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EDITORIAL GUIDE

Advances in Fiber and Cable

The lifetime of the average fiber-optic cable is 20 years or more. But that doesn't mean the technology is standing still. The articles in this Editorial Guide will highlight how fiber and cable advances have led to lower installation costs and more efficient support of the latest optical transmission technologies.

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Industry debates value of OM5 multimode fiber

By **STEPHEN HARDY**

WITH FINISAR'S RECENT announcement that its QSFP28 SWDM4 transceivers have reached the production stage, the building blocks are in place to enable OM5 fiber to see application in 100-Gbps data center networks as well as the 40-Gbps applications for which the necessary transceivers are already available. However, as OM5 roll outs at this lower speed have proven less than brisk so far, one could be forgiven for wondering if the fiber will be any more popular at the higher data rate. The fact that optical cable vendors vary in their enthusiasm for the technology probably doesn't help its popularity.

Multiwavelength in multimode fiber

OM5, originally called wideband multimode fiber (WBMMF), differs from its multimode predecessors in that it has been designed to support the transmission of four wavelengths instead of the conventional one. As specified within ANSI/TIA-492AAAE, the fiber accommodates transmission from 850 nm (the focus of conventional multimode fiber) to 953 nm. The effective modal bandwidth (EMB) is 4700 MHz·km at 850 nm (the same as OM4, which helps ensure compatibility with that fiber type) and 2470 MHz·km at 953 nm. Lime green has been approved as a color-based identifier.

OM5 fiber, in its distinctive lime green jacket, offers the ability to support four wavelengths when paired with SWDM optical transceivers.

OM5, paired with shortwave WDM (SWDM) optical transceivers, aims to forestall the need to switch to single-mode fiber in medium-reach applications as requirements evolve to 40 Gbps and greater. It is designed to offer more reach than OM4 and other multimode fiber types paired with IEEE standards-compliant transceivers. While different vendors quote different numbers, a conservative estimate offered in a recent article in *Cabling Installation & Maintenance* suggests OM4 will support 40 Gigabit Ethernet over 150 m with 40GBASE-SR4 optics; OM5 will support 440 m with SWDM4 modules. At 100 Gigabit Ethernet, the advantage isn't as pronounced. OM4 with 100GBASE-SR4 can accommodate 100 m; OM5 with SWDM4 will travel 150 m.

The key here is comparing SWDM4 performance over OM5 with Ethernet-standard transceiver performance over OM4. SWDM4 is not an IEEE-approved approach. That opens the door to comparison with other non-standard optics, such as extended reach SR4 at both 40 and 100 Gigabit Ethernet. Not surprisingly, the reach advantages the OM5/SWDM4 pairing offers shrinks when eSR4 optics are applied to OM4. For 40 Gigabit Ethernet, the OM5/SWDM4 approach provides only 40 m more reach than OM4 and 40GBASE-eSR4, according to the same article. And the use of 100GBASE-eSR4 and OM4 supports operation at 300 m — *twice* the reach of OM5 and SWDM4 for 100 Gigabit Ethernet applications, if transceiver vendor estimates are to be believed. To combat this shortfall, Finisar has developed an extended reach SWDM4 QSFP28 module for 100G that it demonstrated at ECOC 2017. The device will support reaches of 400 m over OM5, Finisar says.

The waters muddy further if you decide to apply SWDM4 optics to OM4 – which transceiver vendors such as Finisar and Lumentum, the other company that has announced support for such modules, encourage you to do. Finisar, for example, says its 40 Gigabit Ethernet SWDM4 QSFP+ optical transceiver will support 350-m runs over OM4; the company demonstrated 100-Gbps transmission of 300 m over OM4 at ECOC 2017 using the extended reach QSFP28 transceiver.

So when should you use it?

The need to sort through these permutations may partially explain the reportedly low number of OM5 deployments so far. Even cabling suppliers with OM5 in their portfolios note that most 40 and 100 Gigabit Ethernet links are likely to fall within the reach of OM4, making the extended reach of OM5 unnecessary.

