THE BOOK ON FTTX

From Design to Deployment: A Practical Guide to FTTX Infrastructure

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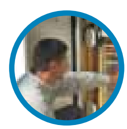

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Edited by Steve Grady

Forward by Sharon Stober,
Editorial Director of Outside Plant Magazine

ADC

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Forward

How Do We Get There From Here?

By Sharon Stober, Editorial Director of Outside Plant Magazine

Convergence is a word many of us in the industry grow weary of hearing. It oozed from the mouths of marketers during the dot-com explosion and even during its violent implosion. Now, as our market moves from survival to recovery mode, the word has begun to take on a life of its own once again. It seems that convergence is as popular in the telecom world as other over-used catch phrases such as Next-Generation Networks (NGN), Quality of Service (QoS), and Scalable Networks.

Those who throw the term about loosely seem to ignore the reality of such a potent theory. Although convergence is the nirvana of a single network handling voice, data, video, and other data applications in a seamless manner, it is by no means a simple and straight-forward evolution process. As one industry observer said recently, "It is the Gordion Knot. You cannot unravel one knot without creating another as a result."[1]

Quite frankly, I enjoy watching convergence collide with today's infrastructure. To understand the vast implications surrounding that collision, we must first examine the market conditions leading to a renewed interest in making convergence a cost-efficient reality. And that's where my passion lies.

Market Conditions

A market ripe with change brings both challenges and opportunities to service providers aiming to thrive. Incumbent providers are losing about 9% a year in voice traffic, which currently provides the majority of their overall revenues. (McKinsey Study). At the same time, pricing structures are declining by nearly 10% a year, according to the Gartner Group.

What's more, service providers today are dealing with losses exceeding $1.5 million each year for every 1000 customers they lose due to inadequate technology. (Gartner Group). Indeed, the pressure is mounting.

The good news? Over the next four years, broadband subscriptions are expected to grow by 16%. (IDS Worldwide Broadband Access Services, 2004-2008). And by 2008, the video market is forecasted to climb from $54 billion to nearly $63 billion. Now, more than ever, the infrastructure will help determine which providers will capture the lion's share of these growing markets.

The potential is great for those providers willing to invest in fiber technologies while harvesting the assets of their legacy plant. The old philosophy of "If we build it, they will come" no longer applies. Smart Incumbents know they must walk a fine line, deciding when to invest in fiber and when to upgrade the legacy plant. They are intent on tactically squeezing each and every megabit out of their current infrastructure and building future-proof networks when it makes sound financial sense.

We see Verizon and SBC walking that fine line as they race to capture a piece of the digital home networking market. The *Wall Street Journal* reported that Verizon was the first RBOC to launch TV services in one Texas city, and will introduce the service in other Texas communities as well. On the heels of that first launch, Verizon will roll-out TV offerings in Fairfax

County, Virginia, a fast-growing suburb of Washington, D.C.; along with a New York City suburb Massapequa Park, New York.; and a community outside of Tampa, Florida.

SBC, which initially said it will roll out TV in late 2005, has pushed its launch date back, possibly to early 2006. Their updated launch reflects the company’s aim to provide TV service to 18 million homes by the first half of 2008, nearly half of those reached by the company's networks. Their objective: to dominate the home entertainment market with a single package of TV, high-speed Internet, and landline services. And if telecom analysts are correct, close to 40% of U.S. households may have the opportunity to get TV service from their telephone companies by 2010. (Sanford C. Bernstein & Co). That would translate into a huge opportunity for consumers and survival assurance for Incumbents. Indeed, the future lies in holding end-users' attention. Forrester Research says that telcos can do this by offering three things:

- Personal Entertainment
- Intelligent Devices
- Core Services

Why Fiber?

We have entered a time where the amount of bandwidth users want for Internet services is nearly insatiable. Even just five years ago, a dial-up modem delivering close to 56 kbps was an acceptable connection. Today end-users find acceptability in the range of 1 Mbps and 3 Mbps. That’s nearly 35 times the bandwidth that was acceptable in 2000. Now, jump ahead 10 years; if this growth continues, a subscriber will demand between 35 and 70 Mbps by 2010.

Clearly, subscriber appetites are driven by evolution and advancement of broadband applications. Internet-savvy users are now active participants in the on-line experience. They transfer high-resolution digital photos, serve content to friends, participate in interactive, graphics-intensive gaming, and often have more than one PC connected to their home networks. Soon, users will demand higher upload speeds, similar to that which they experience on downloads.

And we haven't even begun to consider future applications! Today's service providers face hungry end-users and cable and/or satellite competitors who intend to satiate them. Telcos have the choice to engage in the feeding frenzy or, quite simply, be eaten.

What are the options for delivering that bandwidth? As we said before, convergence (with its real definition, thank you) is the coming together of disparate networks. Today, as the industry propels itself toward a single, unified network, the very harsh reality is that service providers are still dealing with the realities of a mixed grouping of network architectures.

These three varied architectures make for a very interesting OSP:

1. The legacy plant utilizing ADSL2/2+ and/or VDSL to deliver up to 12 megabits.

2. The SBC model of FTTN where fiber is brought to about 3,000 feet but copper capabilities are relied on to the customer premises.

3. The Verizon, FTTP model as an optimal choice for new builds and MDUs. For those applications, the cost of FTTP is similar to copper.

Converging these networks is both the promise and the problem for providers today.

Today, as the telecom market has moved from survival to revival mode, worldwide sales of telecom services are expected to rise by 6% to 7% this year and next, according to Gartner Inc.[2] Much of that momentum is attributable to growth in fiber optics. And while we'll never see the frenzied pace that the dot-com bubble offered before it burst, we will likely see convergence occur as providers meld these once disparate networks (fiber and copper).

Drivers for this migration toward fiber include: an aging copper plant, anticipated high take rates on bandwidth intensive applications and the potential for customer retention when Incumbents offer bundled services.

Quite clearly, service providers looking for long-term success in this competitive marketplace must find cost-efficient architectures that employ FTTX solutions.

It's All in the How

That's why ADC's "The Book on FTTX" is so helpful. When making cost-sensitive decisions about deploying FTTX, service providers must look at today's initial installation costs, and also peer into the future regarding operational and maintenance expenses following service turn-up. (I wish I had written that sentence instead of borrowing it from chapter 2!)

It's so easy to miss that important distinction as we scurry about the "How do we get there from here?" decision-making process. Often we don't take the time or we decide it's unimportant to see both the forest and the trees (F&T - my own acronym). All the while, we wonder why we can't find the right strategic and tactical solutions to the problems confronting our organization.

This F&T theory rings true with our provider partners in SBC, BellSouth, and Qwest as well. Each time I tell them the necessity of educating ALL their team members – from executive level all the way into the field – I use the F&T metaphor. They listen and soon their heads nod in agreement, eyebrows raise and glances are exchanged across the conference room table. We all suddenly experience that Ah-ha! moment. They get it.

To succeed, service providers must take action and educate their teams about both the forest of FTTX as well as its trees. Without a vision from above and clear sight of the details below, how can cost-sensitive, smart deployment decisions be made?

That's why I find myself drawn to Chapter 2 about Seven Killer Bs that can help create a solid business plan by using a sound decision-making process.

The Seven Killer Bs are:

1. Baseline
2. Bundled Services
3. Broadband Technology Options
4. Bandwidth Boundaries
5. Business Case
6. Budget
7. Build

I've included a great paragraph from Chapter 2 so you can see how this device supports my argument that providers must always use a forest-and-trees analysis as they look toward the future:

> From Baseline to Business Case to Build, the ratio of CAPEX vs. OPEX must be evaluated. In other words, carriers must decide on whether to invest more in equipment and technology or operations and maintenance. The decisions made to save CAPEX could result in additional OPEX down the road – and what is the downside if the network fails to achieve its operational goals?
> --- "The Book on FTTX", Chapter 2

ADC's rather clever Killer B pneumonic device is substantive, not fluff. It can be memorized by each member in your organization and, even better, applied to the analysis you're doing as you evolve the network. Doesn't it make sense for a C&E department to evaluate a problem on a similar set of criteria (the forest) and have everyone speak the same language (the trees)? "B" honest – you know it does.

Another forest we tend to ignore is the unpredictability of Mother Nature. With the deadly wrath of hurricanes along the gulf coast, we have to respect their sheer force. Less obvious, however, is the impact more normal weather exerts on FTTX architectures. That's why planning for the worst case is critical.

Temperature, particularly cold temperatures and wide temperature variations, are directly related to insertion loss failures due to cable and cable assembly component shrinkage. This is something manufacturers like ADC address before equipment goes in the field. Read more about this in Chapter 9, Challenges of Cold Temperatures on OSP Cable Assemblies, to remind yourself that planning for the worst Mother Nature can deliver will allow your FTTX architecture to be resilient in even the worst weather.

Then, there are the issues that stretch beyond the OSP. Not too long ago, all the intelligence of the network resided in the Central Office (CO). And while a fair portion of it has moved to the networks' edge, the implications for the CO must be considered in the equation as well. We know all too well that one change made to the network impacts another. You can remind yourself of its complexity and how it dovetails with the OSP by reviewing Chapter 4, Central Office Implications for Deploying FTTP.

Another major consideration is building the link between customer and the CO – that is, the fiber distribution portion of the network. Much debate continues around the issue of splitter configurations. Should providers use a centralized or cascaded approach? I'd recommend reading Chapter 3 on this topic to help determine which side of the argument you plan to take.

Once providers make the determination about their FTTX architecture, they must consider the unknown: In new build situations, how will the fiber be protected from the end-user? Consumers have no problem digging up their backyard for that D.I.Y project they intend to complete this weekend. They don't follow the one-call rules. They dig. Therefore, providers must decide upfront HOW they plan to treat drop cables in Greenfield applications. Unexpected cuts and troubleshooting can translate into big dollars. So, spend a bit of time with Chapter 10, Above vs. Below Ground Drop Splicing, comparing these two tactics in splicing. It could be that this portion of the decision-making process will make or break your OPEX budgets in the near future.

As a final note, being an editor, I always check out the glossary of any well-written book. It allows me to quiz myself and my team on the useful and un-useful acronyms in our industry. (Nothing worse than hearing one of my new staff members pronouncing "CLEC" as "C-LEG" in a phone conversation with one of our provider partners. Just what is a C-Leg?)

Here's your assignment: Spend some refresher time with the glossary, and send me an email sharing the page number where the authors inserted my education-oriented acronym F&T. Remember, it's the forest-and-trees philosophy of learning. Then, make F&T part of your own vocabulary and vision. Go ahead, try it at home. Most important, teach the F&T philosophy to your team members.

Given the convergence of the copper and fiber networks, we'd better be darned sure to learn a little about the F&T of FTTX. This book by ADC is a great tool to do just that.

[1] *Midas, a king of Gordion, dedicated his chariot to Zeus with the yoke tied to a pole in a very intricate knot, and declared that whoever could untie this knot would become the king of all Asia. Many people came to untie the Gordion Knot without success. According to legend, when Alexander the Great came to Gordion he looked at the problem from a different perspective and resolved it quickly by cutting through the knot with his sword, thereby revealing the ends of the cord that were hidden in the middle of the knot. Now, "cutting the Gordion Knot" has come to mean victory over a difficult business problem.*

[2] *See "Telecom Comes Calling," Barron's Online, Weekday Trader, July 12, 2005, http://online.barrons.com*

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As you progress through each chapter, you will find a wealth of technical know-how, practical advice and real world experience. The following contributors have freely shared their hard-won lessons: Tom Kampf, Trevor Smith, Pat Thompson, Hutch Coburn, Randy Reagan, Gary Bishop, Diane O'Keefe, Laura Whipple, Chuck Grothaus, Bob Pease and Pat Sims. The format of this book is clean and very accessible. This is due to Terri Benson who did an outstanding job on the layout and production. Many thanks to each of them.

We would like to thank Sharon Stober for her insightful Forward.

And just like an Oscar speech, there are those who I did not get a chance to thank. Of course I will hear about this later, but thanks in advance to all of you as well.

Best of luck with your FTTX network. I hope that you will consider contacting the ADC team to help you succeed. Please feel free to let me know how it is going at steve.grady@adc.com.

Best Regards,

Steve Grady
Vice President Global Marketing - ADC

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Chapter 1
FTTX: An Overview

The Next Generation Network

Simply put, to meet the demands of current and future applications, it is imperative that broadband access networks be able to provide the necessary bandwidth.

Optical fiber provides the only true solution for existing and future requirements. With optical fiber technologies, bandwidth demands are satisfied, bringing the communications infrastructure more powerful tools that can interface directly with homes, businesses, offices, community centers and government agencies. Optical fiber technology provides a higher capacity data transfer at very high speeds, enabling the community or service provider to supply a wide range services and applications, such as High Definition TV (HDTV), Video on Demand (VoD) and high-speed data all while providing the basic fundamentals of voice connectivity.

Broadband access equipment providers are able to offer technology advances through the converged services of triple-play features using network aggregation and subtending in combination with Passive Optical Network (PON) technology. A PON is made up of fiber optic cabling and passive splitters and couplers that distribute an optical signal through a branched “tree” topology to connectors that terminate each fiber segment.

The following is a partial list of advantages in using optical fiber systems:

- Higher Bandwidth Capacity
- Longer Reach
- Longer Life
- Resistance to Outside Interference
- Lower Maintenance Costs
- Better Reliability

Communities and service providers are able to offer a wide range of value-added services, above and beyond existing services, over a fiber optic infrastructure.

FTTX Architecture

Communities and service providers have responded to the growing demand for broadband services by either moving towards a wireless solution, or upgrading their existing copper infrastructure with xDSL technologies. Both of these technologies are readily available today and represent a natural evolution to more applications and better utilization of the copper plants. But this is considered to be an intermediate solution, due to rate limitations of wireless and the transmission limitations of copper lines. Both technologies impose a technical trade-off between rate and reach, affecting the number and types of services that can be offered. It is becoming more economical and strategically imperative for communities and service providers to start bringing fiber as close to residential and small business premises sooner rather than later.

To accomplish this, a number of optical fiber architectures can be considered, which include:

- Fiber-to-the-Premises (FTTP)
- Fiber-to-the-Business (FTTB)
- Fiber-to-the-Node (FTTN)
- Fiber-to-the-Home (FTTH)
- Fiber-to-the-Curb (FTTC)

These architectures can all be grouped under the category Fiber-to-the-x (FTTX).

Fiber-To-The-Premises (FTTP), though an evolving technology, is not new. Fiber-to-the-Home (FTTH) has been available for about 10 years, and FTTP is viewed as the next logical step in the evolution of the access network. In an FTTP architecture, an optical fiber is deployed all the way to the customer's premises or location; either to the residence (FTTH - Fiber To The Home) or to a business (FTTB - Fiber To The Business). A Network Interface Device (NID) is located at the customer premises in the form of an Optical Network Termination (ONT), or Optical Network Unit (ONU). The ONT/ONU terminates the optical access network providing direct connectivity to feature-rich services.

FTTX is also discussed in the context of deployment scenarios such as greenfield, overbuild, and rehabilitation, as well as hybrids of the three.

In the early years, the high cost of building an "all optical" network limited deployments to new build or "greenfield" areas. Just as infrastructure costs have decreased, and bandwidth needs have increased, communities and service providers are now recognizing the alternative solution to "overbuild" their networks with optical fiber.

