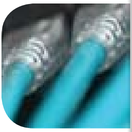
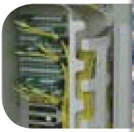
Connectorization

Solutions for Flexible Network Architectures

For Builders of Next Generation Fiber Networks





Foreword by: **Carol Wilson**, Editor
Telephony Magazine

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For Builders of Next Generation Fiber Networks

Discover the benefits of connectorization and gain the knowledge to improve network efficiencies, lower operating costs and boost network performance from the central office to the outside plant to the customer premises.

ADC®

ADC Telecommunications, Inc., P.O. Box 1101, Minneapolis, Minnesota USA 55440-1101

FOREWORD

Lessons Learned from FTTP

The history of fiber optic deployment in the local loop has been one of trial and error. From the earliest trials of the late 1980s to the massive deployments happening today around the globe, experience has been the best teacher, and the smartest companies learned as much from previous failures as from successes.

Those earliest deployments were failures in the sense that they didn't lead to major deployments of fiber-to-the-premises, but they were successful in teaching telecom service providers something for which they weren't prepared, namely the complexity and cost of handling fiber in the local loop. Those early lessons, and some that followed, have informed the decision-making of major global service providers as they chose their next generation of access technologies and architectures.

Since those early days, advances in technology have eased some of that complexity and driven down many of those costs. But technology improvements cannot change one basic fundamental of success in fiber deployment. And that is the reality that any mass deployment of fiber in the local loop cannot succeed unless the fiber can be deployed reliably and in reasonably short time frames by technicians who can handle the task without high-level intensive training while achieving a degree of quality that avoids the need for repeated truck rolls to address problems.

That deployment reality is born out of the economic reality of competitive broadband services. Service providers spent mightily to acquire customers, particularly in the FTTP scenario. Installation problems not only drive up those acquisition costs considerable but put customer retention at risk. Churn is the number one enemy of a successful local loop fiber deployment.

Mass deployment of FTTP also requires a much larger workforce, putting pressure on service providers to find and use tools that best enable technicians to get the job done right the first time.

In this handbook, ADC Telecommunications is bringing you the benefit of its decades of experience, literally in the trenches, of local loop fiber deployment. This isn't advice based on lab research or theoretical studies, it's real-world wisdom from a leader in fiber infrastructure products. The value of that advice can be measured in real currency, in fiber deployments that deliver quality service at lower cost.

The value of ADC's experience, shared here, is that it doesn't just cover one phase, such as installation, but all aspects of a successful FTTP project, including longer-term issues such as troubleshooting and truck rolls, are addressed as are real-world workplace challenges. This handbook specifically discusses the value of connectorized fiber, in a variety of environments, including the outside plant, the Central Office, and the multi-dwelling unit.

As the earliest deployments of FTTP discovered, the devil really is in the details. What follows here is a detailed look at avoiding details that bedeviled FTTP in the past and following a more cost-effective path to a quality FTTP build.

Carol Wilson, Editor
Telephony Magazine

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CHAPTER 1

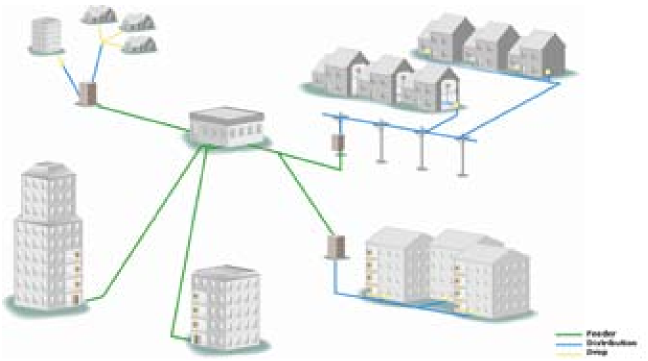
The Role and Value of Connectorization Throughout the Network

When building Next Generation Networks, service providers around the world obviously must balance construction-cost considerations with the need to install flexible, reliable and long-lasting networks. Leading service providers are discovering that one way to achieve that balance is to use connectors, rather than splicing, wherever possible to create junctions in the network.

For more than 20 years, service providers have benefited from the advantages provided by connector interface points inside the central office (CO); these advantages include easy access for troubleshooting, re-configuring the network and turning up services. Now, more and more service providers are achieving the same advantages throughout the network; specifically, they are using connectors at appropriate locations not only in the CO but also in the outside plant (OSP) and at the customer premises. In the case of the latter, connectors are proving to be especially valuable in multiple dwelling unit (MDU) installations.

By adopting a connectorization or "plug-and-play" strategy wherever possible across the network, service providers can:

- quickly deploy flexible, reliable fiber infrastructures
- reduce the number of splices, splice technicians and splice crews required for installation and maintenance
- lower their operating expenditures (OPEX)
- turn up services quickly
- deliver bandwidth cost-effectively
- speed up return on investment

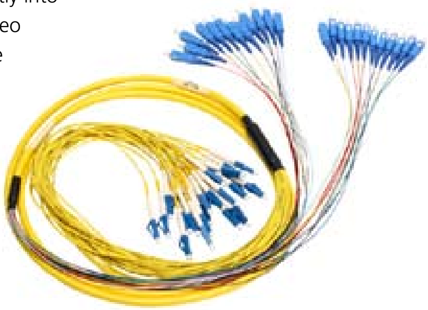


In the CO

Within the CO, one of the most valuable aspects of a connectorization strategy is the multi-fiber push-on (MPO) connector. Using an MPO connector, a technician can terminate multiple fibers with one connection, rather than needing an SC connector to terminate each individual fiber. Although the MPO connector first appeared several years ago, its use generally was limited to multimode fiber applications within data centers. It is relatively new to the CO, in part because of the higher initial costs of connectorization, relative to splicing. However, for many service providers, these higher up-front costs may be offset by the lower opex that results from having to make fewer splices and from needing only one MPO connector to make multiple connections on the back of a panel. The MPO connector now is an industry standard, and the Telcordia GR-1435 specification defines the baseline requirements for MPO performance levels.