For these reasons and others, some cabling suppliers have opted not to add OM5 to their lines. In a blog posted this past April, Gary Bernstein, senior director of product management for fiber and data center solutions at Leviton, described why his company doesn't support OM5, stating:

- The reach advantage of OM5 over OM4 is minimal.
- OM5 won't reduce costs. (OM5 fiber carries a cost premium, and 100-Gbps optics prices are in decline, reasons Bernstein).
- It won't enable higher port densities, since you can't break out SWDM transmissions into their component parts the way you can with parallel fiber approaches.
- A lot of large-scale data centers with a need for 40 or 100 Gigabit Ethernet have or will soon move to single-mode fiber anyway.

This is not to say that the fiber does not have its proponents, particularly for applications that require that extra bit of reach (see, for example, this whitepaper from CommScope). Meanwhile, there is an advantage beyond reach to OM5 and SWDM that could prove useful in future high-speed networks – the ability of one fiber to offer the transmission capacity that currently requires four in conventional use. At 40 or 100 Gbps, that ability could prove helpful when operating in space-constrained environments.

The four-in-one advantage promises to blossom further in 400 Gigabit Ethernet applications. The IEEE's 400 Gigabit Ethernet Task Force, P802.3bs, has settled on a parallel approach with 25-Gbps optical lanes. That means 16 fibers for transmit and another 16 for receive – 32 fibers in all. The appeal of trimming this number to eight fibers total is one reason IEEE 802 hosted a call for interest in "Next-generation 200 Gb/s and 400 Gb/s MMF PHYs" at its plenary meeting in Orlando, FL, November 5-10. The members approved the creation of a study group on this topic, which is expected to consider SWDM for these high-speed data rates. OM5 fiber would be a good bet for extended reach in such applications.

While OM5 deployments have yet to become numerous, the technology remains new. The rapidly shifting data center environment may yet spark greater interest in the fiber – particularly when data centers begin to adopt 400 Gigabit Ethernet.

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STEPHEN HARDY is editorial director and associate publisher of *Lightwave*.

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GPON *test tools*

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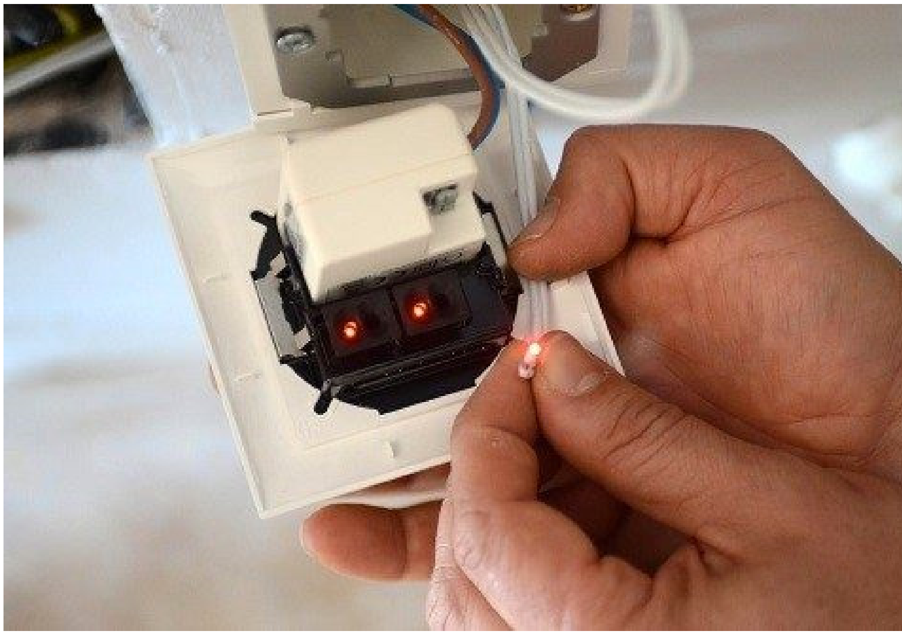
Has Plastic Optical Fiber's Time Finally Arrived?

By **STEPHEN HARDY**

MANUFACTURERS OF PLASTIC optical fiber and related technologies have long touted the medium as an alternative not only to copper but glass for wired communications applications. Yet, despite some success in aircraft, automotive, and industrial applications, plastic optical fiber hasn't made much of a dent with service providers. Telefónica, however, recently announced the successful completion of gigabit home network trials with the technology. The confluence of factors that led to these trials may signal that network operators may finally see a role for plastic in their networks.