The initial investment required for optical fiber deployments is still fairly high and may require a proven return on a particular business case. A phase-by-phase approach is an alternative where the optical fiber access starts with a Fiber-to-the-Node (FTTN) type of deployment. In FTTN configurations, an optical link is deployed to the ONU in a Service Area Interface (SAI) cabinet located near a residential community, subdivision or business setting. The ONU will convert the optical signal into an electrical signal where the services are easily transferred to existing copper facilities. Due to the shorter reach of the copper infrastructure, service providers are able to offer higher bandwidth services without having to place the optical fiber directly to the premises. Future FTTP configuration upgrades can be economically justified, as a natural second phase, service requirements grow.

Greenfield

The ultimate FTTP deployment is the greenfield scenario in newly built areas where there is no existing broadband infrastructure and no constrictions exist. In new neighborhoods and planned communities, the application of FTTP is easy to justify as initial overheads are quickly repaid; the difference in infrastructure costs for fiber and copper is negligible, and construction costs are equivalent. Fiber greatly reduces future maintenance costs for the physical plant, thus it makes sense to deploy fiber to residences and businesses in greenfield applications. Greenfield customers include:

- Single-Family Units (SFU)
- Multi-Dwelling Units (MDU)
- Small Business Units (SBU)
- Small/Medium Business Multi-Tenant Units (MTU)

Because of the nature of these new developments, a relatively high take-rate for second phone lines, data, and video services can be assumed, creating higher revenues and lowering the cost of deployment. Furthermore, due to the dense populations of FTTP customers in greenfield applications, fiber can be cost-effectively run all the way from the Central Office (CO) to the Local Convergence Point (LCP), where the first passive split can be made.

Overbuild

The full overbuild scenario is an FTTP application. Where market demand for advanced data and video services exists in serviced neighborhoods, it may be desirable to deploy fiber along with the existing copper network. The following factors can contribute to a decision to overbuild an existing plant:

- Aging infrastructure
- High projected take-rates
- Competitive pressures
- Requirement for higher bandwidths than available with the current copper technologies.

The objective of the full overbuild with fiber is to gradually transition all customers to the FTTP system, while concurrently, retiring the aging copper plant and the active infrastructure such as Digital Loop Carrier (DLC).

Rehabilitation

The rehabilitation scenario aims to minimize capital expense when there is insufficient justification. It is identical to that of the greenfield scenario, and all services are provided to all customer premises. The difference is that rehabilitation involves existing customers, served with existing services over an existing copper plant. Voice and data services are provided on the copper network, and video on an existing coaxial network, if such exists. FTTP and FTTN Optical Network Units (ONUs) are installed in close proximity to customer premises. Should there be a need for high-speed data, it can be provided from the ONUs to requesting customers.

The Various Flavors of PON

The great promise of PON is the ability to relieve bottlenecks in the access network, but there are several different PON standards to consider when planning your network, as well as many different acronyms to help confuse the issue. As PON technologies have evolved over the past two decades, a variety of “flavors” of PON have emerged.

APON (Asynchronous Transfer Mode PON)

The first PON standard was APON, which uses ATM encapsulation of transported data and is aimed primarily at small business applications. Over time, APON was followed by BPON.

BPON (Broadband PON)

Currently the most popular form of PON being rolled out today, BPON offers improved and additional features. It is a robust network that includes WDM support for video overlay, higher upstream bandwidths, and upstream bandwidth allocation.

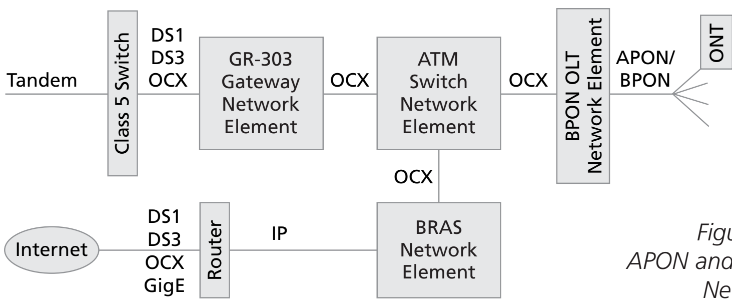


Figure 1.1
APON and BPON Networks

EPON (Ethernet PON)

Ratified in 2004, EPON is the standard of the Institute of Electrical and Electronics Engineers Inc. (IEEE) Ethernet in the First Mile (EFM). Running at 1.25 Gbit/s symmetric, it is highly suitable for data services. EPON uses Ethernet rather than ATM data encapsulation.

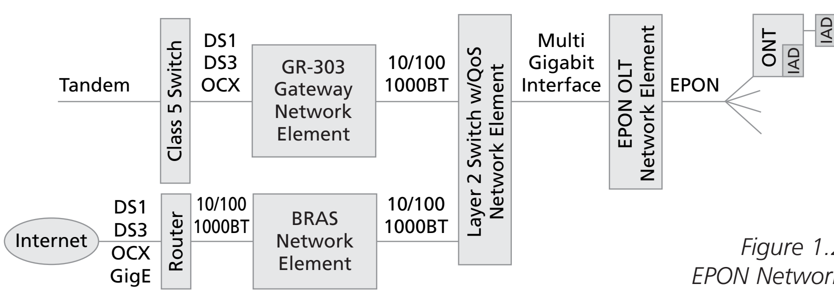


Figure 1.2
EPON Network

GPON (Gigabit PON)

GPON is an IP-based protocol designed for IP traffic and is the standard choice for high-volume FTTP carriers. GPON is often described as combining the best attributes of BPON and EPON at gigabit rates. It recognizes gigabit Ethernet interfaces to enable pure IP transport and does not require active powering points in the access network. GPON is the platform for all FTTP deployments, enabling the "triple play" of voice, video and data.

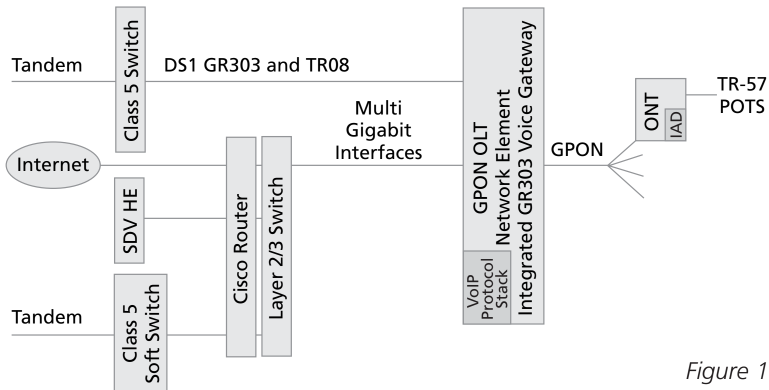


Figure 1.3
GPON Network

What You Need to Consider

This introductory chapter provided you an overview of the various FTTX architecture options. The next chapter explores the drivers and conditions that determine which architecture you select. The choices you make early in the planning process are make-or-break decisions that have lasting impact, so it is critical that you assess a number of internal and external factors before the planning even begins. A thorough, clear-eyed analysis is the key to crafting a solid deployment strategy.

Chapter 2

The "Killer Bs" of Successful FTTX Deployment

This chapter walks through the seven key elements of creating a winning business plan for FTTX. As you will see, each of these seven elements begins with the letter B. Hence, the name of this chapter: *The "Killer Bs" of Successful FTTX Deployment*. Understanding these seven business plan elements is important to placing the rest of this book into context. The following chapters describe quite a few FTTX technical concepts and trade-offs that ultimately drive the success of your FTTX rollout. You may find it useful to come back to this chapter from time to time as you read through the book and ask, "How does this FTTX deployment decision affect one or more of the business plan elements?"

New bandwidth-hungry broadband data and video services require optical fiber to push deeper and deeper into the access network as the capacities of new service bandwidth requirements exceed the capabilities of traditional copper plants. To remain competitive by offering cutting-edge services to end users, fiber networks must be extended beyond the central office and out towards customers. The nagging question for most carriers is whether to bring the fiber to the node, curb, or all the way to each customer's home premises via FTTX (where X=N, C or P).

As the industry tries to get a fix on the best approach in terms of cost, flexibility, and overall operational performance, a number of trends have emerged. Viewing these trends at the highest level is critical before deciding which approach works best for each situation. The drivers behind these trends must be closely considered, as well as the cost justification for each approach.

Addressing these concerns and making informed decisions on how to build an FTTX infrastructure will yield the best possible solution for providing advanced voice, data, and video services to the customer. Furthermore, the network is future-proofed for whatever new technologies lie ahead. Before even beginning to decide on an FTTX approach, one must understand the key market drivers and where they are leading the industry.

Key market drivers

There are three key market drivers that are influencing the direction of FTTX. They include competition, the transition of services to packet technology, and the evolution and advancement of broadband technologies over copper, fiber, and wireless infrastructures. How each of these drivers will affect the decision-making process in the early stages of building the ideal FTTX network cannot be overemphasized.

Competition – Today’s carriers are in a life-and-death race to maintain and extend their customer base to secure the highest possible market share. The fact remains that those who provide a fiber infrastructure that reaches every user will ultimately win this race. Incumbent local exchange carriers (ILECs) are most likely to deploy some combination of fiber and existing embedded copper infrastructure in a fiber-to-the-node (FTTN) or fiber-to-the-curb (FTTC) solution. Smaller service providers, however, must be the first to deploy some flavor of FTTX in their service areas to remain competitive among larger carriers. The bottom line is that those who do not make a move toward any fiber-to-the-premises (FTTP) architecture, particularly in greenfield situations, run the risk of being overbuilt. Competition is intense for providing the latest in triple play services and the continued existence of some service providers may very well depend on constructing the right FTTX network that best meets the demands of current and potential customers.

Transitioning services to packet – During the deployment of most existing access networks, only high-speed data was transmitted over an IP infrastructure. Today, however, video has evolved from multicast to packet with services such as video-on-demand (VoD) and IP television (IPTV). Additionally, voice is moving from a channelized, time-domain technology to packetized Voice-over-IP (VoIP). As all three segments of the triple play service offering migrate to delivery over an IP infrastructure, significant economies of scale are created. It greatly simplifies the overall network infrastructure and changes everything about the way these services have traditionally been provided.

Evolution and advancement of broadband – The introduction of new technologies and the evolution of existing technologies are changing the landscape of telecommunication services.

- The advancement of broadband copper technologies, such as ADSL, ADSL2+, and VDSL, are stretching the capabilities and allowing further use of existing copper infrastructure for delivering new services.
- Fiber transceiver technology is enabling longer distances and more reliable transport of triple play services.
- Wireless technologies are continuing to improve with new offerings, such as WiMax and WiFi mesh, that can compete with wireline competitors.

Each of these advancements will affect the way carriers and service providers deploy their FTTX networks. However, how fast to drive the bandwidth will ultimately come down to which combination of bundled services the provider intends to offer customers. In turn, these decisions will help determine the flavor of network (FTTN, FTTC, FTTP, etc) the carrier will decide to deploy.

The decisions each carrier makes today will determine the quality, cost, flexibility, and performance of the FTTX network during and long after its deployment. ADC has developed a set of deployment considerations, known as the “Killer Bs,” that can assist carriers in making correct deployment decisions. Giving careful consideration to each Killer B will help ensure success in building the right FTTX infrastructure in terms of cost and performance while providing the best available services to customers – today and tomorrow.

The Killer Bs

The seven Killer Bs of FTTX provide guidelines to carriers and service providers for making informed decisions prior to and during FTTX network deployment. Carefully considering the options proposed by each of the Bs will enable carriers to gain the most from their investment in terms of capital and operational cost, time, flexibility, reconfigurability, and overall performance. Let’s take a look at the seven Killer Bs of FTTX deployment one at a time.

Baseline

The first step is to perform a baseline evaluation of the current network and its capabilities. It begins with an audit to determine objectives of the FTTX network deployment, network infrastructure considerations, and the operation requirements facing the carrier. This involves documenting current equipment and infrastructure, such as copper and fiber content. At this stage, carriers would view the strengths and weaknesses of their network while determining what upgrades may be required. A prime example of this strategy is ensuring the central office (CO) is FTTX-ready by reviewing equipment inventories, understanding new DC power requirements, performing cable mining and fiber characterization procedures, and identify the areas that must be examined to affect a smooth transformation. Addressing possible problem scenarios early, while adding additional flexibility and scalability for the future network, will provide a significant competitive edge in terms of time-to-market and ease of deployment.

An example of an FTTX audit can be found in appendix A.

Bundled Services

It's important for carriers to determine which service bundles – HDTV, broadband, IPTV, VoIP, etc. – will enable them to be the most competitive while meeting customer demands. The primary driver should be the need to deliver the broad range of services demanded by business and residential customers. A complete bundle that includes voice, video, and high-speed data services must be offered – one that meets subscriber expectations for service quality, ease of use, and customer support functions. Industry studies have shown that putting the right bundle in place will attract the right customers, and minimize churn while maximizing the average revenue per user (ARPU). Once the appropriate services bundle is determined, the actual FTTX infrastructure requirements begin to take shape.

Broadband Technology Options

The next logical step is to determine which copper, wireless, and fiber broadband technologies are available that will enable the carrier to offer the selected bundled services. As was explained in the previous FTTX Architecture Overview chapter, there are several options for delivering broadband services. At this point, it's important to examine the use of existing infrastructure to minimize capital expenditures. Using technologies such as ADSL2+ or VDSL2 will leverage existing copper plants.

A study must also be made for deploying one of the a passive optical network (PON) options vs. an active optical network technology for the FTTX network. The PON architecture allows for seamless scalability with minimum cost while still supporting a near-term business case. Additionally, a successful FTTX network must be capable of evolving to satisfy future demands, such as accommodating a growing subscriber base, increasing penetration, and introducing new services.

Bandwidth Boundaries

The term Bandwidth Boundaries refers to the points in the network where bandwidth speeds change, protocols change, or media changes (e.g. copper to fiber). Bandwidth Boundaries typically involve active electronics, but also happens with passive infrastructure such as optical splitters. Bandwidth Boundaries manifest themselves in different configurations in different networks. Based on the results of the Baseline audit and Broadband Technology selection, various Bandwidth Boundary options become available.

An important decision must be made on how far to extend the optical fiber network toward the customer. Again, the concerns of capital and operational costs, flexibility, and future-proofing will be major factors when deciding on running fiber to the node, curb, or premises. The presence of existing infrastructure will play an important role in this determination as carriers decide whether it’s best to replace, overbuild, or deploy some combination to enable an easy transition to providing future cutting-edge services.

One important element of Bandwidth Boundary deployment is to understand how the network will evolve given the introduction subsequent services and competitive response. In some cases a choice to use FTTN may need to evolve to FTTP if/when a service delivery speed in excess of ADSL2+ or VDSL is required. It is essential to select an FTTX infrastructure that can be easily upgraded should the need arise.

Business Case

At this point, a carrier should have a comprehensive view of the proposed FTTX network in terms of the value of existing infrastructure, what service bundles will be offered, which technologies will deliver those services, and how to configure the optical and copper portions of the network to best leverage bandwidth capabilities. Business Case considerations include time-to-market criteria such as construction time frames, take rates, and network reconfigurability issues.