Within the CO, where physical space is at a premium, and single-mode applications are necessary, service providers clearly want a small form factor footprint. Vendors such as ADC have responded by producing 8- and 12-fiber MPOs, thereby making high-performance connectorization possible for much of the active equipment. In fact, ADC produces MPOs for use in applications in the CO, using large MPO connectors in distribution-type cables to house higher fiber counts. The interconnect cables, which typically contain 8 or 12 fibers, function as single-ribbon patch cords. Original equipment manufacturers (OEMs) also use MPO connectors as well, including inside the passive panel used for fiber management and in a termination panel on a large frame containing a switch or router.

Another plug-and-play approach in the CO centers on a “breakout style” assembly--a more rugged cable that plugs directly into the active equipment on one side, with the frame on the other side. Although it resembles a patch cord, the breakout assembly contains up to 24 fibers. Plugged directly into a transceiver–for example, video equipment–and with only one cable required for each shelf, the assembly makes it much easier for service providers to configure the network.



Throughout the OSP

If service providers expect to maintain adequate return-on-capital ratios and to reduce the capital expenditures (CAPEX) required to make the network subscriber-ready, they obviously need to build an efficient fiber distribution plant. Ever since service providers began more than a decade ago to build fiber networks, they typically have created the distribution segment by splicing drop cables at drop points during the actual construction phase. However, the emergence of hardened connectors and adapters has enabled service providers across the globe to expedite construction of their fiber distribution plants. By dramatically reducing the number of splicing hours required to turn up new serving areas, hardened connectors and adapters also have helped service providers save on labor costs during network construction. These savings in time and cost translate into even more savings when it comes to deploying services.

Technological advances, along with increases in the volume of fiber equipment, have significantly improved connector quality and performance in the network. Manufacturers now design and test hardened connectors specifically for use in the OSP. Improved manufacturing processes, combined with stringent performance standards, such as the Telcordia GR-326-CORE specification, have resulted in:

- lower insertion and return loss
- automated tuning
- superior endface workmanship
- vastly improved factory-termination methods

Manufacturers integrate hardened adapters into environmentally sealed, pre-terminated multiportservice terminals; with pre-terminated cables, using 50 to 2,000 feet of OSP cable in 2-, 4-, 6-, 8- or 12-fiber configurations. With each MST tail returning to a centralized splicing point, splicing crews now need much less time than before to make the same number of splices.

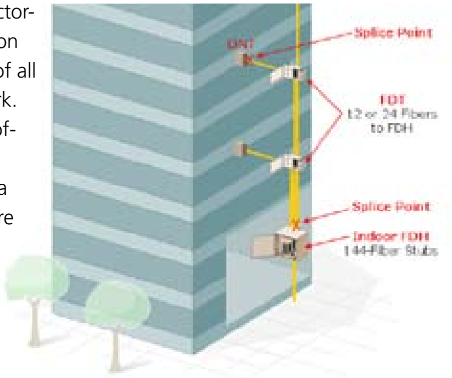
With simple, fast mounting options, the MST not only reduces splicing time and costs but also accelerates the overall rate of service deployment.

Each terminal ships with a bracket or adapter that is specifically designed for the OSP environment, and technicians can install them in hand-holes or pedestals, mount them on utility poles, overhead strand or simply secure the terminals to any flat surface.

At service turn-up, connectorized solutions begin to deliver operational savings as well. With a splicing approach, installers may have put in the drop cable during initial plant construction, or the service provider may have to dispatch splice crews to turn up new customers. However, technicians now can install the drop cable without splice labor by simply inserting the factory-connectorized cable into adapter ports at the MST and at the optical network terminal (ONT) on the customer premise.

Hardened drop cables are factory-connectorized assemblies with hardened connectors on each end. Manufacturers pre-test them and certify that they satisfy performance requirements. Further, a cap or plug protects each hardened connector and adapter until a provider puts it into service and, after the connector is engaged with the adapter, a watertight O-ring seals it. An arrow on the hardened connector aligns with a notch on the adapter to ensure precise alignment into the optical port. Finally, simplified connector cleaning techniques make it even easier for technicians to connect and maintain the OSP portion of the network.

Into the MDU

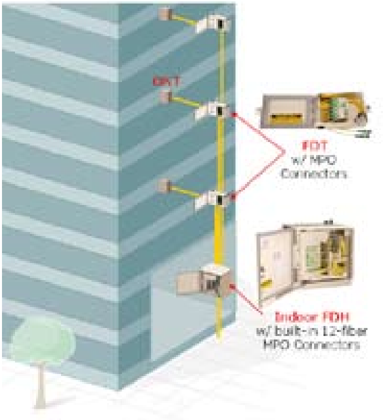


As shown thus far, a connectorized or plug-and-play solution accelerates the installation of all portions of the fiber network. Yet nowhere is that speed-of-installation advantage more evident than in MDUs–and a building owner is much more likely to choose a fiber architecture if the fiber installers can be in and out of the building as quickly as the construction workers.

For example, within a mid- or high-rise building, a service provider deploys on the lower level an indoor fiber distribution hub (FDH) with several 144-fiber stubs. Residing on each floor of the building is a fiber distribution terminal (FDT) that routes 12 or 24 fibers down to the indoor FDH where technicians splice them in. In this scenario, technicians would have to splice 288 fibers between the FDH and the FDTs. This approach creates another splice point because it is impossible to predict the exact length of each cable.

Compare that scenario with using a plug-and-play solution within the same MDU. Again, an FDT resides on each floor, but in this case, an MPO connector is mounted on the stub end of each cable. Installers deploy the fiber from each FDT to the indoor FDH, which now also has built-in 12-fiber MPO connectors. Installers can easily plug each connection into the FDH from every floor. In other words, installing fiber in an MDU is a simple matter of mounting the enclosures and making plug-and-play connections with the cables.

Further speeding up and simplifying the installation work is a built-in fiber spool on the FDT. Because the distance varies from each FDT to the FDH, the spool holds up to 500 feet of fiber cable. Installers can easily spool the cable out to the FDH and plug it in, and any extra cable remains neatly coiled on the spool. Installers can lock down the small box containing the spool with a shroud that covers and protects the excess fiber.



A connectorized strategy enables installers to get into and out of the building much faster. Equally important, it minimizes one of the biggest problems service providers encounter throughout the network: the cost, in both time and money, of splicing operations, especially in MDUs. A technician typically takes about an hour to splice 12 fibers; that labor cost may be as high as $100 per hour. In addition, a service provider has the capex costs of splicing–including the splice machines themselves, which cost as much as $30,000 each, plus cleaving machines and stripping equipment. After comparing a connectorized approach with splicing, in terms of installation time and labor plus capital equipment costs, more and more service providers today recognize that connectorization offers tremendous advantages over splicing.