Telefonica's trial of plastic optical fiber in home networks may signal a resurgence of interest in the technology among broadband services providers.

Almost as good as glass

Plastic optical fiber (or "POF," as many of its backers call it) aims to address many of the same applications as glass fiber, albeit via a different material. Step-index fiber made from polymethylmethacrylate (PMMA) is the most commonly discussed approach for communications applications, although there has been work on graded-index fibers based on other polymers as well. (POF also has been touted for lighting and signage requirements, as well as for use inside consumer devices and in sensing applications.)

POF aims to provide the same advantages as glass fiber when compared with copper alternatives: greater capacity, resistance to electromagnetic interference, improved security, etc. As the nearly invisible installations glass fiber and cable suppliers have launched for multiple-dwelling unit (MDU) applications have demonstrated, POF also should provide a less intrusive and more esthetically pleasing deployment than would copper or coaxial wiring for in-building requirements.

The technology also has deployment advantages over glass fiber, its makers have insisted. For example, the fiber has a core area typically of 1 mm, larger than glass, which makes coupling easier; the fiber also is simpler to handle and requires less complex tools. It has been less bend sensitive than glass as well, although the advent of bend-insensitive glass fiber has diminished this advantage in recent years. POF typically works with LEDs in the 650-nm window, which makes it eye safe – an advantage that would better enable self-installations at the customer premises. The overall system generally doesn't require as much power as glass-based networks as well.

However, POF doesn't offer the same reach/capacity benefit as glass fiber, which is why operators have shunned the technology for the outside plant. Until recently, POF transceivers generally topped out at 150 Mbps over 50 m in Ethernet applications and 250 Mbps with proprietary approaches. And, until recently, most in-building applications haven't required fiber-scale capacity; copper (frequently coax) and WiFi have met most needs.

These factors have left POF adherents to focus on in-building networks where copper isn't an option and where WiFi falters – mainly, where the building's materials deaden WiFi signals and prevent full coverage, while limited duct space and interference issues prevent technicians from snaking copper communications cables alongside existing electrical wiring. Such environments are more common in Europe than the U.S., which is why most of the prominent trials of POF in the West, including those conducted by Telefonica, Swisscom (which invested in a POF transceiver vendor), Orange, and Telecom Italia, have occurred on that side of the Atlantic. The European Community also has funded research projects such as "Plastic Optical Fibre for Pervasive Low-cost Ultra-high capacity Systems" (POF-PLUS) in 2008 to further expand POF's capabilities.

So why now?

Two factors have led to a recent increase in interest in POF for home networks. One is the gigabit broadband phenomenon, which has exceeded the performance limits of many existing in-home copper and wireless networks. The other is a new IEEE Ethernet specification that provides a pathway toward POF support of gigabit transmission rates.

IEEE 802.3bv, ratified in February of this year, comprises specifications for three applications – home networks, industrial networks, and automotive networks. 1000BASE-RHA contains the home network specifications: 1 Gbps using 1000BASE-H encoding over at least 50 m of duplex POF via red light (at approximately 650 nm). The connector snaps directly onto the plastic fiber.

Of course, WiFi has advanced to accommodate gigabit speeds, and new technologies and specifications efforts for copper infrastructure, from Gfast to MoCA Access, promise to do the same for such media. Still, the problem of what to do with troublesome buildings in Europe remains – which is where the Telefónica trial comes in.

Telefónica paired POF with gigabit WiFi, using the POF as a backbone to connect wireless access points and a WiFi amplifier around the house to circumvent potential WiFi interference obstacles. The service provider says the cabling can be deployed through a variety of conduits within the home "without connectors and at a cost considerably lower than glass fibre."

What Telefónica didn't say was when, if ever, it would use the technology in mass deployments. Nevertheless, the advent of 802.3bv should provide incentive for other operators in Europe and elsewhere (Latin America is sometimes cited as an appropriate market) who have tested POF at lower transmission rates to look at the technology again. The time may finally have arrived when POF takes its place alongside glass fiber in broadband services delivery.