The Business Case is where the balance between capital expenditures (CAPEX) and operational expenditures (OPEX) is determined. There are first installed costs and costs incurred over the life of the network that, in total, drive the Total Cost of Ownership. TCO is a key calculation in determining the long-term profitability of an FTTX network. Many carriers spend an inordinate amount of attention on First Cost, which is understandable given corporate mandates. However, the Infrastructure layer of the network has a useful life in the 10-20 year range. Spending more on CAPEX typically reduces OPEX over time. Important issues include using centralized or cascaded splitter configurations, where to use connectors vs. hardened splices, and other characteristics that determine whether additional CAPEX will save on OPEX as the network is installed and operations commence.

Budget

Once decisions have been made regarding how to most cost-effectively construct the network, it's time to create the actual budget for CAPEX and OPEX. Carriers must evaluate equipment and labor costs as well as procurement and operations. This can often result in a balancing act between CAPEX now or OPEX later. In many cases, spending additional CAPEX can result in significant OPEX savings as the network matures and expands.

Build the Network

The culmination of all the previous steps is the actual building of the FTTX network. Here, a detailed construction bills of material and installation instructions are created. The FTTX infrastructure is engineered, furnished, installed, and ready for turn-up tests to initial subscribers. New subscribers are added as take rates grow and consumer demands increase. One of the key areas to save money is the creation of optimized Installation Methods and Procedures documents. Utilizing best practices across all installation organizations has shown to accelerate network installation and reduce errors.

CORE: CAPEX vs. OPEX Risk Evaluation

The Killer Bs of FTTX deployment enable carriers to make cost-sensitive decisions at each step of the process – not only evaluating initial installation costs, but peering into the future regarding operational and maintenance expenses following service turn-up. Extensive cost modeling indicated compelling financial benefits to making correct decisions in the earliest stages of network planning.

From Baseline to Business Case to Build, the ratio of CAPEX vs. OPEX must be evaluated. In other words, carriers must decide on whether to invest more in equipment and technology or operations and maintenance. The decisions made to save CAPEX could result in additional OPEX down the road – and what is the downside if the network fails to achieve its operational goals?

Keeping the CAPEX and OPEX ratio in sync is critical for successful FTTX network deployment and operation. A comprehensive evaluation of each Killer B will help strike the right balance.

Summary

There has never been more pressure on carriers and service providers to "get it right" when it comes to FTTX deployment. At the same time, consumer demand for new and better services has created a "do or die" competitive environment for building a network infrastructure that can offer the latest high-tech service bundles or be ousted by the competition.

Understanding the issues surrounding a successful FTTX deployment will make the difference. The 7 steps in the Killer Bs process offer logical guidelines for meeting the unique challenges presented by FTTX and making step-by-step informed decisions that enable carriers to minimize costs while maximizing performance, flexibility, and revenue generation.

Chapter 3

Advantage of Centralized Splitters in FTTP Networks

In today's and tomorrow's fiber-to-the-premises (FTTP) architectures, the best solution for offering multiple services to subscribers will be the one that is the most cost effective, flexible, and scalable. With its 75-year history of innovative solutions for managing the physical cable plant, ADC is bringing all its experience to bear in the outside plant (OSP) and fiber-to-the-premises (FTTP) markets. Driven by the service provider's need for overall affordability and operational flexibility, ADC is designing and building the first true FTTP solution – from the ground up.

A major consideration in building the fiber distribution portion of the network – the link between customer and central office – is which optical splitter approach will work best. Since today's optical line terminal (OLT) card can service a maximum of 32 customers, it is important to ensure efficient use of each card. In large developments, inefficient use of OLT cards costing about $5000 each can quickly increase initial deployment costs. Of equal importance is the network's ability to adapt to future technological changes as the telecommunication industry continues to mature.

The two common splitter configurations are the centralized and the cascaded approaches. The centralized splitter approach typically uses a 1x32 splitter in an outside plant (OSP) enclosure, such as a fiber distribution hub. In the case of a 1x32 splitter, each device is connected to an OLT in the central office. The 32 split fibers are routed directly from the optical splitter through distribution panels, splice points and/or access point connectors, to the optical network terminals (ONTs) at 32 homes.

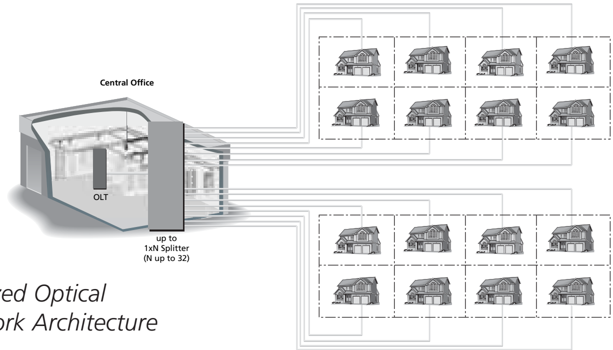


Figure 3.1
FTTP Centralized Optical Splitter Network Architecture

A cascaded splitter approach is normally configured with a 1x4 splitter residing in the OSP enclosure and connected directly to an OLT in the central office. Each of the four fibers leaving the 1x4 splitter is routed to an access terminal housing another splitter, either a 1x4 or 1x8. Optimally, there would eventually be 32 fibers reaching the ONTs of 32 homes.

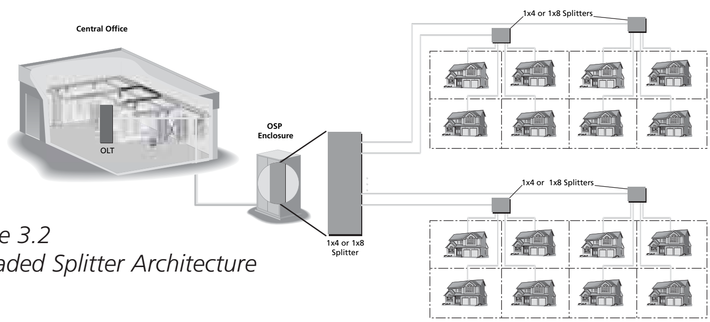


Figure 3.2
Cascaded Splitter Architecture

OLT Efficiency

For most applications, ADC recommends the centralized approach because of several significant benefits. First and foremost, the centralized approach maximizes the highest efficiency of expensive OLT cards. Since each home in this approach is fiber-connected directly back to a central hub, there are no unused ports on the OLT card and 100% efficiency is achieved. This also allows a much wider physical distribution of the OLT ports – extremely important when initial take rates are projected to be low to moderate.

A cascaded splitter approach requires dedicating 32 fibers from a single 1x4 or 1x8 configuration back to the central office. This requires homes to be in the same physical vicinity because they must tap into access terminals that are linked together. Without a very high service take rate, many of these fibers or ports could be stranded. This approach absolutely requires a guarantee of high take rates in order to efficiently use every OLT port.

For example, let's look at a typical 128-home neighborhood. Service to each home would require the purchase of four PON cards and all the necessary splitters to ensure service through the cascaded and dedicated 1x4 or 1x8 splitters. However, a centralized 1x32 splitter approach would provide services with a single PON card and one splitter to the first 32 homes, regardless of their physical location. As revenue is generated and more homes desire service, an additional PON card can be purchased to add each additional 32 homes as the system grows, with no stranded, unused fiber runs. When this method is scaled to many new greenfield or city overbuilds with hundreds or thousands of homes passed, it's easy to see the economical differences between the two methods, particularly in terms of additional PON card requirements of a cascaded system.

Even if a service provider is expecting take rates of 90% or higher, that rate may not be fully realized for several years. By delaying the capital purchased until additional customers subscribe, the service provider can save money. Even in a greenfield deployment anticipating a 100% take rate, there are considerations to keep in mind before choosing a cascaded approach, even though it works best in high take rate situations.

For example, MSOs might be building that same subdivision to offer voice services, diluting the take rate figure to something less than 100%.

Additionally, if the subdivision is built over a period of several years, there could be a wide diversity of take rate times as houses are actually built and occupied many months apart. If this is the case, some ports could be stranded as much as a year or more, tying up capital that could be better spent elsewhere in the project.

Network Testing Ability

The second benefit of a centralized splitter approach is its ability to provide easy testing and troubleshooting access. It is very difficult to use an optical time-domain reflectometer (OTDR) to test multiple splitters unless the network is built with each fiber characterized to enable the OTDR to recognize each individual fiber run. From a centralized point, it's nearly impossible to "see" down individual fiber lengths through a series of splitters.

A centralized splitter configuration, on the other hand, provides one centralized hub for truck rolls to troubleshoot instead of two or more. Another benefit is in terms of overall network management. All the splitters are in one central location for easy access by maintenance technicians faced with such tasks as locating a cable break or dealing with a fiber macrobend issue.

There are three basic tests performed prior to qualification of an OSP network: end-to-end link or insertion loss; optical return loss (ORL); and link mapping or characterization via OTDR trace development. These tests require certain network features for adequate data collection, including a well-defined path that can be measured with an OTDR and connector interfaces for link loss and ORL.

The centralized 1x32 splitter with distribution ports enables OTDR trace development upstream to the central office and downstream to the access terminal. Also, the connector ports available at the distribution hub enable qualification testing of the distribution cabling during turn-up of each FTTP customer. This provides test results from the hub through to the ONT at turn-up, rather than during the initial cascaded splitter deployment that may have been accomplished months earlier.

Splitter Signal Loss

Each time an optical signal encounters a network component or connection, such as a splitter, it suffers a certain degree of signal loss. Therefore, when splitters are cascaded together, loss will occur at each device. The combined loss effect can reduce the distance a signal can travel, imposing distance limitations on fiber runs. The centralized splitter minimizes that signal loss by eliminating extra splices and/or connectors from the distribution network.

More importantly, each manufactured splitter has its own variability, both port-to-port variability and variability-over-wavelength. This characteristic is also referred to as "uniformity." When cascading multiple splitters together, the uniformity of each splitter must be added together, negatively impacting the system with a much larger overall uniformity. Tolerance stack-up issues also impact the cascaded splitter approach, similar to the stack-up issues related to mechanical assemblies. In a centralized approach, however, these uniformity issues can be controlled during one manufacturing process.

Take Rate and Cable Cost

The service take rates are always a consideration in choosing network architectures. It may be argued that in a high take rate area, a cascaded splitter approach may make more sense. In this case, there would be no requirement to have a wider reach and OLT cards could be used efficiently. However, the savings on cabling costs may not outweigh the benefits of easier testing, more flexibility, and lower signal loss.

Another argument for cascaded splitters deals with the benefit of saving money by using less fiber and lower fiber-count cabling. The lower cost of today's fiber-optic cable has lessened this argument somewhat, but each deployment is different and, again, more importance will likely be placed on take rate. However, distribution cable costs are normally lower for cascaded architectures – but the question must still be whether or not to forfeit the benefits of easier troubleshooting, lower signal loss, and overall flexibility of the distribution network.

Cascaded splitter architectures, in certain situations, may have merit. By using different split ratios, for example, fiber runs can travel various distances from the same splitter. If a signal is initially split 1x4 with three or four customers separated by considerable distances, the next split could be another 1x4 rather than a 1x8 – potentially buying several kilometers of distance while only reducing the number of supported homes from that particular PON card to 28.

The centralized approach would require a 1x16 splitter rather than a 1x32 to reach those customers, reducing the number of customers served to 16 on that particular PON card. Record keeping should be considered as well, since multiple split patterns and multiple architectures in the same network make this task much more difficult.

In summary, a cascaded splitter approach can make sense in some applications, particularly when high take rates are certain or in extremely rural areas where fiber costs become more of a factor. However, careful consideration must be taken in light of the many benefits offered by a 1x32 centralized approach, particularly its flexibility, ease of testing, and overall cost efficiencies in many applications.

Chapter 4

Central Office Implications for Deploying FTTP

The successful deployment of any flexible, cost-effective FTTP network requires thoughtful decisions regarding all segments of the network, from the optical line terminal (OLT) in the central office to the optical network terminal (ONT) attached to each home and everything in between. While much attention is focused on the distribution and access elements within the outside plant (OSP) network, it's also important to consider the implications of FTTP architectures within the central office (CO).

Probably the biggest mistake any carrier can make is believing that an FTTP network does not require the same flexibility as a transport network. However, a mindset that the FTTP network does not require the same level of access, flexibility, and protection given to other aspects of the network is too often the case when network planners are first looking at deploying an FTTP network. In reality, however, FTTP architectures pose significant implications for the CO in meeting the same levels of performance required for transport segments.

First up – architecture decisions

Before specific product selections can be made, some critical network architecture decisions are necessary. These key decisions involve connection strategies, flexibility in terms of test access points, and WDM positioning. Deciding on a CO network architecture for FTTP networks requires the planner to perform a balancing act. The goal in any network is to minimize capital expenses and long-term operational expenses, while achieving the highest possible levels of flexibility within the network. The basic function of an FTTP network in the central office is to connect the OLT equipment to the OSP fibers, deploying WDM somewhere in the middle to enable voice and data signals to be combined with video signals.

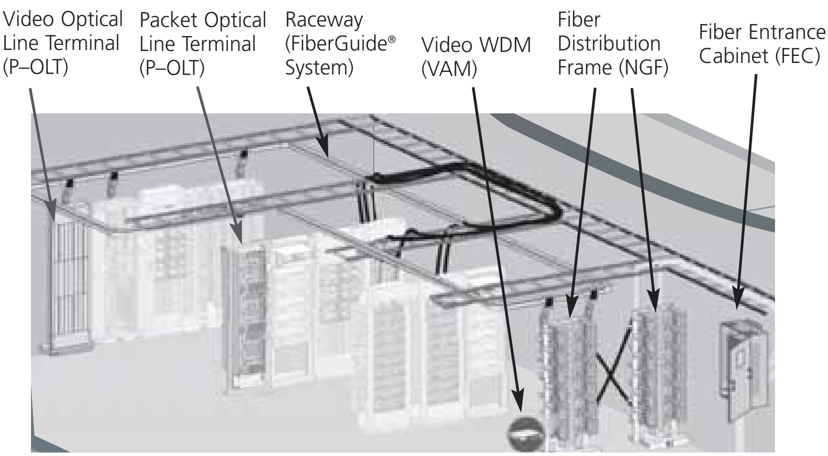


Figure 4.1 Central Office FTTX Architecture

While every carrier's goal is to reduce capital expenses, particularly in new network deployments, sacrificing flexibility and increasing operational expense should not be the cost of achieving that goal. Since equipment cost in any optical network is directly related to the number of connector interfaces, one way to reduce capital expenditures is to eliminate or minimize the number if optical connector interfaces wherever possible. Proper placement of connector interfaces in the CO environment will also greatly lower operational expenses involved with service turn-up and network reconfiguration.

The one constant in telecommunications has always been change – and even though the current network build-out may be designed specifically for FTTP, its adaptability to change should be a key issue for the network planner. Assuming that none of the fibers in the OSP cable used for FTTP will ever be used for anything other than FTTP could be a costly mistake. If a business customer along the route of the cable orders a service requiring an OC-3 line, a carrier would want to use available fiber in the existing optical cable rather than bury new fiber. Maintaining flexible access to and use of the OSP network in the CO will be critical for long-term operations.

