the world of fire alarm and life safety.

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