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Architecture Choices in FTTH Networks

By **FRITZ AMT**

MORE THAN A decade has passed since the first fiber to the home (FTTH) network deployments, starting with Japan and Italy. Yet the cost of building a network remains the primary obstacle to ubiquitous fiber connectivity for every household. According to news reports, from 2005 to 2015, the cost per home passed dropped from $1,021 to just under $700. Why does Moore's Law apply to transistor density and disk storage capacity, but not to FTTH?

The labor factor in FTTH costs

Building an outside plant fiber network can be labor-intensive. Construction, civil works engineering, obtaining permits, and rights-of-way can account for roughly two-thirds of the total cost, while the equipment accounts for one-third. While GPON and fiber equipment costs have indeed fallen, skilled labor rates have risen. Any attempt to take costs out of the network needs to look closely at reducing labor costs.

Architecture drives costs in FTTH networks, and there are different types: centralized split versus distributed split, star versus daisy-chain, and all-spliced versus hardened connectivity. Let's look at the benefits of each approach.

Centralized split architecture

The centralized approach uses single-stage splitters located in a central hub in either a star or daisy-chain topology. It provides optimal flexibility in management of subscriber connections and utility of connected equipment.

Centralized split architecture has been used extensively to reach subscribers in initial FTTH deployments. A centralized approach typically uses a 1x32 splitter located in a fiber distribution hub (FDH), which may be located anywhere in the network. The 1x32 splitter is directly connected via a single fiber to a GPON optical line terminal (OLT) in the central office. On the other side of the splitter, 32 fibers are routed through distribution panels, splice ports, and/or access point connectors to 32 customers' homes, where they are connected to an optical network terminal (ONT). Thus, the PON connects one OLT port to 32 ONTs.

However, as areas unserved by FTTH become costlier to build on a per-home basis, alternatives must be considered to reduce costs and speed deployment time. Hardened connectivity is one key to reducing deployment time. The other key solution is the use of distributed splitting.

Distributed split (cascaded) architecture

A cascaded approach may use a 1x4 splitter residing in an outside plant enclosure. This is directly connected to an OLT port in the central office. Each of the four fibers leaving this Stage 1 splitter is routed to an access terminal that houses a 1x8, Stage 2 splitter. In this scenario, there would be a total of 32 fibers (4x8) reaching 32 homes. It is possible to have more than two splitting stages in a cascaded system, and the overall split ratio may vary (1x16 = 4x4; 1x32 = 4x8 or 8x4; 1x64 = 4x4x4).

Distributed split approaches reduce the amount of fiber in the distribution area by moving a portion of the splitting process to the access point where the subscriber drops are connected. The 1x32 splitter in the primary FDH or fiber-optic splice closure (FOSC) is replaced by a 1x8 splitter, for example, and 8 fibers leave the FDH into the distribution network instead of 32. At the subscriber access point, one fiber is split to four outputs to the drops. A variation to this is to place a 1x4 splitter in the area entrance cabinet and 1x8 splitters in the access point. Either approach still delivers 32 connections to the OLT, but has achieved several important advantages:

- CommScope research shows that the FDH capacity can be reduced by 75%, allowing smaller cabinets, easier placement, and the prospect of moving from a cabinet to a splice closure.
- The distribution fibers required have been reduced by 75% as well, reducing capex for cable as well as for splice closures and splicing labor.
- The access point now includes a splitter, so a modest change here permits significant savings in the entire approach.

Star architecture

A star architecture pulls cables back to a central location using pre-terminated cabling, so it's very efficient from a splicing perspective. It uses about 35%-45% more cable than daisy-chained architectures and there can be more part numbers due to different cable lengths. While cable is often viewed as a relatively inexpensive part of the overall cost of an FTTH network, the extra cable required in the star configuration carries additional labor costs for deployment.

Star architecture can use a multi-port service terminal (MST), a component of hardened connectivity lines – it offers the option of not splicing any of the dropped fibers at the distribution point. It's called star because each terminal tail is brought back to a splice location. When used with centralized split, each cable going between the MST and splice case will have one fiber per terminal port. When used with distributed split, a single fiber between the terminal and splice case is used, and the terminal incorporates a 1x4 or 1x8 splitter. Distributed split architectures use about the same amount of cable as centralized, but the fiber counts are a fraction, and consequently the splicing costs are a fraction.