The traditional crossconnect architecture in a CO is a well-established connection strategy for providing the best network flexibility while minimizing operational expenses. In the crossconnect environment, all OLT fibers, as well as all OSP fibers, are terminated to the rear side of a fiber distribution frame (FDF). The OLTs are connected to their appropriate OSP fibers via fiber patch cords routed on the front of the FDF. The front of the FDF provides flexible, easily-accessible interface to all equipment using the individual patchcords. This strategy enables significant long-term network flexibility, allowing easy adds, moves, and/or changes at the FDF.

FTTP networks must have similar architectural strategies. The assumption that an FTTP network will remain static and can, therefore, be hard spliced or direct connected to save short-term capital expenditures is flawed. In reality, this mindset will result in significant long-term operational expense and flexibility issues. Therefore, the traditional crossconnect architecture will still allow the most flexible use of OSP fibers deployed in an FTTP network and enable the easiest implementation of OLT equipment changes.

WDM location

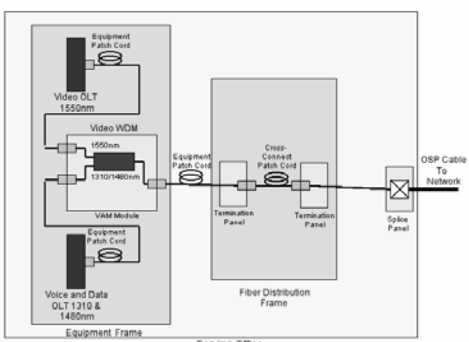
Another very critical architectural decision is where to place the video WDM (Wavelength Division Multiplexer). In an FTTP network, a video WDM is used to combine voice/data signals with video signals onto a single fiber. This is necessary since most FTTP networks today use a single fiber to each subscriber for "triple play" voice, video and data services. Since the OLTs for voice and data differ from those used for video services, the signals must be combined onto the single fiber at some point in the CO.

The placement of this WDM has a significant impact on the network CAPEX/OPEX ratio and flexibility issues. Assuming a crossconnect architecture is agreed on, there are two basic choices for video WDM placement. The first scenario is to position the video WDM at the OLT equipment frame; the second involves placing it within the FDF.

Placing the video WDM at the OLT terminal appears logical at first, but further investigation shows it will actually create more expense in the network, both initially and in the long term. The diagram below shows why this option soon becomes a very unattractive proposition.

As shown, the video WDM would be placed in a panel in the same frame as the OLT equipment. A patch cord connects the OLT equipment to the inputs of the video WDM. The common port on the video WDM is, in turn, connected to the back side of the equipment FDF, where a cross-connect patchcord connects OLT ports to the designated OSP ports. The obvious advantage is the need for only one patch cord running from the OLT frame to the FDF for every PON circuit.

Figure 4.2 Potential Central Office Fiber Management System Layout

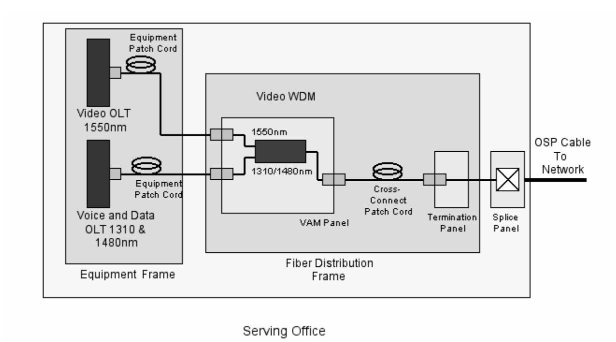


However, the downside to this architecture is that four connector pairs are required and network flexibility is greatly reduced. One critical assumption required for this strategy is that the voice/data OLT will be located very close to the video OLT associated with it. While this may seem easy in a field trial or small roll-out scenario, full-scale FTTP deployment may prove otherwise. The video WDM must be placed in a location that provides any voice/data OLT easy connectivity to any video OLT, regardless of its location in the CO.

A better approach to placing the video WDM at the OLT frame is to place it in the FDF line-up. This method offers many advantages to an FTTP network. Placing the video WDM in the crossconnect FDF line-up in the equipment frame provides the lowest overall cost, the minimum number of optical connectors and the greatest amount of network flexibility, as shown below.

In the above scenario, the video WDM is placed in the equipment frame in the FDF line-up. Patch cords connect the OLT equipment to the inputs of the video WDM. A crossconnect patch cord is used to connect the video WDM common port to the designated OSP port. There is an immediate advantage of requiring only three connector pairs while maintaining maximum flexibility.

Figure 4.3
Ideal Central Office Fiber Management System Layout



Since the video WDM is located at the FDF and all OLT patch cords are routed directly to the FDF, greater flexibility is provided regarding how the OLTs are combined and configured. Any OLT can be easily combined with any other OLT, regardless of its location in the CO. Now that the architecture decisions have been addressed, the connectivity product selection can begin.

A look at the numbers

Before any true fiber connectivity product selection can occur, network planners must carefully consider the numbers involved with full-scale FTTP deployment. As discussed previously and outlined below, planning the network layout and product selections must be based on long-term needs rather than initial deployment numbers.

Consider the number of OLTs:

- Current and future possibilities
- 3200 homes passed will require at least 100 WDMs, more likely 120 or more
- Plan ahead by reserving floor space for future expansions or fewer homes per OLT

Considering incoming OSP fiber counts:

- OSP cable should be sized to meet future demands
- 3200 homes passed requires at least 100 fibers back to the CO, with up to 432 more likely depending on network strategy
- OSP cable fiber counts will be overbuilt to ensure future capacity requirements can be met without installing additional fiber
- Non-FTTP-related services on the cable

The incoming OSP cables used for the FTTP network will have large fiber counts for accessing as many homes as possible. Since a major expense to any network is burying the OSP cable in the ground, any OSP cable installed should be sized for future service needs. For instance, reaching a neighborhood of 3200 homes, an OSP cable would minimally require 100 fibers (1 per 32 homes) based on full utilization of the 1x32 optical splitters used in the OSP distribution cabinets. However, considering take rates, spare fibers, splitter usage, future service offerings, distance from C/O and other unknowns, the number of fibers in the OSP cable would more likely end up being closer to 1 per 8 homes.

Also, these OSP cables will likely pass several other areas, including businesses, providing even more opportunities over the same cable being used for the FTTP network. Potential business customers that can be serviced over the same cable cannot be overlooked. Therefore, back in the CO, each fiber needs to be easily accessible by all areas of the network – not just the FTTP-designated equipment. Additional flexibility, built into the central office, will enable the carrier to get the most out of the fiber, including the ability to use the same fiber to take advantage of any non-FTTP service opportunities that may arise.

Due to the large potential fiber counts in the CO and floor space availability issues, FTTP networks will require high-density fiber distribution frames that enable the maximum number of terminations available in the least amount of space possible. While a high-density FDF system may be important for reducing physical space required for FTTP deployments, the density gain cannot be achieved at the sacrifice of fiber cable management within the frame.

Critical cable management

Any high-density fiber distribution frame must be functionally designed to accommodate the large number of incoming fibers and the maximum number of terminations associated with FTTP infrastructure – not simply a standard frame with more terminations added. Also worth mentioning is that unlike traditional OSP networks, FTTP networks are not protected – there is no diverse path to provide network redundancy in the event of a major outage. This fact changes the way services are provided and maintenance is accomplished within the CO for FTTP architectures.

For example, typical service outage windows may not be available for performing maintenance in an FTTP network. Rather, because there is just one link per customer, technicians may delve into the network any time of day to do required maintenance. This makes easy accessibility a critical attribute for servicing or reconfiguring the FTTP network with minimal impact on adjacent networks.

Creating a high-density FDF – defined as 1440 or more terminations – is technically very easy. Creating a functional high-density FDF with good cable management features that enables technicians to quickly and efficiently turn-up, test, and reconfigure the network is more complicated.

Telcordia's GR-449-CORE, Issue 2, July 2003, Generic Requirements and Design Considerations for Fiber Distribution Frames, contains design guidelines and test requirements for high-density FDF systems. These requirements help ensure proper functionality and performance of a high-density FDF system in a high fiber-count network.

There are four key aspects of cable management to consider when evaluating any FDF or panel product: bend radius protection, connector access, cable routing paths, and physical protection.

Bend radius protection – Proper bend radius protection as defined in Telcordia GR-449-CORE, Issue 2, requires all bends made by a fiber within the network to be protected with a radius of 1.5-inches or 10 times the outside diameter (OD) of the cable, whichever is greater. This protection is critical to ensure long-term optical performance and the ability to support future high-speed services.

Connector access – Physical connector access is very difficult to achieve in a high-density frame. The system must be designed to allow tool-less access to front and rear connectors without disturbing adjacent fibers or connectors. Easy front and rear connector access is needed for service turn-up and connector cleaning – very critical to an FTTP network, since much of the access for turn-up and troubleshooting will occur during normal business hours. Telcordia GR-449-CORE, Issue 2, provides testing requirements at OC-768 transmission rates to ensure a system provides good connector access without interfering with adjacent circuits.

Cable routing paths – Cable routing paths within any FDF-related system must be clear and easy to follow. The quality of the cable routing paths within the system will be the difference between congested chaos and neatly routed, easily accessed patch cords. In high-density FDF systems, the need to easily follow cable routing paths is magnified due to the large number of fibers present. Telcordia GR-449-CORE, Issue 2 also provides design and test requirements to validate the quality of the cable routing paths within a fiber distribution frame system.

Physical safety – Laser safety must also be a concern in FTTP networks, since high-power lasers used in the analog video OLT can be potentially harmful to technicians. Since infrared lasers are not visible to the human eye, it's important to take precautions when exposure is possible. Fiber distribution frames need to have built-in laser eye safety features, ensuring connectors don't point directly at technicians minimizing the possibility of exposure to high power laser radiation. Designs that have connector ports contained within a tray or other enclosure and pointing side-to-side, rather than straight out of the panel, help protect technicians, regardless of their level of training or awareness.

Figure 4.4 ADC FDF Equipment

Success in the CO

It cannot be overstated that FTTP networks require similar if not more stringent cable management attributes as any OSP network that comes into the CO. Flexibility and accessibility are particularly important since, although FTTP may be the application of the day, non-FTTP applications cannot be overlooked as additional revenue sources over the same fiber.

Carriers are beginning to realize the full potential of FTTP networks and are embracing the fact that changes are imminent. Whatever is done today will be done differently tomorrow. Designing FTTP networks with proper care and planning will provide added benefits to the carriers -- maximum efficiency, easy access, high flexibility, and lower cost.

Chapter 5

Splicing vs. Connectorization in FTTP Networking

Deploying a successful FTTP network requires careful planning and execution. Taking FTTP networks from the lab/field trial mode to full-scale network deployment presents many significant challenges for service providers. One of these challenges is deploying the network for the lowest possible cost, while creating a fiber network infrastructure that has the flexibility and reliability to last long into the future.

When network visionaries first began looking at deploying FTTP networks, they were focused on a fiber network that was all spliced. That is, every junction in the fiber network from the CO to the subscriber was made via an optical splice. At the time, the primary justifications for this mindset were cost and concerns regarding the reliability of optical connectors in OSP environments. While splicing the entire OSP fiber network is going to provide the lowest initial equipment cost, the reality is that those cost savings will quickly be lost to increased operational expenses and reduced network flexibility. The use of fiber connectors inside the CO for connecting fiber network elements has long been standard practice. Service providers around the world have realized the value that connector interface points provide in the network when it comes to troubleshooting the network, re-configuring the network, and turning up services. Similar benefits can be realized in the OSP portion of an FTTP network when connectors are properly placed.

Let's take a look at a general FTTP fiber network architecture outside the central office (see Figure 5.1). The network consists of feeder cables routing to a fiber distribution hub (FDT) where the optical splitters are housed. From the FDT, a distribution cable will route to the access terminal (FAT) where the drop cables will tie in. From the FAT, the drop cable will route to the optical network terminal (ONT) at the subscriber premises. Throughout this network, there will be many locations where fibers will need to be joined together. Along the feeder and distribution cable runs, where an in-line splice is normally used, that would still be the case. The locations that are of interest for optical connectors are at the FDT, the FAT and the ONT. What we are looking for is locations where technicians will need to go on a more regular basis to test, turn-up, and re-configure services. These are locations where having a connector interface will provide significant operational cost and time savings advantages over fusion splices.

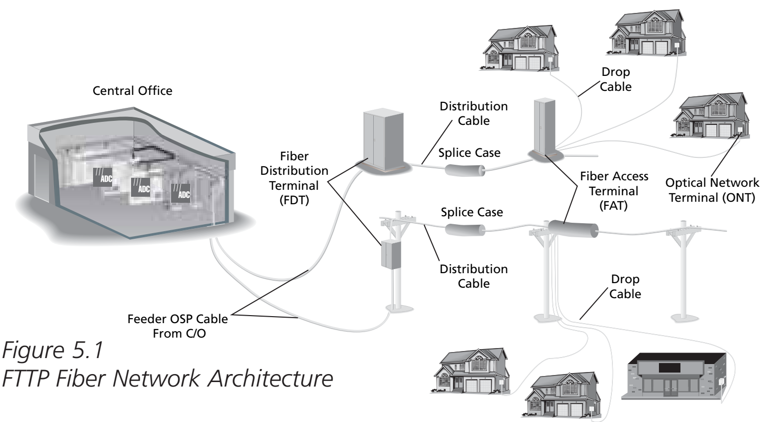


Figure 5.1
FTTP Fiber Network Architecture

Easier Test Access

The first consideration for replacing a splice with connectors is the need for test access points. Fault isolation in an FTTP network presents new challenges for a service provider. Typically, fault isolation in a fiber network involves using an optical time domain reflectometer (OTDR). The

OTDR trace will tell a technician where the fault is located within the fiber network. There are two key challenges that FTTP networks pose to technicians when it comes to fiber fault isolation. The first involves the 1x32 optical splitters that are used to minimize the number of optical line terminals (OLT's) used in the central office. OTDR traces are difficult to decipher once the trace hits the 1x32 splitter in the FDT.

The second challenge involves accessing the fiber without taking up to 32 subscribers out of service to test a network when only one subscriber has a problem. In a scenario where more than one subscriber served by a splitter of FDT is reporting a problem, the problem is most likely somewhere between the OLT in the CO and the FAT in the field. In this case, accessing the fiber network inside the central office will provide a good look at the network from the OLT to the FDT. However, testing the network from the FDT to the subscriber will require a truck roll. This is the point where network design will have a significant impact on how quickly the problem can be isolated.

Putting the test access points at the ONT on each home requires a technician to tap into a network interface device at each individual residence. These interface points may not be easily or readily accessible. However, using the splitter output in the FDT as a centralized demarcation box provides a single location with test access to any fiber for multiple homes, thus allowing easy access to the network between the FDT and the ONT. In an application where the splitter is spliced into the network, a splice technician will have to be sent to the FDT location and break into the appropriate splice between the splitter output and the distribution cable, connecting the OTDR launch cable with a bare fiber adapter or temporary splicing in a pigtail. Once the trace is done, the technician has to then re-splice the splitter output to the distribution fiber. This process can be very time consuming and costly as splice technicians and their equipment are billed at a higher rate than other technicians.

This procedure also poses a significant danger to the network. The process of accessing the distribution fiber to run an OTDR trace requires the technician to manipulate several fibers and break the fibers that are to be tested. The fibers then need to be spliced back together. This process will shorten the lengths of fiber available and there is a risk of breaking the fiber to a length that is too short to work with, thus stranding some of the network's capacity. With the additional time, cost, and risk to the fiber required to test from this particular location, a spliced connection simply doesn't make the most sense.