Connectorization Strategy Delivers Competitive Advantages

Connectorized fiber is enabling a growing number of service providers around the world to strike a practical balance between network construction costs and long-term network flexibility and reliability. By using connectors where they make the most sense in the CO, the OSP and on the customer premises, today's top service providers achieve several advantages they cannot get from splicing, including:

- easy access for troubleshooting, re-configuring the network and turning up services
- reduced labor cost

- lower OPEX
- more cost-effective delivery of bandwidth
- superior long-term performance of the network
- faster return on infrastructure investments

Today’s next-generation connectorized solutions are proving their value throughout fiber networks around the world. For more and more service providers, connectorization is an essential component for long-term success in an increasingly competitive market.

CHAPTER 2

Spliced vs. Connectorized
A Comparison of Architectures

Every service provider, when planning to deploy a next generation fiber network, must determine how to build that network for the lowest possible cost and in a way that creates a flexible, reliable, long-lasting infrastructure. In determining the best strategy for achieving both objectives, service providers must make some critical decisions, and one of the most important is whether to use splices or connectors when creating junctions in the network.

Ever since service providers began more than a decade ago to build the first fiber networks, their standard practice has been to use connectors inside the central office to connect fiber network elements. They know how valuable connector interface points are when it comes to troubleshooting, re-configuring the network and turning up services. However, many carriers are still using an all-spliced approach from the central office to the subscriber's premises. Their primary objections to connectorization are:

- The capital expense (CAPEX) savings of a fusion-spliced approach outweigh the operational expense (OPEX) savings of connectorization.
- Extra connection points within a connectorized approach can affect the loss budget and create additional points of failure in the network.
- Service providers are not certain that the number of network failures will not be large enough to require the additional test access points connectorization provides.

Reduced OPEX for Service Turn-ups

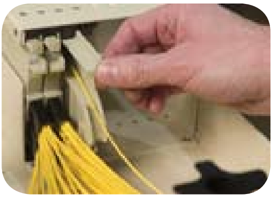
In some cases splicing segments of the fiber network is less expensive than using connectors, at least in terms of initial equipment costs. However, many have discovered those upfront savings inevitably evaporate as splicing-related issues increase OPEX, as well as reduce the flexibility of the network over time. In fact, more and more service providers around the world now are turning to connectorization to achieve in the OSP the same benefits they get in the central office. For example, in early 2008, China's Minister of Information Industry (MII) released the China FTTH National Standard, which advocates a connectorized approach throughout the network, including feeder cables.

One of the areas in which the OPEX benefits of connectorization are readily apparent is service turn-up, and there are two network locations where connector interfaces offer clear advantages over splicing—at the fiber distribution hub (FDH) and the fiber access terminal.

In a greenfield application where there may be an expected take-rate of 100 percent, splicing all the optical splitter outputs to the distribution cables, as well as the distribution cable to the drop cables, may seem to make sense. However, the reality is not all of the homes will be occupied, or even built, on Day One. Because of this, service turn-ups will not occur all at once. In a brownfield or overlay application with a take-rate of less than 100 percent, most service providers prefer to deploy splitters one at a time, on an as-needed basis, and to have easy access to the distribution fibers at the access terminals for fast service turn-up.

In a splicing scenario, the service provider must dispatch a splice technician to splice a single fiber in the FDH and fiber access terminal each time a single customer requires service turn-up. Similarly, splicing forces the service provider, when upgrading service, to convert all customers, rather than just those who want the upgrade. As every service provider knows, both situations are expensive propositions in terms of equipment, manpower requirements, training and time.

By contrast, using connectorized interfaces at the FDH and fiber access terminal greatly simplifies the service turn-up and upgrade processes. A technician only has to plug the splitter output into the distribution output in the FDH and a drop fiber to the distribution fiber at the fiber access terminal. Service turn-ups and upgrades are as fast and easy as mating two connectors.



Further, connectorization, unlike splicing, enables service providers to customize their offerings more easily, quickly and cost-effectively—and customized offerings obviously help to attract and retain subscribers. When it comes to scaling the network, a connectorized approach also enables service providers to transition easily from a 1x32 to a 1x64 or from one PON to a different PON platform.

The Right Connectors at the Right Locations Improve Flexibility and Loss Budgets

Although service providers initially rejected a connectorized approach in part because of their concerns about its potential impact on their loss budgets, connector placement options and technology advances in the connectors themselves have persuaded many to change their strategy. It is true that for every connector in a fiber network, there is loss. Yet it is important to note that while connectors at certain locations in the OSP segment of the FTTP network definitely add value in terms of flexibility, deploying them at every location where fibers meet is not cost-effective. Service providers basically have three options for using connectors in the FDH:

1. **Provide a full splitter cabinet interface within the FDH –** The FDH comes loaded with the incoming, factory-terminated feeder fiber routed to the splitter chassis and distribution fibers to the rear ports of the distribution fiber bulkhead in the FDH. The 1xn splitter module is also factory terminated, with the splitter input connector mated to the feeder fiber in the splitter chassis. At the time of service turn-up, the technician simply routes a splitter output connect to any of the distribution output port. Adding splitter modules on an as-needed basis requires the technician simply to plug the splitter into the next available slot in the splitter chassis. The output connectors are placed in the appropriate parking lot location.

   Despite the fact that this option, with completely accessible fibers, offers the greatest flexibility, it has two downsides: added cost and the added signal loss of two mated fibers. The highest typical loss is .5 dB.

2. **Use pigtails from the optical splitter output to connect directly to the distribution fiber ports –** A technician loads the optical splitters into the FDH on an as-needed basis and puts the output ports from each splitter into a “parking lot” configuration within the cabinet. In the parking lot, dust caps protect the connectors until they are assigned, on demand, to customer distribution fibers.