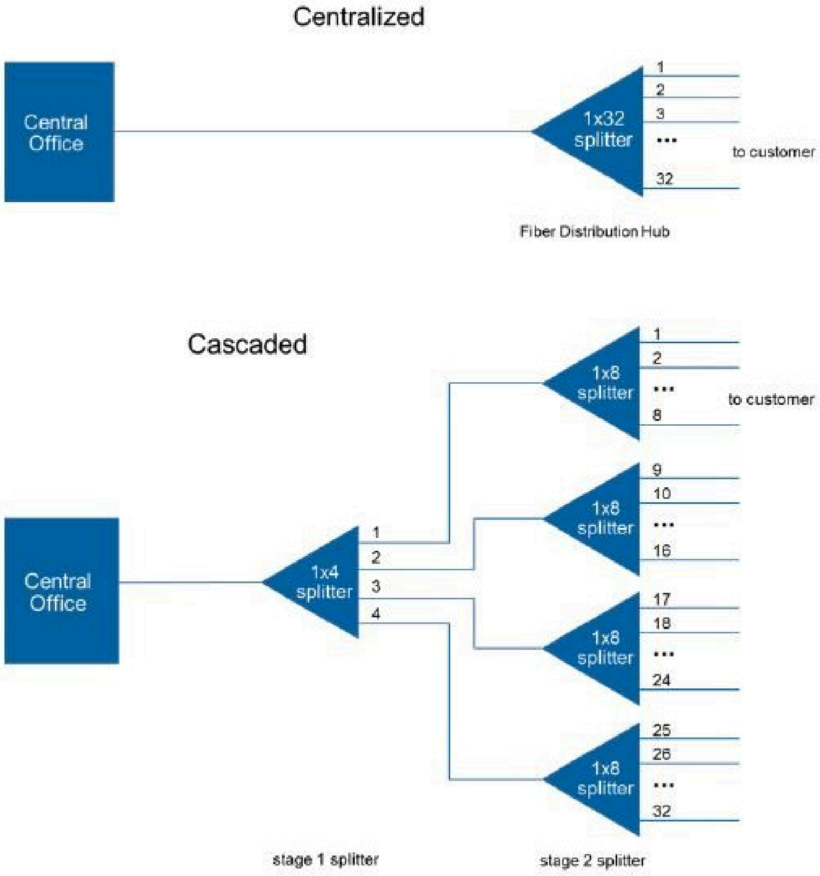


FIGURE 1. *Centralized versus cascaded splits.*

Daisy-chaining

Daisy-chaining can be a faster approach to deploy. It uses one cable and connects it through a cascade of fiber access terminals, leading to efficiency from a cable use and deployment labor standpoint. However, it may also require special splicing skills because it may need more splicing than the star architecture.