With a connector interface placed at the splitter output, easy test access is achieved for all of the distribution cables. In this case, test access is just 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 done, the launch cable is disconnected from the distribution port and the splitter output pigtail is re-connected. In this procedure, no fibers are broken and no splicing is required. Also, in this application, since all of the splitter output fibers are connected to a bulkhead they are protected with jacketing that prevents them from being damaged during normal handling. Connector pairs in the FDT enable easier, less time-consuming testing, as well as lower labor rate requirements and much less risk to the fiber network.

Faster Service Turn-up

Service turn-up is another area offering a benefit for using connectors rather than splices in certain locations of the network. There are two locations where connector interfaces provide service turn up advantages, at the FDT and the FAT. Splicing all the optical splitter outputs to the distribution cables and the distribution cable to the drop cables may seem to make sense in a greenfield application with a 100% expected take-rate. But the reality is that the homes will not be occupied from day one and service turn-ups will not occur all at once.

In a brownfield, or overlay, application with a take-rate of less than 100%, it makes sense to deploy splitters one at a time as needed and to have easy access to the distribution fibers for fast service turn-up. In a splicing scenario, a splice technician must be deployed on a regular basis to splice a single fiber in the FDT and FAT every time one customer requires service turn-up - an expensive proposition in terms of equipment, training, and manpower requirements. When connectorized interfaces are used at the FDT and FAT, service turn up is a much simpler process. Distribution fibers are simply plugged into the splitter output in the FDT and drop fibers are plugged into the distribution fibers in the FAT and service turn-up becomes as simple as mating two connectors.

Network Implications

As discussed, having connectors at certain locations in the OSP segment of the FTTP network is valuable, but having them at every location where fibers meet is not cost effective. Connectors should only be used at locations where they can add value to the network without adding additional cost or loss points. A major issue in using connectors, aside from more initial expense, is loss budget concerns.

There are three common architecture options for using connectors in the FDT field. The first is to provide a full crossconnect within the FDT. In this scenario, shown in Figure 5.2, the incoming feeder and distribution fibers are factory terminated and loaded to the rear ports on a bulkhead in the FDT. The 1x32 (or 1x16) splitter is also factory terminated with the input fiber connecting to the feeder fiber and the outputs connected to the rear ports on a bulkhead. The splitter output ports are then connected to any distribution fiber via a cross-connect patchcord.

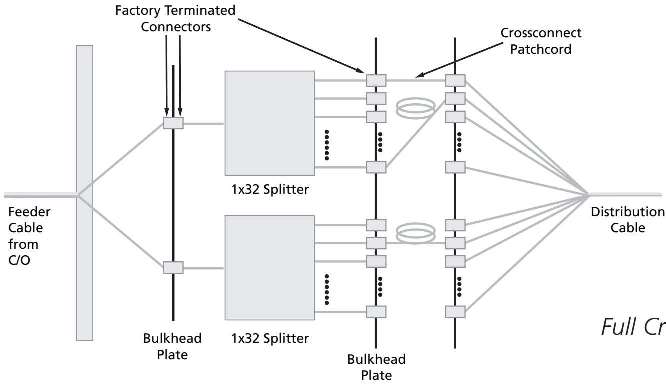


Figure 5.2
Full Cross-Connect
within FDT

In this application, the splitter modules are also added on an "as needed" basis simply by plugging the input and output connectors into the appropriate locations. Although this architecture offers the ultimate flexibility with completely accessible fibers, the downside is the added cost and the added signal loss of three connector pairs. The additional loss can be as much as .6 db in a FTTP network that may need to be stretched to its distance limit. The result could be up to 1-1/2 km of distance loss or a substantial number of unreachable homes. Therefore, although the full crossconnect adds substantial flexibility and protection for the optical splitters and OSP cables, it may not justify the cost - both in dollars and db loss.

An alternative architecture solution would be to use pigtails at the optical splitter output to connect directly to the distribution fiber ports. In this case, the optical splitters are loaded into the FDT on an as-needed basis. The 32 output ports from each splitter are put into a "parking lot" configuration within the cabinet. In the parking lot, connectors are protected with dust caps until being assigned to distribution fibers on demand. a service order is issues, the technician simply goes to the cabinet and accesses the next available splitter output port and plugs it into the distribution fiber port - turning up service by simply mating a pair of connectors. In this scenario, the optical splitters are still added as needed, minimizing up front equipment costs and maximizing OLT usage efficiency.

This scenario provides ample flexibility and the up-jacketing provided on the splitter out-put ports provides considerable protection from damage during routing. An optimum balance is provided between cost and operational efficiency by using just two connector pairs, thus lowering cost and db loss.

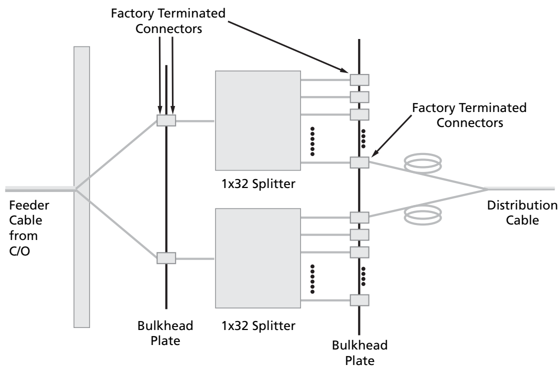


Figure 5.3
Pigtails at Optical Splitter Output

A third scenario deals with high power required by the video signal to drive the receivers at the customer premises. The analog video signal leaves the central office with relatively high power and reaches the splitter in the FDT with a power level around 20dBm. This high power level at the splitter input port can create a potential laser eye safety issue for technicians. Therefore, the decision is whether or not to have a connectorized interface at the splitter input.

In order to eliminate this potential safety issue from the network, the input to the optical splitter could be spliced. Although less flexible than the two connector pair scenario, this architecture would still have a connectorized splitter output for easier test access and on-demand service turn-up at the distribution end. This scenario reduces cost, lowers db loss, and eliminates the high power laser safety issues. However, it still requires a splice technician to be present to add splitters to the FDT, mitigating some of the sought-after cost savings.

Long-term Performance

The goal in any network is to achieve the right balance between up-front initial equipment costs and the operational costs involved in long-term performance of the network. Connectors are always more expensive than a splice in terms of initial equipment costs. However, network planners must look ahead to operational costs for service turn-up to individual customers and easy test access. Using connectors where they make the most sense in the network justifies the initial equipment costs by saving operational expenses over the life of the network.

Vast improvements have taken place in fiber-optic connectors over the years that have improved their performance in the network. Higher performance standards and manufacturing improvements have resulted in lower insertion and return loss, automated tuning, superior endface workmanship, and vastly improved factory termination methods.

Several studies on connector performance have been done over the years and Telcordia GR-326-CORE addresses connector performance requirements in OSP applications. ADC put its connectors to the ultimate test back in 1995. On a rooftop in Minneapolis, Minnesota, a series of fiber connectors were exposed to the harsh Minnesota climate for five years. Enduring temperatures ranging from -43 degrees F to 137 degrees F, each connector was automatically performance-tested every hour. Despite the severe extremes in weather observed in Minnesota, the connectors performed within the manufacturer specifications through the duration of the test. Over the years, technical design and manufacturing improvements have been made on optical connectors to ensure that they will continue to perform reliably in a wide variety of environments.

Today's next generation connectors have a proven track record for successful deployment in OSP applications. In a more competitive business environment, there is little margin for error when deciding to splice or connectorize the FTTP network. Although the majority of connections will still be spliced together, replacing some of those splices or interfaces with connector pairs will provide additional flexibility and test access - and improve turn-up time to the customer. Superior long-term network performance is achievable for the FTTP network that deploys connectors where they make the most sense. The sensible use of connectors will result in optimal performance while providing cost and flexibility benefits that cannot be attained through splicing alone.

Chapter 6

Dramatic Attenuation in Fiber Access Terminals at Low Temperatures

Attenuation is common in applications where access terminals are used to terminate only a portion of the fibers brought into the enclosure while allowing the remainder of the fibers to pass through. When loose tube cable is used, the sub-units that are not terminated are "expressed" through, and the sub-unit material is not opened at any point. To provide customers with adequate sub-unit length for splicing under all conditions, ADC specifies a mid-span access length of 150" to 170". Testing of the enclosure with expressed sub-units of this length alerted ADC to potential low temperature issues.

While there are no written standards governing this application, ADC has concluded that in some cases, loose tube OSP cable (dielectric or armored) can experience excessive attenuation loss at low temperatures (0˚C to -40˚C). Subsequent research also reveals that the issue becomes more severe for cables exposed to initially high temperatures (greater than 50˚C) prior to their exposure to low temperatures. Attenuation loss can be as high as 10 to 20 dB in extreme cases.

After identifying the problem, ADC proactively began researching the probable cause and discovered information from a 1998 Bellcore (now Telcordia) white paper that outlined similar problems with certain fibers in varying temperature environments. The paper, entitled "Time- and Temperature-Dependent Material Behavior and Its Impact on Low-Temperature Performance of Fiber Optic Cables," by Osman S. Gebizlioglu, seemed to address the very issue ADC was observing in several of its own case studies.

According to the paper, "a series of service-affecting field failures in cold weather (-40 degrees C to 0 degrees C) initially and in more moderate conditions (up to 15 degrees C) recently have raised concerns about the temperature-dependent transmission performance of loose tube fiber optic cables." The effect was transmission loss "resulting from fiber microbending due to random fiber contacts with the buffer tube walls caused by the axial shrinkage of the buffer tubes relative to the cable central member."

With Bellcore's previous research confirming ADC's own data, engineers set out to pinpoint and formulate a preventative process for dealing with the issue in the field.

Problem Solved

Believing that the contraction of the sub-unit could be pulling the fiber and causing microbends, ADC set out to test the theory. Choosing a sub-unit that was exhibiting high attenuation loss at low temperature, they stripped the sub-unit material off the entire mid-span access area. The goal was to eliminate the clamps and panels as being part of the problem. After stripping the mid-span section, the attenuation disappeared - thus isolating the problem to the fiber sub-unit alone.

Although this, in itself, provided a potential field solution–stripping the entire length of sub-unit material was both labor-intensive and risky to the fiber. As a result, ADC set out to establish a craft-friendly procedure that would simplify the solution to the problem.

Using a typical fiber cutting tool to apply "ring cuts" to the buffer tubes that are expressed through the cabinet, the same end result is possible. The ring cut is a radial cut through the sub-unit wall without removing material. For the mid-span length required in the ADC access terminal, three ring cuts are applied - one at the entrance point, one at the exit point, and one in the center of the slack loop in the mid-span access. Each ring cut is then protected by sliding a protective sleeve over the cut that is about three inches in length. Finally, a small metal "carrier" provides a method of bundling up to six of the protective tubes together and securing them to the sides of the enclosure panel. This prevents movement during any future maintenance activity.

Final Notes

Ribbon cable is not susceptible to the same low temperature attenuation issue since the ribbon strands are completely removed from the center tube for accessing individual fibers. Rather, the issue appears to be isolated to specific types of loose tube fibers, depending on each manufacturer's own specifications.

The major variables from manufacturer to manufacturer include the sub-unit material, the sub-unit dimensions (specifically the inner and outer diameters), the type of gel used, and the amount of extra fiber within a sub-unit length. Any or all of these variables can present different effects in terms of this attenuation issue.

References
O.S. Gebizlioglu, "Time- and Temperature-Dependent Material Behavior and Its Impact on Low-Temperature Performance of Fiber Optic Cables." (1998)

Chapter 7
Challenges of Deploying APCs

PON infrastructures deployed in FTTP networks require numerous fiber connections to achieve the distribution of services to multiple homes. Although splicing has its place in these systems, use of reliable angle-polished connectors (APCs) provides numerous advantages in terms of overall network flexibility, testing and troubleshooting.

Fiber-optic connector return-loss performance is dependent on maintaining good physical contact between the fiber core endfaces. Any air gap created between the fiber cores causes significant reflectance and degrades connector performance. The endface geometry on APC connectors, however, has traditionally been difficult for manufacturers to control since it is dependent on the outcome of the endface polishing process and requires very tight tolerances in the manufacturing process.

Endface geometry's big three

Controlling each of the "big three" – radius of curvature, apex offset, and fiber recess – is critical to ensuring core-to-core contact is maintained under all operating conditions for both inside and outside plant environments.
Radius of curvature is the curvature of the ferrule endface measured immediately around the fiber core. The apex offset is defined as the offset distance between the fiber core axis and the apex of the radius of curvature. This measurement is critical to the performance of APC connectors to ensure glass-to-glass contact is maintained. Preventing ferrule rotation within the connector is the key to achieving consistently optimal contact. Fiber height is the distance between the fer-

rule surface and the fiber end. Positive fiber height is often referred to as fiber protrusion, while negative fiber height is referred to as fiber undercut.

During connector mating, a compression of the ferrule ends occurs, creating a deformation that enables even two undercut fibers to achieve core-to-core contact. Manufacturers must control each endface geometry parameter to prevent performance degradation within the connection due to poor contact. For example, if the two fiber cores do not make physical contact, poor reflectance performance occurs.

ADC adheres to the following tolerances on endface geometry for its connectors (SC and FC):

- Endface radius of curvature – minimum 5.0 mm; maximum 12.0 mm
- Apex offset – minimum 0.0 microns; maximum 50.0 microns
- Fiber height – minimum -50.0 nm; maximum 50.0 nm

ADC developed the polishing process for the singlemode connector using Six Sigma techniques. The results of this study enabled ADC to achieve excellent process capability for the three main endface geometry attributes. In this study, the key inputs and outputs for each processing step were clearly defined and documented. The outcome was a very robust, cost effective, easily transferable, patent-pending process.

Preventing ferrule rotation

The key to gaining a technical and competitive advantage for connector reliability is ADC's anti-rotational features contained in its APC SC and LX.5 connectors. Changing and inconsistent interfaces that allow ferrule rotation about the ferrule axis have the potential to create air gaps between the mated pair fiber cores, resulting in service that significantly degraded, if not interrupted.

A small ferrule rotation can change the apex offset of an APC connector by an unacceptable amount. Therefore, it is critical that the connector be designed to minimize this rotation while the connector is in service. Any air gap created by a large apex offset will increase insertion loss and reflectance, so keeping apex offsets as low as possible is a critical issue for high-performance connectors.

Several industry standards address acceptable specifications for apex offset in APC connector endface geometry. The predominant standard is IEC-60874-14-10 which defines apex offset to be less than 50 microns in APC connectors. Likewise, the Telcordia GR-326, Issue 3, also specifies a 50-micron maximum apex offset. A 50-micron apex offset, when combined with the radius and undercut requirements of these two documents, will achieve the required glass-to-glass physical contact in austere environmental conditions.

How does apex offset positioning occur?

First, the apex offset position is set during the polishing process. Generally speaking, ferrules have a chamfer around the endface that is symmetric with the axis of the ferrule. However, when polished at eight degrees, the apex of the polished area changes with respect to the fiber core. As more material is removed in polish, the surface of the endface becomes relatively larger on one side, moving the center of the ferrule endface to one side and away from the ferrule axis.