   This option enables the service provider:

   - to add optical splitters as needed, thereby minimizing upfront equipment costs and maximizing efficient use of the optical line terminal (OLT)
   - have ample operating flexibility, further enhanced by the fact that upjacketing on the splitter output tails protects against damage during the routing process
   - achieve an optimum balance between cost and operational efficiency by using just two connector pairs and thereby reducing both cost and dB loss

3. Splice the input to the optical splitter/connectorize the output – This option addresses the safety issues associated with the high power required by the video signal to drive the receivers at the customer premises. Although the analog video signal leaves the central office with relatively high power, it reaches the splitter in the FDH with a power level around 20 dBm. This high power level at the splitter input port can create a potential laser eye-safety issue for technicians, but this concern has been resolved by employing a protective splitter shutter adapter.

To eliminate this potential safety issue from the network, a technician can splice the input to the optical splitter. Although less flexible than the two-connector-pair option, this option:

- still has a connectorized splitter output for easier test access and on-demand service turn-up at the distribution end
- reduces cost
- lowers dB loss

Real-Life Plug-and-Play Deployments

Technicians Drive the Transition to Plug-and-Play
Technicians at a large Southeastern carrier drove the transition to a connectorized architecture because they felt a spliced approach was too cumbersome and slow. In addition to addressing immediate field technician concerns, this approach also addressed various OPEX challenges including upgrades and testing.

Retrofitting a Brownfield Network
A mid-size carrier in Calilfornia needed to retrofit a legacy network that was experiencing severe bottlenecks. Their challenge in this brownfield environment was to keep CAPEX costs in line while minimizing service interruptions.

They elected to use multi-port service terminals and connectorized drops, executing all the initial work within a four-week time period.

Simplified Testing
A small Midwestern carrier uses connectors as test points to give them flexibility for monitoring and troubleshooting without impacting service to customers.

Nevertheless, it may not deliver all the cost-savings the service provider wants, simply because a splice technician must be present to add splitters to the FDH.

As noted earlier, technological advances also have persuaded many service providers to turn to a connectorization strategy. As FTTP equipment volumes increase, vendors such as ADC have significantly improved connector quality and performance in the network. More stringent performance standards, such as the Telcordia GR-326-CORE specification, combined with improved manufacturing processes, have resulted in:

- lower insertion and return loss
- automated tuning
- superior endface workmanship
- vastly improved factory-termination methods

ADC, in a test that began in 1995, put a series of its fiber connectors on a rooftop in Minneapolis, exposing them for the next five years to the harsh Minnesota climate at temperatures ranging from -42° to 58° Celsius (-43° to 137° Fahrenheit). Automatic performance tests on each connector every hour demonstrated that despite the severe extremes in weather, the connectors performed within ADC's specifications throughout the entire five years.

In the years since service providers first began building FTTP networks, vendors have improved the technical design and manufacture of optical connectors to ensure they perform reliably in a wide variety of environments over long periods of time. In addition, vendors have improved optical splitters to reduce loss even more; typical loss for a splitter has improved from about 17.4 dB previously to about 16.5 dB today. The combination of these design and manufacturing improvements significantly increases the loss budget for service providers adopting a connectorized architecture.

Connectors Provide Easy Test Access

Acknowledging that connectorization provides additional test-access points in the network, many service providers have argued that is not an important factor. They believed, at least initially, that the number of fiber network failures is too small to necessitate extra test sites. However, in the long run, as their fiber networks grow larger and more complex, leading service providers have come to recognize that simplified test access is very important, and is one of the strongest arguments for replacing splices with connectors.

The first and most necessary testing requirement takes place during service turn-up. If there are no connectors in the network, technicians are required to splice connectors onto bare fibers, perform testing on both ends of the network fiber and then break the fiber. A connectorized approach streamlines this process dramatically.

Regarding ongoing test access needs, service providers are faced with two tough challenges when trying to isolate faults in the network: The first involves the 1x32 optical splitters in the FDH. Typically, a technician uses an optical time domain reflectometer (OTDR) to trace the location of the fault, but OTDR traces are difficult to decipher once the trace hits the 1x32 splitter.

The second challenge arises when only one subscriber has a problem. How does a technician access the fiber to test a network—without taking as many as 32 subscribers out of service? When more than one subscriber served by a splitter in the FDH reports a problem, that fault likely has occurred somewhere between the OLT in the central office and the FDH in the field. In that scenario, a technician can access the network inside the central office to get a good look from the OLT to the FDH. However, testing the network from the FDH to the subscriber requires a truck roll. Here, network design has a significant impact on how quickly a technician can isolate the problem.

If the service provider adds test-access points at the optical network terminal (ONT) on each home, the fault isolation process requires a technician to tap into the network interface device at each individual residence. These interface points may not be easily or readily accessible. However, using the distribution output port in the FDH as a centralized demarcation box, gives a technician a single location with test access to any fiber for multiple homes, thus allowing easy access to the network between the FDH and the ONT.

In cases in which the installers have spliced a splitter into the network, a splice technician has to:

- go to the FDH location
- break into the appropriate splice between the splitter output and the distribution cable and
- connect the OTDR launch cable with a bare fiber adaptor or temporary splicing in a pigtail

After completing the trace, the technician then has to re-splice the splitter output to the distribution fiber—a very time-consuming and expensive process, particularly because the service provider bills for splice technicians and their equipment at a higher rate than for other technicians.

This process also poses a significant danger to the network. To access the distribution fiber in order to run an OTDR trace, the technician must manipulate several fibers, break those that are to be tested and then splice the fibers back together. Consequently, the lengths of available fiber are shorter; there also is the risk, if the technician breaks the fiber to a length that is too short to work with, of stranding some network capacity. When it comes to testing from this particular location, a spliced connection—with its time, cost and risk to the fiber— simply is not a practical, cost-effective approach.

By contrast, placing a connector interface at the splitter output provides easy test access for all of the distribution cables. It simply is a matter of:

- locating the suspect distribution fiber on a bulkhead
- disconnecting the splitter output pigtail from that port and
- plugging in the OTDR launch cable

Once the ODTR trace is complete, the technician disconnects the launch cable from the distribution port and reconnects the splitter output pigtail—without having to break any fibers or do any splicing. Further, because all of the splitter output fibers are connected to a bulkhead, protective jacketing prevents the technician from being damaging them during normal handling. Compared with splicing, connectorized fiber in the FDH clearly makes it possible for service providers to test the fibers faster and more easily, at lower labor rates and with much less risk to the network.