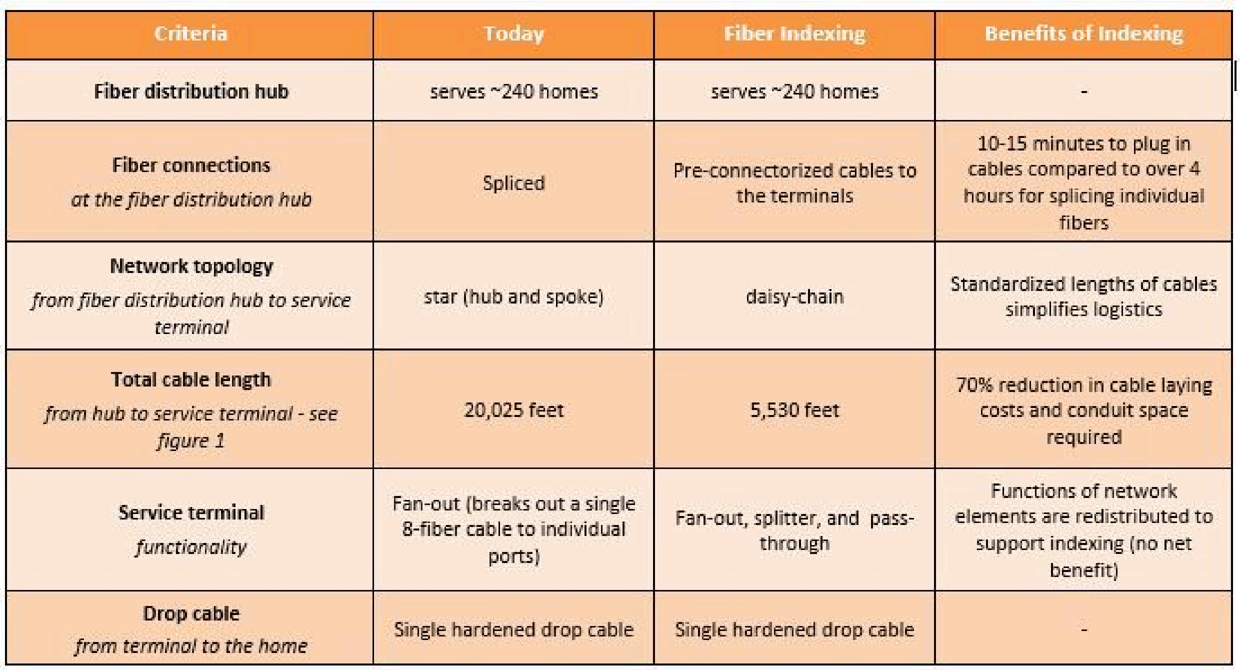
In fact, splicing labor is a key cost factor in FTTH deployments. In a star topology, fiber splicing is done at the hub, where individual cables are laid from the hub to each terminal. In a daisy-chained topology, fiber cable is run through the streets and a hardened terminal is spliced onto the cable; this design forces compromises in deployment time while increasing costs via the need for expensive, specialized splicing labor.

Splicing costs for centralized split, whether star or daisy-chain architecture, will be generally higher than for distributed split, as the splitter outputs are factory terminated. And fiber costs are lower for distributed split than for centralized, and generally lower for daisy-chained versus star architecture.

Fiber indexing

Fiber indexing is another alternative here. It uses connectorized cables and terminals, and enables installers to use a cookie-cutter approach to build out the network. A reduced set of cable lengths are daisy-chained together, limiting the need for custom cable assemblies or splicing. The basic building block, which

TABLE 1. *Fiber Indexing versus Centralized Split*



Criteria	Today	Fiber Indexing	Benefits of Indexing
Fiber distribution hub	serves ~240 homes	serves ~240 homes	-
Fiber connections *at the fiber distribution hub*	Spliced	Pre-connectorized cables to the terminals	10-15 minutes to plug in cables compared to over 4 hours for splicing individual fibers
Network topology *from fiber distribution hub to service terminal*	star (hub and spoke)	daisy-chain	Standardized lengths of cables simplifies logistics
Total cable length *from hub to service terminal - see figure 1*	20,025 feet	5,530 feet	70% reduction in cable laying costs and conduit space required
Service terminal *functionality*	Fan-out (breaks out a single 8-fiber cable to individual ports)	Fan-out, splitter, and pass-through	Functions of network elements are redistributed to support indexing (no net benefit)
Drop cable *from terminal to the home*	Single hardened drop cable	Single hardened drop cable	-

is repeated throughout the service area, could be a 150-foot length of cable (for a majority of terminal locations), a terminal with a built-in splitter, hardened 12-fiber inputs and outputs, and four or eight hardened drops to the homes.

Fiber indexing has the potential to reduce construction and civil works costs in the distribution network by up to 70% and, in the process, significantly reduce deployment times and speed time-to-market. Table 1 compares fiber indexing with today's typical (centralized split) deployment model in a suburban network. One key savings lies in the length of cable needed, made possible by changing the network topology and consolidating the functions of multiple network elements into the service terminal. The other savings come from reduced splicing labor, minimizing site surveys, and reduced inventory management costs.

How fiber indexing works

Fiber indexing begins with a 12-fiber cable entering the first terminal (Figure 2). In the terminal, Fiber 1 is routed to a splitter for servicing local customers, and the remaining fibers are "indexed" or moved up as they exit the terminal to connect to the next terminal. Indexing means that the second fiber entering the terminal will exit as the first fiber to enter the next terminal, and so on in a daisy-chained fashion.