The peak, or apex, of this radius will generally be at the center of the surface being polished, and the distance between the center of the fiber and the center of the spherical surface being polished is the apex offset. As this peak drifts away from the ferrule axis when more material is removed, the apex offset increases.

Second, APC SC connectors are designed to enable the ferrule to float within the connector housing. This float is necessary because the ferrule is spring-loaded towards the front of the connector to ensure proper mating. The downside is that the float can allow the ferrule to rotate about the axis of the ferrule and with respect to the connector key. Even the tiniest rotation can lead to poor apex offset – to a point where physical contact of the fiber cores cannot be guaranteed.

The ferrule rotation within the connector can occur while the connector is in service. For example, when the connector is cleaned, a force could be applied that causes the ferrule to rotate. Also, multiple matings can cause the ferrule to rotate within the connector. Both occurrences will lead to increased apex offsets that can cause a loss of physical contact in APC SC connectors.

Forcing the ferrule back

ADC has developed low-rotation APC SC connectors that correct ferrule rotation. These connectors include features that force the ferrule back into its original position if the ferrule is rotated either clockwise or counterclockwise within the housing.

Forcing the connector ferrules back to their original position (the position in which they were originally polished) following any rotation guarantees that apex measurements will be maintained throughout the life of the connector. ADC's APC SC connectors have several patented internal features that force the ferrule into the original non-rotated position when not mated. Without permanent rotation, the connectors can be mated and remated – still guaranteeing good apex offsets and physical contact because the ferrule cannot remain in a rotated state.

Chapter 8

Enhancing Angle-Polished Connector (APC) Performance in the Outside Plant

FTTP architectures, by their very nature, require numerous fiber connections for distribution of services to multiple home and business locations. Much of the connectorization takes place downstream from the CO in the OSP portion of the network, traditionally a splice-only environment. However, as providers realize the cost-saving benefits – ease of testing/troubleshooting, simpler network reconfiguration, faster service turn-up – the need for higher performance of angle-polished connectors (APCs) in the OSP environment has become a critical FTTP issue.

ADC has made great strides in enhancing its design and manufacturing processes for APCs to provide customers with the highest level of connector performance in OSP applications. This new breed of connector meets the increased performance and reliability required by OSP portions of FTTP networks for offering triple play services to consumers.

OSP Connector Concerns

Until the relatively recent interest in FTTP architectures, no significant reasons dictated a need for APCs to push performance limits. However, the trend toward pushing fiber all the way to the customer premises has resulted in a need for high-performance APCs that can withstand the rigors associated with OSP implementation.

The sheer volume of OSP connectorization driven by FTTP presents a challenge to APC connector manufacturers. For example, a typical FTTP infrastructure may contain five connector pairs between the central office and the home. As an example, with a service take rate of just 5000 homes, the installation could require as many as 50,000 connectors. Ramping up the manufacturing process for these connectors – keeping in mind the added robustness required for OSP use – is critical for manufacturers. ADC is meeting the unique challenges of producing APCs for the OSP that are both cost effective and can perform to the highest industry standards. These standards include minimizing loss budgets and reliability issues, such as endface geometry.

Minimizing Loss Budgets

Insertion loss and return loss are major concerns when building an FTTP network, mainly due to the numerous connections required to route services from the CO to multiple locations. Insertion loss is the amount of light lost as transmissions traverse the optical fiber. Return loss is the amount of light reflected back towards the source. Both are critical to the overall performance of any optical network, but particularly critical in FTTP architectures that require multiple loss-contributing components.

Connectors are the third largest of these loss contributors – particularly when deployed in an OSP environment – due to additional allowance for loss variation under environmental extremes. As an example, connectors that are optimized through processes, such as tuning and design parameters for the ferrule, can achieve as low as 0.1 dB maximum initial loss. These connectors can reduce system loss by 0.3 dB for the central office connections (0.1 dB per connection for three connections).

In the OSP, connectors with 0.1 dB initial loss that can meet insertion loss change of 0.2 dB over environmental extremes are commercially available that could save 1 dB (0.2 dB per connection for five connections). Connectors are available in many styles and with either angled physical contact or non-angled physical contact. Losses are not significantly different between the two types, but costs for the angled physical contact connector can be much higher. The chief advantage over the non-angled physical contact connector is the improved return loss performance that results from the angled polish.

A tuning process improves insertion loss by improving the alignment of the fiber cores in mated pairs. The accuracy of the tuning process has a direct affect on randomly inter-mated connector performance and is improved through automated processes. Combined with consistent and precise endface geometry, a higher level of optical performance over time in an OSP environment can be achieved.

Return loss, caused by changes in the index of refraction, is also associated with each mated connector pair and must be figured into the total loss budget. Higher manufacturing standards can greatly reduce loss budgets and, as a result, enable better performance over longer distances in FTTP networks.

APC-Specific Issues for OSP Deployment

There are a few specific concerns for achieving high performance for APCs in the OSP portion of an FTTP network. Improving endface geometry in APC connectors provides more consistent core-to-core contact under all operating conditions, including temperature swings, and provides a good seal to prevent debris from migrating to the core during operation. ADC provides improved endface geometry through a very repeatable high-quality manufacturing process.

ADC measures and provides data for each of the following measurements during the manufacturing process:

- Apex offset to < 50 microns
- Fiber recess to +/- 50 nanometers
- Radius of curvature to 10-25 milimeters

Apex offset measures the location of the "dome" produced during the polishing process. The dome locations must line up when mating to another connector, serving as the foundation for permitting core-to-core contact.

Fiber recess is important because when two extremely high, protruding fibers are mated, they induce stress on the fiber that can degrade performance over time. Likewise, two very recessed fibers may lose contact if the temperature or humidity changes, causing air gaps that result in significant reflectance.

Radius of curvature refers to the measure of how "flat" or "pointed" the shape of the endface becomes. It works in tandem with apex offset and fiber recess to ensure the two fiber cores come in proper contact – and remain in contact.

Preventing Ferrule Rotation

The key to gaining a technical and competitive advantage for connector reliability are the anti-rotational features designed into ADC's APC connectors. A small ferrule rotation can change the apex offset of an APC connector by an unacceptable amount. Therefore, it is critical that the connector be designed to minimize this rotation while the connector is in service. See Chapter 7 for more detail on the importance of preventing ferrule rotation.

Temperature Variation

Temperature, particularly cold temperatures and wide temperature variations, are directly related to insertion loss failures due to cable and cable assembly component shrinkage. ADC has designed its connector components to overcome this challenge to prevent shrinkage, and even fiber breakage, as a result of temperature in the OSP.

The environmental operating requirements for cable assemblies in the North American market are defined by industry standards. Telcordia GR-326, Issue 3, requires cable assemblies to be subjected to two one-week thermal cycle tests from -40 degrees C to +75 degrees C 21 times. Each temperature extreme is held for a minimum one-hour period, at which time the insertion loss and return loss are measured. To meet the GR-326 requirement, insertion loss cannot change more than 0.3dB at any time during the test. ADC's optical connectors meet the requirements of GR-326, Issue 3.

Results Are in the Testing

Independently certified test results to GR-326-CORE, Issue 3 are a critical component for ensuring connector performance in the OSP. The GR-326 test procedure has two rigorous components: 1) service life testing, which tests out-of box, mechanical and environmental sequences, and end-of-life measurements; and 2) reliability testing, which drills down to very specific single tests designed to kill a connector.

Because of this rigorous and comprehensive approach, a supplier indicating "built to the design specifications of GR-326" or "built to the intent of GR-326" is not good enough. Actual independently certified test results should always be required and the given vendor should explain those results in detail. ADC uses Underwriters Laboratories, Inc. (UL) for independent test certification and makes all results available upon inquiry. Service providers must choose a product that demonstrates superior mechanical and environmental performance – the FTTP network depends on it.

ADC connectors undergo stringent service life and reliability testing – and test results must be certifiable. Out-of-the-box samples are subjected to an entire suite of tests to measure insertion loss, return loss, and the parameters of apex offset. Mechanical and environmental testing includes multiple mating and unmating, thermal shock, temperature cycling, humidity exposure, and water immersion.

Finally, a factory process audit ensures consistency of product and performance across manufacturing facilities. Through extensive testing processes, ADC ensures its customers are deploying APCs specifically designed for the OSP portion of the FTTP network – providing long service life, reliability, durability, and the highest performance available.

Chapter 9

Challenges of Cold Temperatures on Outside Plant Cable Assemblies for FTTP

FTTP architectures are presenting new challenges and opportunities regarding the use of connectors in the OSP. At no other time have connectors been as necessary in OSP architectures – and they are destined to become even more prevalent in the days ahead as the FTTP networking market continues to gain momentum. Service providers competing for the FTTP market require the same flexibility in test access and the ability to provision that they have typically enjoyed in the central office. They need to scale service in a cost-effective manner.

Splicing is expensive and, since it is basically hard-wiring, it is not very flexible. Therefore, to achieve the flexibility required for FTTP networks, it simply makes sense to use connectors at several key points of the network architecture. So for the first time, network architects will be using more connectors – and cable assemblies with connectors attached – to gain the best flexibility for the OSP portions of their FTTP networks. This creates some significant challenges for connectors, particularly their effectiveness in harsher outside environments.

Connectors in the OSP

Meeting the unique challenges of FTTP requires the production of components that are cost effective, yet still perform to OSP standards under austere temperature conditions. In this chapter, ADC will address one important performance measurement issue for OSP cable assemblies – how well they can adapt to cold temperatures.

Insertion loss failures, for instance, are a direct result of cable and cable assembly component shrinkage due to low temperatures. If this shrinkage isn't somehow addressed in the manufacturing process, the optical fibers can eventually break. ADC assemblies are designed to overcome the challenges of low temperature effects and the associated problems. Through proven manufacturing techniques, these assemblies prevent shrinkage and the problems – including fiber breakage – that can otherwise result.

Recall from Chapter 8 that the environmental operating requirements for cable assemblies in the North American market are defined by industry standards. Telcordia GR-326, Issue 3, requires cable assemblies to be subjected to two one-week thermal cycle tests from -40 degrees C to +75 degrees C 21 times. Each temperature extreme is held for a minimum one-hour period, at which time the insertion loss and return loss are measured. To meet the GR-326 requirement, insertion loss cannot change more than 0.3dB at any time during the test. Telcordia GR-20 defines similar requirements for non-terminated OSP cable. The minimum operating environment in this standard is also -40 degrees C.

Cold Temperature Challenges

Exposing cable and cable assemblies to low temperatures is typically the most common cause of insertion loss failures in OSP architectures. Figure 9.1 shows a typical ribbon OSP cable assembly at normal temperatures. But as temperatures approach -40 degrees, the thermoplastic components in the cable breakout, jacketing, and fiber fanout sections will tend to shrink more than the optical fiber. These are the potential problem areas that will be addressed.

As temperatures drop to -40 degrees, the effect on the cable assembly becomes significant as it begins to shrink. The optical fiber in the cable, however, remains at its original length. This can cause the optical fiber to bunch up inside the temporarily shortened assembly, causing microbends and high insertion loss at 1550 nm.

The bends generally recover once the cable assembly is brought back to room temperature. This failure mode normally occurs in two places – the cable breakout (the point at which the ribbons break out of the OSP cable), and the fiber fanout (the point where the ribbons break out into individual fibers).

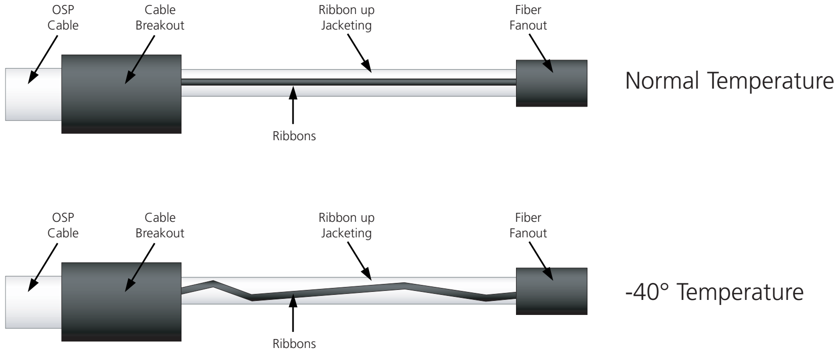


Figure 9.1 OSP Ribbon Cable Assemblies

Fiber fanout splits the ribbons into individual fibers and up-jackets them to .900mm for termination to the fiber with a connector. Because it is made of plastic, the .900mm up-jacket tube shrinks more than the optical fiber at -40 degrees. Since the optical fiber itself does not bend inside this tube, it will "piston" back into the fiber fanout housing because the .900mm up-jacket tube is smaller. A typical fiber fanout failure caused by cold temperatures is shown in Figure 9.2.

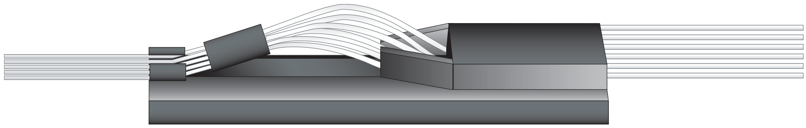


Figure 9.2 Fiber Fanout Failure

Figure 9.2 shows the housing with the cover removed. However, with the cover in place, severe bending will occur as the fibers are pushed back into the open space of the fiber fanout. In this particular non-ADC example, all 12 fibers broke at -40 degrees.

A similar problem occurs at the cable breakout point where the ribbons are split out of the cable. At -40 degrees, the entire OSP cable will shrink up to 5% as allowed by GR-20. Again, since the ribbons do not shrink relative to the plastic cable components, they will bend within the cable breakout, causing microbends and insertion loss problems as they approach -40 degrees. A failure similar to that depicted in Figure 9.2 can occur.

ADC's Cold Temperature Solution

ADC's ribbon OSP cable assemblies are designed with special features that enable them to endure temperature changes without failure and meet all GR-326 requirements at -40 degrees C. This is accomplished by selecting low-shrink plastic components and filling the fiber fanout and cable breakout sections with a silicone adhesive. This process prevents the fibers from being pushed into an open space where bending can occur.

Since the .900mm up-jacketing has a small inside diameter, bending will not occur. The fiber is effectively under a small amount of compression because the .900mm tubes will shrink about 1% at -40 degrees.

However, since there are no open spaces for the fiber to bend – in neither the .900mm tube or the fiber fanout – insertion loss remains low. Fiber bend is similarly prevented at the cable breakout point. The ribbons are prevented from bending in the cable breakout housing because it is also filled with silicone adhesive. This procedure forces any excess ribbon length caused by low temperatures to be taken up within the OSP cable. Inside the OSP cable, there is adequate room for the ribbons to adjust at -40 degrees.

To summarize, ADC OSP cable assemblies meet the insertion and return loss requirements of GR-326 at low temperatures for the following three reasons:

- ADC only uses optical cable that is GR-20 compliant;
- ADC optical connectors meet the requirements of GR-326, Issue 3; and
- ADC deals with the issues surrounding cable assembly components at -40 degrees C.

Components used to construct OSP cable assemblies are typically made of plastic and, therefore, tend to shrink at cold temperatures. ADC's cable assemblies are factory designed to compensate for cold temperature shrinkage – preventing microbends, high insertion loss, and fiber breakage at -40 degrees C.