Connectors Ensure Long-term Network Performance

The goal of every service provider building a next generation fiber network is to strike a balance between upfront equipment costs and the operational costs involved in long-term performance of the network. When it comes to the former, connectors may be initially more expensive than splicing. However, savvy network planners look ahead to the operational costs incurred by service turn-ups for individual customers and to the ongoing need for easy test access. Leading service providers have discovered that using connectors where they make the most sense in the network justifies the initial equipment costs because it reduces OPEX over the life of the network.

Today's next-generation connectors have proven their value in OSP applications around the world. Although service providers continue to splice the FTTP network connections, many are replacing some of those splices in the OSP with connectorized fibers where it makes sense to do so.

As a result, they get maximum operating flexibility, easy test access, shorter service turn-up times, lower overall costs and superior long-term performance of their networks. These benefits, which are not available from splicing alone, are essential to success in today's extremely competitive market.

CHAPTER 3

Connectorization in the MDU

The most important aspect of any strategy for delivering fiber-based broadband services to residential subscribers is the construction of a flexible and reliable fiber network at the lowest possible cost. Within the residential market, Multiple Dwelling Units (MDUs) represent an enormous opportunity for service providers. However, with their conduits and wide variety of layouts, they also present some unique challenges, requiring service providers to spend a great deal of time in planning and installing the fiber infrastructure.

A "plug-and-play" approach, based on the use of connectors rather than splicing, enables service providers to address these MDU challenges cost-effectively and relatively quickly. A connectorization strategy significantly reduces the amount of splicing equipment and the number of splices and technicians required to install the fiber network and turn up services.

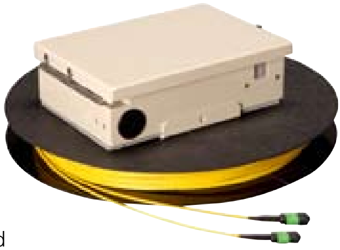
Lucrative MDU Market Demands Fast Fiber Build-outs

MDUs come in all shapes and sizes, from towering high-rises to garden-style apartment complexes. They include apartments, condominiums and town homes, and many incorporate multi-tenant units (MTUs), or commercial blocks or towers, within their structures. Studies conducted by RVA Market Research & Consulting, based in Tulsa, OK, reveal that one-quarter to one-third of U.S. residents, half of European residents and more than 75 percent of Latin American and Asian residents live in MDUs–a total of 670 million living units worldwide. Not surprisingly, service providers everywhere are targeting this lucrative market segment, and they know that if they are to capture market share, they must move quickly to build next-generation fiber networks.

However, in addition to grappling with diverse architectural challenges, carriers must resolve other MDU issues as well. For example, how much time will they need to install the network? Building owners and tenants will not tolerate much disruption, so service providers must get in, install the fiber network and get out as quickly as possible. How much building access will they need to deploy the network? Each type of MDU structure has a limited amount of physical space in which installers can work.

Clearly, service providers need installation and service turn-up strategies designed to save time and money, both during construction and in the long term. Many carriers have discovered that using connectors, rather than splicing, is essential to the rapid, cost-effective construction of next-generation fiber networks in MDUs.

Connectors Speed Up Network Installation



In the MDU environment, connectors accelerate network construction, thereby making installation less expensive for the service provider and less intrusive for building owners and tenants. The key to a plug-and-play strategy is the multi-fiber push-on (MPO) connector, which can mate several fibers and terminations together with a snap. A typical MPO connector has 12 fibers, so each snap effectively eliminates the need to splice 12 individual fibers. Further, because a factory-installed MPO connector has already been tested in the factory, there is no need for reliability testing during installation. By contrast, a splicing approach requires technicians to test each splice between the fiber distribution terminal (FDT) and the fiber distribution hub (FDH) for reliability.

A splicing technician typically needs an hour to splice 12 fibers. The labor costs, combined with the capital equipment costs of splicing machines and the installation time required, make connectorization a far more cost-effective approach.

One MDU Fiber Network, Two Different Strategies

To see how connectors can speed up network installation in an MDU, it is helpful to compare splicing and connectorization approaches in a large high-rise MDU with 23 floors and 15 units per floor. In a stub-pull configuration, a 432-fiber indoor fiber distribution hub (FDH) with three 144-fiber stubs is located on the lower level. On each of the above floors, a fiber distribution terminal (FDT) routes 12 or 24 fibers down to the indoor FDH where a technician splices them in. In this example, the technician splices 432 fibers between the FDH and the FDTs. From the FDT on each floor, an individual fiber drop routed to an optical network terminal (ONT) at each residential unit delivers service. Here, 345 individual drop cables would run from the FDTs to the ONTs, creating another potential splice point because it is not possible to predict the exact length of each drop.

Using a loop-through configuration in the same building, with a 432-fiber indoor FDH on the lower level, installers would pull several 72-fiber (or larger) distribution cables between the FDH and the FDTs on higher floors. On each floor, a technician routes one of the cables through the FDT, opens it, opens two of the 12-fiber ribbons and routes 15 individual fibers to the splice tray in the FDT. In this example, the technician would splice 345 fibers between the FDH and the FDTs. Again, 345 individual drop cables would run from the FDTs to the ONTs, creating a potential splice point. Per-splice costs are higher in this configuration because the splicing technician must spend additional time routing cables through the FDT and opening them.

Creating the same MDU fiber infrastructure by using MPO connectors between the indoor FDH and the FDTs offers several advantages over splicing. This time, the indoor FDH has built-in 12-fiber MPO connectors, and an MPO connector is mounted on the stub of each FDT. Technicians can easily plug each connection from every floor into the FDH. Installing fiber in an MDU is a simple matter of mounting the enclosures and making plug-and-play connections with the cables. There is no need to set up, strip and clean fibers, align a splice, fuse the fibers or apply a splice protector or sleeve. Installers only have to clean and plug in the connectors.

To make the fiber installation even easier and faster, a connectorized plug-and-play system includes a built-in fiber spool on the FDT to accommodate the varying distances between each FDT and the FDH. The spool holds up to 500 feet of fiber cable, thereby allowing installers to spool out the cable to the FDH and simply plug it in. They do not need to cut cables to length, have slack storage or deal with cable storage during the installation. The spool pays out exactly as much cable as is needed and stores its own slack, up to 200 feet. Installers can lock down the box containing the spool with a shroud to cover and protect the excess fiber. The only splice required in the connectorized approach is to connect the feeder cable to the FDH.