Traditional cascaded architectures require different terminals with different fiber lengths that require complex planning and custom cable orders, whereas fiber indexing uses a reduced set of cable configurations throughout the network. There are several variations of this architecture so it can meet requirements of

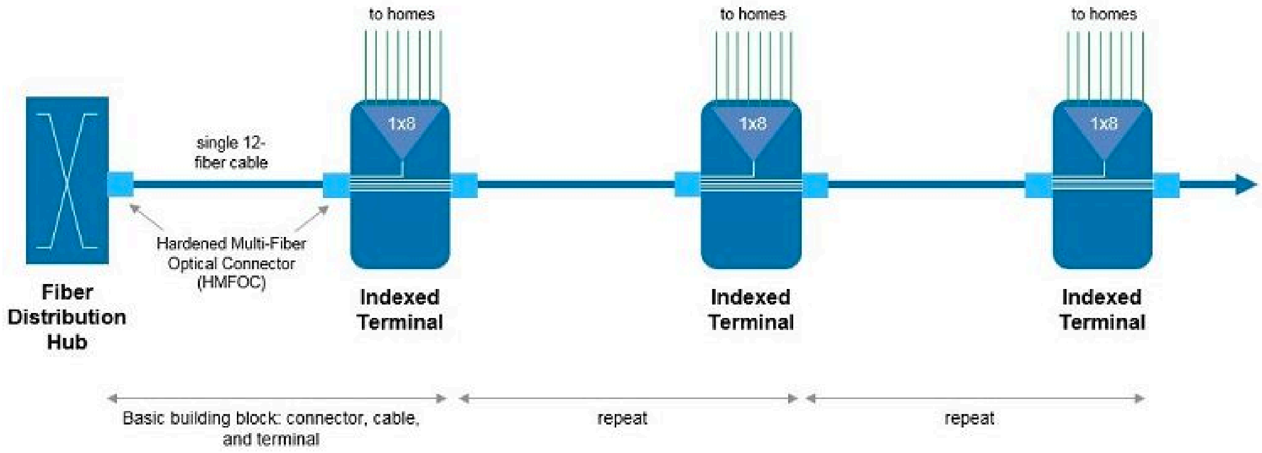


FIGURE 2. *A look at fiber indexing.*

different deployment scenarios. For example, it helps defer terminal costs and enables rapid installation when subscribers request services. By using approaches that eliminate splicing and can be installed more quickly, customers can be turned up faster and with lower overall installation costs.

There are several other advantages of fiber indexing:

- **Flexibility without signal loss problems.** There is little impact on signal strength, contrary to what might be expected from cascaded terminals. Low-loss hardened connectors maintain good link budgets, even to the end of the daisy-chain.
- **Enhanced fiber utilization.** By connecting the last terminal in the fiber run to any fiber distribution hub, the network can then feed the reverse path of each terminal's reverse port. This could then be connected to a subscriber's cable drop cable or be used to deliver other services at that terminal location.
- **Streamlined inventory management.** There are fewer part numbers, so inventory management and ordering are easier.
- **Reduced or eliminated site surveys.** Through the use of standard cabling parts, site surveys are reduced or eliminated.
- **Trouble-free deployment.** Factory-prepared cables and terminals prevent technicians from handling fibers and disturbing the signal during installation. Testing is also reduced versus conventional FTTH architectures.

All-splice vs. hardened connectivity

The various splitting alternatives and distribution architectures can generally be built with either all-splice or as hardened connectivity approaches. Clearly, moving the splicing function to an environmentally controlled factory will not only eliminate splicing costs in the field, and the associated expensive splicing equipment, it will also improve reliability, reduce opportunities for human error during construction, and reduce construction labor and time to deploy. The move to distributed split promotes cost reductions, and moving that into an indexing configuration provides even greater benefits.

Service providers will choose different architectures in their quest to deliver services rapidly and cost-effectively, but in the face of rising labor rates, distributed split architectures allow network operators to reduce overall labor costs and reduce deployment times by streamlining FTTH installations. As operators continue to expand their FTTH networks, these newer, hardened connectivity architectures will help improve business models and lead to speedier rollouts.

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