Chapter 10

Above vs. Below Ground Drop Splicing

Considerations for Drop Cable Connections in the FTTX Network

As more FTTP networks are being deployed, many questions have surfaced regarding the best way to connect the large number of drop cables feeding into the network. Drop cables typically connect each optical network terminal (ONT) at the subscriber premises to a fiber access terminal where they are then connected to a main fiber distribution cable.

The fiber plant will likely be built in one of two categories: above ground (aerial) or below ground (buried). With an aerial plant, the service terminal is typically mounted on a stand or pole. In a buried plant, the drop cable will be buried below the frost line. This chapter discusses the methods of service terminal access from a buried plant and the key considerations for selecting the method that best suits the service provider's requirements.

For more detail regarding splicing or using connectors at the fiber access terminal, see Chapter 5. In that chapter, ADC points out that a connector pair is a better choice at any location where technicians will need to go on a regular basis to test, turn-up and reconfigure services. At these locations, a connector interface will provide both significant operational cost and time savings advantages over fusion splices. The fiber access terminal is one such location. Therefore, connectorization is the most economical option.

Hand Hole vs. Pedestal Access

The two common methods for creating access points at the drop cable and distribution cable junctures are hand holes and pedestals.

A hand hole is, quite simply, a hole in the ground that the technician can open to access the network. Hand holes are placed at any location that would require access for maintenance, connecting additional drop cables or troubleshooting.

Use of an above-ground pedestal provides easier access for the technician. With the pedestal, the distribution cable and drop cables are underground. Both are brought up through the bottom of the pedestal and connections are made inside the unit. The obvious advantage being that it is easier to enter a terminal than to work through a hand hole.

Another consideration for using pedestals centers around cost. From a construction standpoint, it is typically less expensive to install a pedestal than to place a hand hole. Placing a hand hole requires a very large digging operation, whereas a pedestal only requires a very small hole for mounting, thereby lowering construction costs significantly.

The other benefits of a pedestal include better test access for troubleshooting or working on a connection in the future. Of course, there are some possible disadvantages to using pedestals. Untrained technicians can also gain access, as can any curious person who may want to break in or vandalize the pedestal and equipment. Pedestals are also out in open areas where vehicles could collide with them. More importantly, some neighborhoods may frown on having a pedestal every two to four houses for aesthetic reasons.

Environmental Issues

In cases where pedestals may not be aesthetically appealing or there is concern about possible damage from vehicles or vandals, it may make better sense to deploy terminals below the ground. Putting them below the ground requires a hand hole. Inside the hand-hole, another splice closure provides environmental protection. This splice closure connects the drop cables within the hand hole and, therefore, must be substantially more robust in design as compared to the above-ground pedestal.

Placing it below the ground line presents more opportunity for a flooded environment, so it must be able to withstand submersion under fairly significant water, as well as the possibility of freezing and thawing in northern climates. There are very good splice closures available in today's market that will hold up very well under these environmental conditions.

It's also worth noting that hand holes used in harsh winter environments are subject to being iced over or frozen shut. The technician may spend considerable time and effort just finding a way to chip or melt the ice away to gain access. Once open, there may still be considerable ice and slush to clear away before being able to work, making maintenance particularly difficult during the winter months.

Effects of Temperature

A final consideration is the affects of temperature on connectors used in either a pedestal or hand hole environment. Basically, components used to construct OSP cable assemblies are typically made of plastic and, therefore, tend to shrink in cold temperatures. For more detail on these effects, see Chapter 9.

Exposing cable and cable assemblies to low temperatures is typically the most common cause of signal transmission problems and failures in OSP architectures. Insertion loss failures, for example, are a direct result of cable and cable assembly component shrinkage due to low temperatures. If this shrinkage isn't addressed in some way during the manufacturing process and deployment plans, the optical fibers and components could eventually fail.

As temperatures decrease to -40 degrees, the effect on the cable assembly becomes significant as it begins to shrink. The optical fiber in the cable, however, remains at its original length. This can cause the optical fiber to bunch up inside the temporarily shortened assembly, causing microbends and high insertion loss at 1550 nm.

The hand hole access method provides some protection against cold temperature, since everything is below ground and a cover acts as an insulator for the cable, drops, and interfaces. In a pedestal environment, however, temperature changes will be much more apparent. The temperatures inside the pedestal will likely be as cold as outside temperatures in the winter, and probably warmer than outside temperatures in the summer since the enclosure itself heats up if exposed to direct sunlight.

It is important for network architects to consider the temperature challenges at each network location and the possible affects on drop cable connections. Whether above or below the ground, the drop cable connection points must be protected against potentially harmful environmental characteristics.

Chapter 11

Ribbon vs. Loose Tube Fiber Connectorization

Choosing the Right Fiber Cable can Improve Overall Performance of Distribution Cables in the PON

In the distribution portion of the PON for FTTP architectures, the choice of fiber cabling – ribbon vs. loose tube – can directly impact ease of installation and future performance. As is usually the case in these networks, specific architectural characteristics and particular applications may dictate the deployment of one type of cable over the other.

However, ADC's experience in developing and manufacturing FTTP network equipment has concluded that in most cases, ribbon cable provides a considerable performance advantage over loose tube in the distribution portion of the PON network.

Fiber Density is Key

The most obvious asset for ribbon cable is its higher fiber density. This is particularly important for upstream applications requiring high fiber-count cables. Material costs decrease since less plastic is involved and fewer strength members are required. Additionally, it takes significantly less termination time (and cost) with ribbon cable because of its mass fusion splicing capability as compared to one-by-one fiber splicing. Even with techniques available for "ribbonizing" loose tube fibers – basically stacking the fibers and using a spray adhesive to simulate ribbon cable – for mass fusion splicing, using ribbon cable to begin with eliminates the need for this extra step.

Therefore, ribbon is a better choice for termination in areas of the network that require a high volume of fibers. As the network branches out towards the premises, the need for high fiber-count cable decreases. Once the density becomes less than 144 fibers, loose tube cables have certain advantages. For example, loose tube cables offer the ability to peel off single tubes to access up to 12 fibers without disturbing the other fibers within the cable – even when information is being transmitted through the rest of the cable. Although this is possible with ribbon cable, it is a much more difficult operation since by accessing one particular fiber, all the ribbons are exposed to activity that could result in problems and even outages.

Hybrid Designs

Hybrid ribbon and loose tube designs exist for some applications. In these cases, ribbon stacks are put into loose tubes and the tubes are stranded together. Although this provides the ability to access individual ribbons, dealing with the ribbon stack is still less desirable. These cables tend to be much larger and involve more plastic. Thus, much of the density advantage is lost. They are also more expensive, and the only advantage would be to gain higher fiber counts than could be achieved using a central tube design.

Typically, cable vendors like Sumitomo Electric Lightwave, offer ribbon cables that contain 864 fibers as compared to 288 fibers in loose tube configurations. Although higher density loose tube cables are possible, they require more plastic – making them prone to attenuation problems caused by expansion and contraction of the plastic with varying temperatures. This leads to the need for more strength members coupled to the elements to ensure minimal shrinkage.

Connectorized Distribution Requires Ribbon Cable

Large loose tube cables are much more thermally challenged than dense ribbon cables, making them less ideal for the outside plant of the PON. However, even the ribbon cable in the fiber distribution hub must perform as intended over the temperature ranges. It has been ADC's experience that for connectorized distribution cabling inside the FDT, putting connectors on ribbon cable works far better than any loose tube cable because of the thermal expansion and contraction of the sub-units.

In temperatures starting at about 32 degrees F, the tubing in loose tube cables contracts substantially while the fibers remain in place. This phenomenon induces cable loss caused by attenuation in connectorized loose tube distribution cables of as high as 10 dB. There are only two ways to accommodate the expansion and contraction of the sub-units. One way is to slit the sub-unit material to make it "free-floating" over the fibers. This isn't recommended since it leaves multiple fibers unprotected. The second alternative is simpler – choose a vendor whose products exhibit less of this phenomenon or who has achieved a time-tested way to mitigate it. Most manufacturers of loose tube cable recommend maximum tube lengths of 8 feet outside of the OSP jacketing. Even at these lengths, ADC has often observed considerable shrinkage of buffer tubes, leading to temperature-induced losses at high wavelengths if the cable assembly is not properly designed.

Ribbon cables simply do not have this problem. It is avoided by having all the cables in a central tube that allows ample room for the fibers to move around as sub-unit materials expand and contract. Although it may not be considered a significant advantage, ribbon cables eliminate the need for additional strength members to prevent the end affects of temperature-induced cable loss. However, it is one less operational step required and ultimately saves additional space.

All Things Considered

Connectors are advantageous at any location that may require access for strategic testing or incremental growth. While ADC never advocates replacing splices with connectors when it doesn't absolutely make sense, using connectorized ribbon cables for distribution within the PON of the FTTP system definitely makes sense. In terms of restoration following a major event such as a cut cable, it is much easier to restore a ribbon cable versus a loose tube cable.

Since capital expense must inevitably be addressed at some point when deploying an FTTP network, it may be important to make a comparison between the relative costs of ribbon versus loose tube cable. According to Sumitomo Electric Lightwave, the cost of ribbon cable is generally higher for fiber counts of 72 or less. For counts above 72, the cost differential is less pronounced and diminishes further as fiber counts increase.

There is no real cross-over point whereby ribbon cable is less expensive then loose tube cable. However, most customers are selecting ribbon cable on the basis of its productivity, size, and other benefits that far outweigh the initial cost differential.

All things considered, ADC has concluded that in feeder cables where lower fiber counts are required, loose tube cables are sometimes a good choice based on first cost. However, on the distribution side of the FDT, a connectorized ribbon cable simply performs far better than a connectorized loose tube cable. When giving careful consideration to issues such as size, density, and restoration of cables, it appears ribbon cables are the best choice.

Chapter 12

Hardened Connectors vs. Field Splicing

Making cost-sensitive decisions about deploying FTTX architectures requires service providers to not only look at initial installation costs, but to also peer into the future regarding operational and maintenance expenses following service turn-up. Cost modeling allows the deployer to review the financial benefits of their design choices before deployment begins. This chapter specifically addresses the cost comparisons between using hardened connectors vs. splices in two basic areas of the FTTX network – the distribution plant and drop cable portions.

Cost savings can be achieved on both sides of the service terminal by installing hardened connectors. Although most network architects agree that hardened connectors are optimal for the drop side of the service terminal, many are unaware that the cost on the distribution side is also at cost parity or, in many cases, lower when using connectors in lieu of splicing. The result is an overall lower installed cost for the FTTX network as well as tremendous operational savings over the life of the network.

Large cable and splices

In many typical FTTP architectures, a very large distribution cable containing 48 to 216 individual fibers is deployed from the fiber distribution hub directly to the service terminal. The service terminal could be a splice case, a pedestal, a hand hole, or pole mounted unit. In the case of a spliced network, between one and 12 fibers will be prepared inside the service terminal for connecting to drop cables that service each individual home.

The remainder of the distribution cable will continue to the next service terminal where the next one to twelve fibers will be split off and made available for service. Each time service is ready to turn up at a particular home, a technician will go to the terminal, cut off the appropriate length of drop fiber cable from a large spool, and pull the cable from the terminal to the optical network terminal (ONT) on the side of the home, or vice versa, and splice both ends.

This requires two sets of workers – a construction crew to pull the cable to each location and a splice technician to prepare the cable for splicing. The splice technician will need to visit each individual service termination to prep out the distribution cable, even if splicing is not required at that time. It also requires another trip to the service terminal by a technician each time a drop cable is ready to be spliced in to provide service to a home. It's easy to see that a typical spliced approach requires more overall manpower costs and numerous trips to the service terminals by a larger number of experienced technicians. All of this adds to the start-up costs for the FTTX build-out.

A more economical approach

Using a hardened connector approach on the distribution side of the service terminal is less costly and requires far fewer splice technician deployments. In this architecture, which incorporates ADC's new OmniReach™ Multi-Fiber Service Terminals (MSTs), smaller cables (up to 12-fibers each) are extended from a centralized splice location to each service terminal. This eliminates running very large cables and accessing those cables at numerous locations. Even though the number of splices are about the same, all splices are done at one location, greatly reducing overall costs. Typically, a large portion of this cost is in the set-up. But with a central splice point, the technician sets up one time and splices as many as 12 smaller cables onto the distribution cable.

Additionally, there are no splice cases required at the service terminal, making the hand holes or pedestals that store the service terminals much smaller. This is beneficial from both a materials and installation standpoint. Also, many municipalities prefer smaller, less obtrusive pedestals or smaller hand holes that are easily placed and less expensive.

A cost model comparing the installation costs of the traditional spliced FTTX architecture with one that incorporates MST hardened connector technology in a 192-home subdivision is as follows: Using the MST model, cable costs decreased by over 85% due primarily to the cable now being included in the terminal costs. The cost of pulling fiber cables decreased by about 25% and splicing costs were about 70% lower. Even though the MST approach added additional costs for service terminals, the overall cost was significantly lower for the distribution side of the network – approximately 19% less per home passed.

The drop cable portion of the network – between the service terminals and the ONTs – also reaps many advantages through a hardened drop connector approach. The technician can simply use a pre-connectorized drop cable – pre-connectorized at both ends in the factory and cut to specific lengths – to install between the service terminal and the home. These cables can be installed by any technician, possibly the same person connecting the electronics at each home. This greatly reduces the cost of drop cable installations in terms of time and skill level. A technician simply has to clean the connector faces at each end and plug them in.

The overall cost of using factory-connectorized drop cables in place of spliced bulk drop cable was at least 25% less. Since service providers can realize a combined savings of nearly 25% in the entire OSP portion of the fiber plant, the business case for the architecture that incorporates MST hardened connectors is compelling. But there’s more: additional operational savings over the life of the network should also be considered.

Savings now and later

The operational cost savings gained from having a connectorized FTTX infrastructure becomes evident in terms of faster service turn-up, ease of maintenance and troubleshooting, the need for fewer splice technicians and equipment and overall fewer truck rolls. But through extensive cost modeling, ADC is showing that the cost savings can be achieved at the onset of building the network.

Installation cost models have shown that a spliced approach is far more expensive than a hardened drop connector approach. Splicing is simply a much more expensive undertaking without a centralized splicing location. More locations, more splices and the need for more splice technicians greatly increases initial installation costs in the network.

In the hardened drop connector system, troubleshooting can be done at the service terminal simply by unplugging a connector. The spliced approach requires breaking a splice or going directly to the side of the home to investigate problems. There is less need for splicing equipment, particularly in larger installations.

Despite arguments that connectorized approaches result in more optical loss and also require more inventory and slack storage provisions, the data outlined in Figure 12.1 still reaches the same overall conclusion – the hardened drop connector approach incurs lower overall installed costs for the FTTX network.

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	$ 56,650.00
Splicing Costs	$ 9,072.00	Splicing Costs	$ 2,988.00
Terminal Costs	$ 0.00	Terminal Costs	$ 16,072.00
Total Costs	**$109,072.00**	**Total Costs**	**$ 88,442.00**
Cost/ Home Passed	**$ 568.08**	**Cost/ Home Passed**	**$ 460.63**

Figure 12.1 Specific Cost Module Based on a Phase Project for a 192 Home Subdivision

Specific cost model based on a phased project for a 192 home subdivision, featuring eight homes per block.