Connectors Open the Door to Success in the MDU Market

Capturing a share of the enormous global MDU market is crucial to service providers' efforts to satisfy the growing demand for fiber-based bandwidth and thereby improve their competitive positions and strengthen their margins. Yet the MDU market segment, with its broad range of architectures and the time and cost pressures of installing next-generation fiber networks, presents service providers with some difficult challenges. However, by adopting a connectorization strategy in their MDU network build-outs, they can:

- Reduce the time required to plan the installation, because of the greater flexibility provided by connectors
- Minimize the number of splices and splice technicians required for the installation
- Reduce the amount of hardware needed, by eliminating splice cases
- Use a smaller installation team, with most tasks requiring only one to two people
- Eliminate the complexity of the installation by utilizing features such as slack storage, connector parking and splice-management
- Reduce overall installation costs to achieve a higher– and faster–return on capital investment
- Accelerate the installation process and begin delivering revenue-generating services more quickly

In short, connectors now enable service providers around the world to move more quickly into the lucrative MDU market with next-generation fiber networks that ensure long-term competitive success.

CHAPTER 4

Connectorization in the Central Office

Building a next generation fiber network that is flexible, reliable and long-lasting requires service providers to balance three factors: technology, finances and operations. One of the basic technology decisions is whether to use splicing or connectors when creating junction points in the network, and that choice is especially critical because it directly affects long-term financial and operational considerations as well. After comparing the capital/operating expenditures (CAPEX/OPEX) incurred by both strategies, and after gaining some experience with both splicing and connectors in terms of moves/adds/changes, service turnups and troubleshooting, more and more service providers are opting to use connectors throughout their fiber networks, beginning with the central office (CO).

Connector interface points inside the CO have been delivering operational and financial benefits to service providers for more than a decade. These include the ability to:

- quickly deploy flexible, reliable fiber infrastructures
- reduce the number of splices, splice technicians and splice crews required for installation and maintenance
- lower their operating expenditures (OPEX)
- turn up services quickly
- deliver bandwidth cost-effectively
- speed up return on investment

Comparison of Upfront Costs and Long-Term OPEX

Despite the demonstrated advantages of using connectors throughout the network, some service providers around the world still prefer fusion-splicing, arguing that it is less expensive in terms of CAPEX. While it is true that splicing can be less expensive in terms of initial equipment costs, it does entail significant CAPEX of its own. For example, a splice machine carries a price tag of $25,000 to $30,000 (USD), and may have additional maintenance and operational costs associated with that purchase. In the long term, service providers have discovered that splicing's upfront savings are not sustainable because splicing-related issues often incur greater OPEX than connectors, including higher labor costs. Equally important, splicing reduces the network's overall flexibility, and that can translate into even more costs, both financial and competitive.

Connectors Enhance Flexibility in the CO

One of the most dynamic segments of the next generation networks is the CO, where service providers constantly need to make changes--removing or adding components and upgrading both passive equipment and active electronics, such as the optical line terminals (OLTs). Higher fiber densities in the OLTs mean service providers have to manage more fibers; they also have to add more frames to the bay line-ups to support those higher densities. As a result, operational flexibility and rapid scalability in the CO are crucial, as is the need to conserve physical space whenever possible. "Plug-and-play" connectors help service providers achieve all those objectives.

One of the most valuable aspects of a connectorization strategy within the CO is the multi-fiber push-on (MPO) connector. Using an MPO connector, a technician can terminate multiple fibers with one connection, rather than needing an SC connector to terminate each individual fiber. Although the MPO connector first appeared several years ago, its use generally was limited to multimode fiber applications within data centers. It is relatively new to the CO, in part because of the higher initial costs of connectorization, relative to splicing. However, as mentioned earlier, these higher up-front costs often are offset by the lower OPEX that results from having to make fewer splices and needing only one MPO connector to make multiple connections on the back of a panel. The MPO connector now is an industry standard, and the Telcordia GR-1435 specification defines the baseline requirements for MPO performance levels.

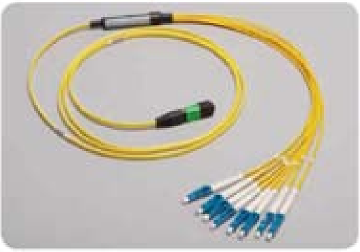
Because of the CO's limited physical space, which necessitates single-mode applications, service providers are looking for a small form factor footprint. In response, vendors such as ADC produce 8- and 12-fiber MPOs,thereby making high-performance connectorization possible for much of the active equipment. In fact, ADC produces MPOs for use in applications at both ends of the CO, using large MPO connectors in distribution-type cables to house higher fiber counts. The interconnect cables, which typically contain 8 or 12 fibers, function as single-ribbon patch cords. Original equipment manufacturers (OEMs) use MPO connectors as well, including inside the passive panel used for fiber management and in a termination panel on a large frame containing a switch or router.

Another plug-and-play strategy in the CO involves a "breakout style" assembly, which is a more rugged cable that plugs directly into the active equipment on one side, with the frame on the other side. Resembling a patch cord, the breakout cable assembly offers a fiber count up to 24 fibers. Because it plugs directly into a transceiver or fiber blade, such as with video equipment, with only one cable required for each shelf, this connectorized approach makes it very easy to configure the fiber network.

Emerging Trends in the Connectorized CO

As technology advances and connectorization becomes more prevalent in the CO, service providers will have more options for using connectors--options which will deliver additional benefits. For example, with higher fiber counts going to the active electronics, service providers now are turning up more circuits at a given time. Rather than running 24 individual patch cords between the active electronics and the ODF frame to bring up a service, they can run one multi-fiber cable assembly and use one MPO connector to bring up multiple fibers/circuits at a time.

This connectorization strategy significantly reduces the time required to turn up fibers--or to turn up the CO as a whole. That translates into lower OPEX and, with faster service turn-ups, it also enhances the service provider's ability to attract and retain customers. Further, if a problem occurs--for example, if a fiber breaks in the CO--the service provider does not have to call a technician to bring a splice machine and splice in a new pigtail. By simply running a jumper cable and plugging it in, the service provider can have the system back up and running much faster than with a splicing approach.



To obtain additional flexibility and to conserve physical space, service providers are beginning to use multifiber cable assemblies and MPO or MTP (mechanical transfer pull-off) connectors much more widely in the CO. For example, in a point-to-point active-Ethernet FTTP architecture, the connectorized multi-fiber cable assembly, rather than individual patch cords, provides the connectivity between the OLT and the ODF. This configuration allows the service provider to run one cable, rather than multiple single fibers (single or dual jumpers); it also eliminates the need for a dedicated fiber-management system, allowing the service provider to route the cable through a dedicated ladder system.

In this particular application, a 24-fiber cable runs between the OLT and the ODF. On the ODF end, 900-micron breakout fibers run to the back of a block or a panel on the frame. At the other end, the cable is broken out and unjacketed to a 2 mm fiber, which the service provider terminates onto OLT.

Service providers also are starting to use MPO cable, that is, a cable assembly with an MPO on one end and a SFF on the other, instead of a cable with SFF connectors on both ends. This type of cable assembly offers two distinct advantages. First, it allows the service provider to plug in only one connector for, say, every 12 fibers at the ODF, thereby simplifying and speeding up connectivity. Secondly, compared with a 24-fiber cable, which is 11.6 mm or more in diameter, a 12-fiber cable is only 3 mm in diameter, so the service provider can run it through a fiber-guide system and store excess slack in that system's built-in storage area. This eliminates the need to engineer specific cable lengths, as a regular breakout-cable assembly requires.

Another emerging connectorization trend in the CO centers on an MPO bulkhead application, in other words, a tie-panel application in which the service provider establishes a cross-connect in the ODF and an interconnect panel in the active-equipment bay. From the front of an MPO bulkhead panel, the service provider runs a shorter cable assembly to the active equipment. This configuration can support a go-as-you-grow approach because it only requires a cable assembly for the circuits which the service provider actually is turning up. A standard assembly available off the shelf, a bulkhead panel with the MPO connector supports very high-density rack units, up to 288 fibers.

Reliable Connectors Help Build a Reliable FTTP Network

In addition to their concerns about the higher initial costs of connectorization, relative to splicing, some carriers have been worried about its potential impact on their loss budgets. However, technology advances in the connectors themselves have persuaded many to change their strategy.

It is true that for every connector in a fiber network, there is loss, yet as FTTP equipment volumes increase, vendors have significantly improved connector quality and performance in the network. More stringent performance standards, such as the Telcordia GR-326-CORE specification, combined with improved manufacturing processes, have resulted in:

- lower insertion and return loss
- automated tuning
- superior endface workmanship and
- vastly improved factory-termination methods

ADC, for example, does the same performance testing on indoor connectors as it does on those destined for the OSP. With connectors today proving their reliability in the OSP, which obviously is a more extreme environment than the temperature- and humidity-controlled environment of the CO, they clearly can deliver the reliability that service providers demand throughout the network.

Splice Where It Makes Sense to Do So

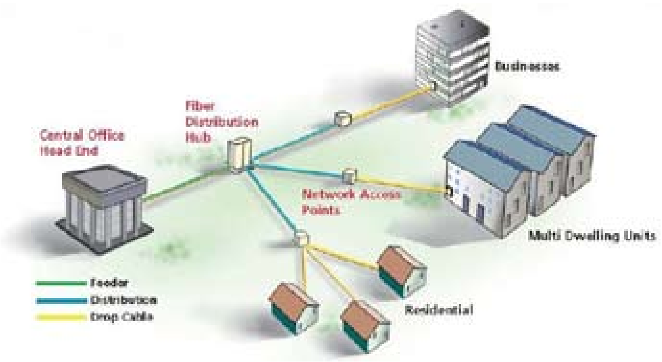
For service providers around the world that have used a splice-only approach in their existing CO's but now are persuaded of the benefits of using connectors, it is important to stress that the choice between splice and connectors should be made on a case-by-case basis. Although using connectors at many locations within the CO definitely adds value in terms of flexibility and lower OPEX, there is one location where splicing is the necessary option: at the CO's fiber-entrance facility, specifically between the outside plant (OSP) cable and the indoor cable. That IFC cable, which runs between the splice point and the back of a pre-terminated panel on an optical distribution frame (ODF), generally is considered permanent cabling.

Except for this particular application, more and more leading service providers have concluded that connectors are a more cost-effective and flexible solution within the CO. Of those that have used a splice-only approach in the past, most now have begun to migrate toward a connectorization strategy. By adopting a cap-and-grow approach, many service providers now plan to use connectors not only in the CO but plan to extend that connectorization strategy into the OSP.

CHAPTER 5

Connectorization in the OSP

When designing a next generation fiber network, every service provider wants to build an extremely flexible and reliable infrastructure–and to do so as quickly as possible and at the lowest possible cost. To achieve all of these objectives, carriers around the world increasingly rely on connectorized ("plug-and-play") solutions, rather than splicing, to create junctions throughout the network, including in the outside plant (OSP).



Specifically designed to ensure network reliability and flexibility, connectors reduce the number of splices required in the OSP and minimize the need for additional splice technicians. As a result, service providers can reduce both their installation costs and operating expenditures (OPEX). Connectors make it possible for technicians to handle installation, maintenance and troubleshooting tasks quickly and easily.

The Costs of Splicing

Efficient construction of the distribution plant is necessary if the service provider is to maintain adequate return-on-capital ratios and reduce the capital expenditures (CAPEX) required to make the network subscriber-ready.

In a typical FTTP architecture, for example, construction places a large distribution cable, containing anywhere from 48 to 216 individual fibers, from the Fiber Distribution Hub (FDH) directly to the service terminal. The service terminal can be a splice case, a pedestal, a hand-hole, or a pole-mounted terminal. When using a splicing approach, technicians must prepare the fibers at the service terminal, and connect the drop cables to the distribution fiber in order to deliver service to each home.

The rest of the distribution cable continues to the next service terminal where technicians again prepare fibers and make them available for service. Each time the provider is ready to turn up service at a particular home, a technician must go to the terminal, cut off the appropriate length of drop cable from a large spool, place the cable from the terminal to the optical network terminal (ONT) at the home, and splice both ends. This procedure often requires two sets of workers: a drop-placing crew and splice technicians.

The typical spliced approach, compared to a connectorized approach, incurs more overall manpower costs and numerous trips to the service terminals by experienced technicians, all of which increases the start-up costs and time required for the fiber build-out.

Connectors Offer a Faster, More Economical Solution

A connectorized strategy in the OSP reduces both initial construction costs and time, as well as the costs incurred by turning up service for each new customer. Because hardened connectors and adapters mean the service provider does not have to dispatch a splicer, labor costs are much lower–and installation of the drop goes much faster.

ADC's Multiport Service Terminal (MST) uses hardened adapters for the optical ports, and each port is sealed with a threaded dust cap to protect against dirt and moisture. MSTs are available in 2-, 4-, 6-, 8- or 12-port configurations, and the optical ports accept subscriber drop cables that are terminated with hardened connectors. After the technician has secured the MST, preconnectorized drop cables provide easy connectivity from the MST to the ONT at the subscriber's residence.

Utilizing a solution like the MST also eliminates the need for splice cases at the service terminal, which means the hand-holes or pedestals that store the service terminals can be much smaller and therefore can reduce materials costs, as well as simplify installation.

When using hardened connectors, technicians place smaller cables–up to 12 fibers each–from a centralized splice location to each MST service terminal location. Consequently, they do not need to run large cables and access those cables at numerous locations. Typically, the set-up accounts for a large portion of splice costs but, with a central splice point, the technician has to set up only one time.

Connectors Designed and Tested for OSP Reliability

Because hardened outdoor connectors are a critical link in the distribution network, they must undergo a full suite of tests to ensure the highest performance and reliability levels for OSP applications. A full qualification program includes an extensive sequence of harsh tests performed under the same real-world conditions likely to be found in the OSP during the service life of the connectors. They must meet Telcordia standards, such as GR-326, GR-771 and GR-3120, designed to test for robust and reliable environmental performance.

To comply with these and other standards, vendors such as ADC conduct a battery of tests to expose the rugged connector and adapter to thermal aging, thermal cycling, humidity aging, humidity condensation cycling, and post-thermal cycling. These components then undergo vibration testing and a full range of mechanical stress tests, including flex, torsion, proof, and transmission with applied load.

Additional requirements include impact and crush-resistance testing to simulate normal incidental forces. Vendors test for water intrusion while submerging the connectors in 3.05 meters (10 feet) of water while also applying mechanical stresses. The hardened connector system undergoes still more tests to certify that it can withstand cyclical freeze-thaw conditions while fully submerged. A variety of optical monitoring tests verify the connector's ability to withstand the rigors of the harsh testing environment while maintaining required insertion loss and reflection performance during and after the extreme exposure. In addition to service-life testing, a full regiment of reliability tests certifies the longevity of the hardened connector system.

Proven OPEX Savings

Using an ADC cost study featuring the MST as an example (see table below), it is possible to illustrate how connectorized solutions begin to deliver operational savings after service turn-up as well. Consider a 192-home subdivision and compare splicing vs. a connectorized approach using the MST. Despite the additional costs of adding more service terminals, the savings in fiber cable, cable placement, and splicing more than offset the added expense of the hardened connector system. In fact, the study confirmed that the hardened-connector approach incurs lower overall installed costs throughout the fiber network.

ADC continues to make it easier for service providers to construct, operate and maintain fiber networks that are cost-effective, flexible and reliable. The use of hardened connectors and adapters requires fewer splicing technicians, minimizing splicing costs and allowing easy access for troubleshooting and maintenance. This translates into faster service turn-up and huge operational savings for service providers. Not surprisingly, leading service providers around the world are adopting a connectorized strategy to save time and money in the OSP and other areas of the next generation network. In doing so, they are gaining an unbeatable competitive advantage in the marketplace.

Connectorized Savings (In U.S. Dollars):

SPLICED APPROACH		HARDENED DROP CONNECTOR APPROACH	
Hand-Hole Costs	$ 10,000.00	Hand-Hole Costs	$ 11,194.00
Cable Costs	$ 15,000.00	Cable Costs	$ 1,538.00
Cable Placing Costs	$ 75,000.00	Cable Placing Costs	$56,6650.00
Splicing Costs	$ 9,072.00	Splicing Costs	$ 2,988.00
Terminal Costs	$ 0.00	Terminal Costs	$ 16,072.00
Total Costs	**$109,072.00**	**Total Costs**	**$ 88,772.00**
Cost/Home Passed	**$ 568.08**	**Cost/Home Passed**	**$ 460.63**
Specific cost model based on a phased project for a U.S. based 192 home subdivision featuring eight homes per block.			

CONCLUSION

Where Do We Go From Here?

There was a time in the history of FTTP when all connection points in a network could be justified using an optical splice. Even today, one could make a case for a splice solution: it offers low initial equipment cost and ensures the minimal amount of signal loss in the network. But adopting a spliced approach throughout a service provider's network based on this information alone is short sighted.

To remain competitive in today's marketplace, service providers need to examine all aspects of their organization's readiness to deliver next generation fiber services. To start, providers need to ensure they have a network architecture built on flexibility, which gives them the ability to respond swiftly to emerging technologies, fiber applications and customer demands. It requires examining all key connection points in the provider's network to ensure fast and efficient service calls, network configurations and upgrades.

A plug-and-play connectorization approach at key network interface points will help to ensure service providers have the *flexibility* to respond to customer's needs. Where technicians are expected to visit frequently for testing, troubleshooting and re-configuring services, connectorization offers significant advantages over a spliced approach: it enables service providers to deliver more combinations of services and caters to customers' specific requests. As a result, service providers can appeal to a larger audience and gain more opportunity to bring in revenue.

Connectorized fiber alone will not solve all the challenges in the local loop. Splicing will continue to show its value in sections of the network, especially in longer cable runs. But knowing when and when not to connectorize fiber: that is knowledge that can translate into real working dollars for a service provider. Hopefully, this booklet has shed some light on this very important topic.

For more information on the benefits of connectorization, we welcome you to visit ADC's Next Gen Library: www.adc.com/adclibrary

There, you'll find a collection of white papers, case studies, videos, podcasts and other solution-based materials which will help put you on the winning track for your next fiber deployment.

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