Chapter 13

Multiple Solutions for Connecting Multiple Dwelling Units

FTTP networks increasingly include Multiple Dwelling Units (MDUs) such as apartments, condominiums and townhouses as part of the network build. Some estimates indicate that MDU structures may account for over one-third of the target FTTP subscriber base. These MDU installations require special consideration for fiber cable interconnection to terminal equipment located at the premises. Connecting MDUs into the FTTP network requires an understanding of the wide diversity of structures and conditions found throughout the country. MDU connection strategies may also vary considerably depending on whether the structure already exists or is under construction/rehabilitation.

A variety of solutions are required to support the many different connection scenarios. All dwellings require a connection from the FTTP cabling network. In some cases the connection may be via a feeder fiber directly from the CO/Headend connected to a splitter hub on the premises. In other cases connections extend from distribution fibers directly from the Fiber Distribution Hub (FDH) located in the network that are routed to a fiber terminal on the premises. Depending on the type and size of the MDU there may be a need for extensive fiber cabling and connections within the structure. Solutions for larger MDU structures may involve splitter hubs located inside the premises and then subtending riser and drop cable networks with intermediate fiber terminals located strategically throughout the building. Key building blocks include both indoor and outdoor FDHs and indoor and outdoor fiber distribution terminals. Additional drop cables, raceways and outlets are needed to support complete interconnection in many of the MDU environments.

Architecture

Some estimates indicate that more than 33% of all US households are located in shared residential structures commonly referred to as Multiple Dwelling Units (MDUs). Furthermore, demographic studies show that the MDU environment is a lucrative and competitive market for providers of broadband services. Each year new construction continues to bring more and more MDUs online. This target MDU market lies right in the heart of FTTP network builds across the country. Connecting MDUs into the FTTP network requires an understanding of the wide diversity of structures and conditions that may be encountered.

Metro High-Rise

In metropolitan areas high-rise dwellings including condominiums and apartments are the norm rather than the exception. High-rise residential dwellings present challenges and often require special planning to assure that FTTP networks can efficiently and reliably scale the heights involved across multiple floors. These structures have typically been designed and optimized for vertical living and as such have planned access for cabling networks through the various floors and sections of the building.

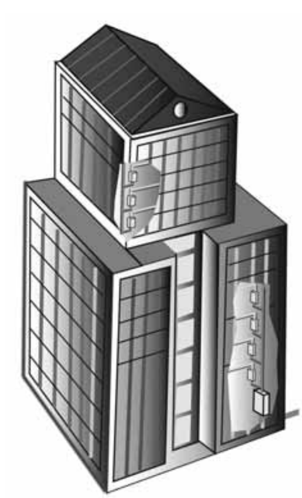


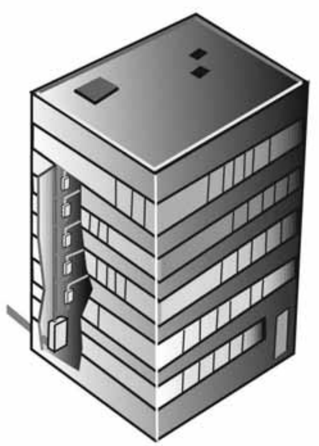
Figure 13.1 FTTP in Metro High-Rise

Because of the large number of living units in these buildings they are typically connected directly to serving FTTP equipment in the central office/head end. The feeder cable extending from the central office/head end is routed to the structure and connected to a Fiber Distribution Hub in the basement. The FDH provides optical splitting and connection for the network within the building. A cabling network of riser cables is distributed to the various floors through designated pathways either inside the building or outside the building. Riser cables are tapered as they traverse the vertical rise with segments of the cable dropped at each floor. Usually the riser cable is connected to a Fiber Distribution Terminal (FDT) located at each floor. Drop cables are installed into each living unit and then routed to the FDT corresponding to that floor. Interconnection takes place when the customer in the living unit requests service.

Mid-Rise

The mid-rise buildings are a major class of structures that include apartment and condominium living units spread across multiple floors. In many cases these are older residential buildings constructed as walk-ups and without provisions for new cabling networks. The challenge for FTTP network builders is to traverse this environment without incurring major cost.

Figure 13.2 FTTP in Mid-Rise Building

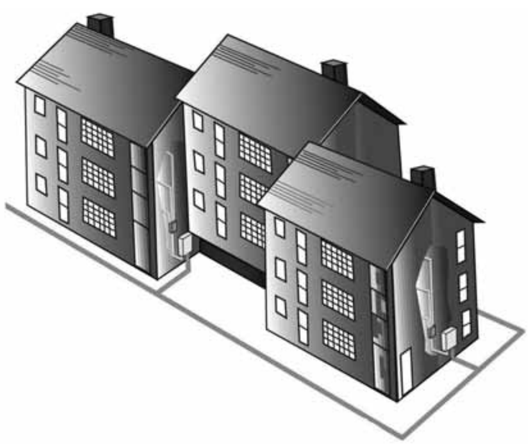


The mid-rise, like the high-rise, is often connected directly to the FTTP equipment in the CO/Headend via a feeder cable routed directly to the building. The feeder cable is routed directly to the basement and terminated at a FDH that provides optical splitting and service connection for the entire building. The connection strategy for mid-rise includes routing riser cables to every floor where FDTs provide interconnection for drop cables. Drop cables are routed from the FDTs and connected to wall plates in the living units. The fiber drop cables are sometimes routed through hallways and protected with raceways or conduit. Mid-rise units raise an important challenge in finding space to install terminals and hubs and then overlaying riser and drop cables efficiently and aesthetically.

Garden Style

A significant amount of new construction for residential apartments and condominiums is occurring in Garden Style structures. These structures are typified by two or three story buildings often with walk-up access and multiple living units per floor. Often these structures are not designed with the forethought that cabling networks will be added at a later date and as such, Garden Style structures present significant challenges installing FTTP network cabling.

*Figure 13.3
FTTP in
Garden Style
Structures*



Garden style structures tend to provide network interface between the outside plant and drop cables either on the exterior surface or just inside a building entrance closet. Often the FTTP network interface will be located at the spot on the building where other utilities are positioned. Routing the drop cables from the living units to the network interface is relatively simple in new construction. In new construction fiber drop cables can be routed through the framing structure before the walls are sealed. Drop cable installation techniques in new construction may include placing fiber drops in conduits or directly into the wall. Alternatively, the new construction scenario lends itself to installing micro-ducts initially and then later blowing fiber into the living units as service is requested. Installing fibers into existing units is much more difficult. Often, overlay installation involves routing drops through the attic, basement or around the exterior of the structure. These installations can be costly and time consuming. New cables have been developed such as indoor/outdoor cable to give the installer more flexibility in routing drops around and through existing structures. A variety of FDTs are also available to provide flexible options for connecting drop cables to the plant at the network interface. One typical FDT provides for standard connector interface on the exterior surface. The FDT may be supplied pre-terminated with standard connectors and supplied with pigtails to facilitate splicing to indoor/outdoor drop cables. Alternatively, external FDTs may be configured with rugged connectors to interface with rugged outdoor drop cables directly. Finally, FDTs may be configured as indoor enclosures with standard connectors and located immediately inside the building entrance to interface with drop cables routed inside the building.

Horizontal Style

A significant majority of new condominiums and town homes are constructed using a horizontal layout that very closely resembles the arrangement of single family homes. Because of the similarity of single family homes the FTTP connector scheme is often identically equivalent.

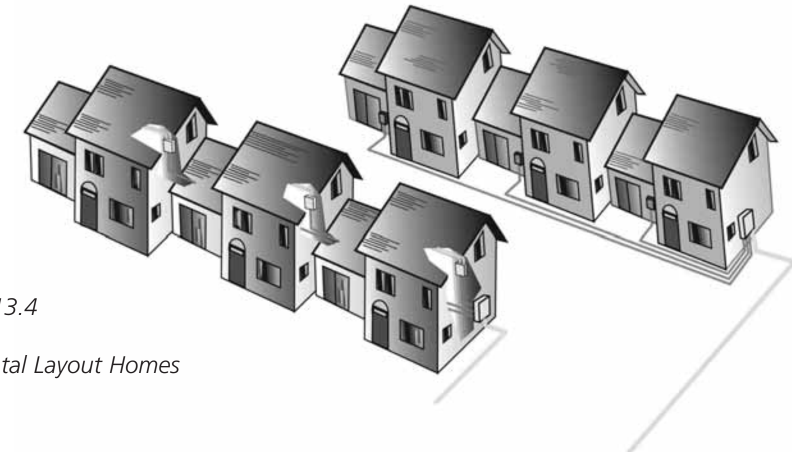


Figure 13.4
FTTP in
Horizontal Layout Homes

Usually the network interface will be a FDT located on the exterior surface of the structure. FTTP distribution fibers are allocated downstream from the FDH to a particular MDU structure. A FDT located on the exterior surface of the structure may be outfitted with either rugged on non-rugged connectors. Rugged connectors are used when hardened fiber drops are routed along a path outside the structure and then connected directly to the ONT on the side of the individual dwelling. Alternatively, non-hardened indoor cabling may be routed via internal pathways from the FDT to ONT equipment in each unit.

Key Building Blocks

The key building blocks for MDU connectivity include Fiber Distribution Hubs, Fiber Distribution Terminals, Riser Cable, Drop Cable, Raceways and wall plates.

Outdoor Fiber Distribution Hub

The outdoor FDH enclosure provides for connections between fiber optic cables and passive optical splitters in the OSP environment. FDH enclosures are available in a range of sizes for terminating distribution cables, e.g. 144, 216, 288, 432, 576, 864, 1152, etc. The enclosures utilize standard SC connectors (APC or UPC) to interconnect feeder and distribution cables via 1x32 optical splitters and connectors. The FDH enclosure is placed strategically in the FTTP network to facilitate service connection specified for a particular fiber serving area that may include MDU structures. These enclosures are either pole mounted or pad mounted and provide environmental and mechanical protection for cables, splices, connectors and passive optical splitters.

*Figure 13.5
Outdoor Fiber
Distribution Hub (FDH)*

The FDH is constructed from heavy gauge aluminum and provides the necessary protection against rain, wind, dust, rodents and other environmental contaminants. At the same time, it remains lightweight for easy installation, and breathable to prevent accumulation of moisture in the unit. The aluminum construction with heavy powder coat finish also provides for corrosion resistance. The enclosure is accessible through secure doors that are locked with a standard tool or padlock. All FDH enclosures are designed for ease of craft access and maintenance to ensure trouble free operation over time.

Indoor Fiber Distribution Hub

The indoor FDT is designed to organize and administer fiber optic cables and passive optical splitters in an inside plant environment typically found in an MDU closet or basement. These enclosures are used to connect feeder and distribution cables via optical splitters in a FTTP network application. The indoor FDH product provides a vital cross-connect/interconnect interface for optical transmission signals at the MDU.

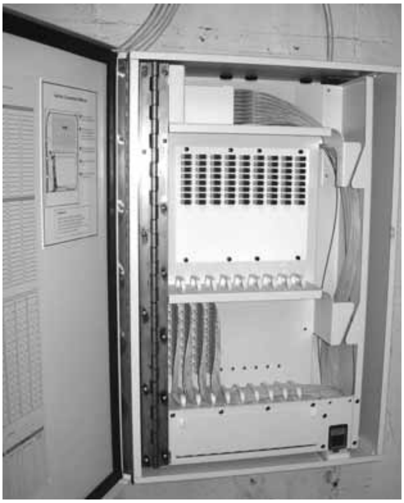


Figure 13.6 Indoor Fiber Distribution Hub (FDH)

The enclosure provides mechanical protection for cables, splices, connectors and passive optical splitters. In addition, the indoor FDH is designed to accommodate a range of fiber counts and support factory installation of pigtails, fanouts, and splitters. The enclosures are available in a range of sizes; 72-, 144-, 216-, 432-fibers, etc.; and are designed for front access via a swing frame configuration so that they can be wall mounted, rack mounted or pedestal mounted.

Outdoor Fiber Distribution Terminal

The outdoor FDHs are designed to terminate, splice and interconnect fiber optic cables in an outdoor environment. This terminal is usually configured to support network interface to 12, 24, 48, etc. living units via standard SC (APC or UPC) connectors. Alternatively the outdoor FDT may be configured with RC connectors to provide an interface to hardened drops. The FDT is mounted to the exterior surface of an MDU structure to provide connection between the distribution cable and drops routed to individual living units. The outdoor FDT is typically divided into sections with distribution cable routed into one section and drop cable routed into the other section. The cables meet at a central connector field that includes termination for the distribution cable and parking for the drop cables. Each side of the cabinet may be configured with splice trays for splicing the cable or the connector pigtails. The outdoor FDT may be pre-terminated on the distribution side with outside plant cable stubs so that the unit is quickly connected to the plant. The outdoor FDT may be pre-wired with pigtails on the drop side so that individual drops routed into the unit can be spliced to the connectorized pigtails. The unit accommodates a variety of OSP cable types via sealed grommet entry. Cables are secured with standard grip clamps to provide the required pull out strength. The enclosure provides grounding for metallic members and for the cabinet.

Figure 13.7 Outdoor Fiber Distribution Terminal (FDT)

Indoor Fiber Distribution Terminal

The indoor FDT provides connectivity between fiber cables within a building environment. One typical application may be as a primary network interface (as an alternative to outdoor FDT) inside the building. Another typical application is to support a tapered fiber distribution network within the building where FDTs are installed on the various floors. The indoor FDT utilizes a rugged design that effectively isolates the splicing and cable termination from the interconnection to the drop cables. Separating the cable splicing and drop cable termination into separate areas provides a space efficient and craft friendly interface unit. The indoor FDT provides easy access to all connections. The indoor FDT enclosure provides standard SC connections (APC or UPC) and may be equipped with parking for locating the staging drops prior to deployment. The indoor FDT products are designed to splice and terminate fibers in a range of sizes including 6, 12, 24 and 48 fibers. The indoor FDT enclosures are for indoor wall mount applications and provide complete access for maintenance and service provisioning. Secure doors are locked with a standard can wrench tool and may optionally be secured with a standard pad-lock to provide security for fiber connections within the building.

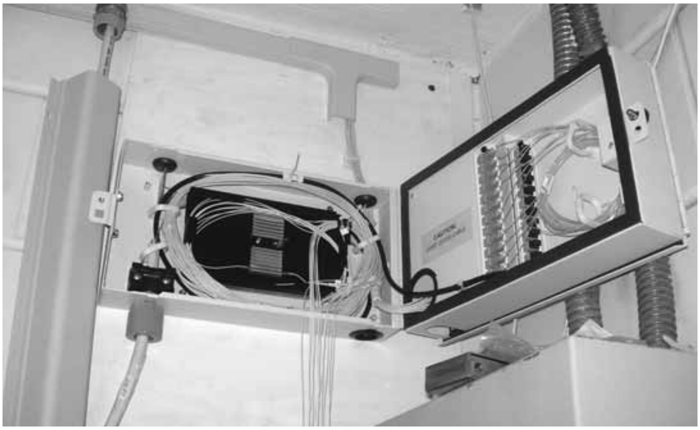


Figure 13.8 Indoor Fiber Distribution Terminal (FDT)

Indoor Drop Cables

Rugged, high performance Indoor Drop Cables connect FTTP premises equipment and outside plant cabling systems in most MDU applications. These cables are typically routed from an FDT (either indoor or outdoor) to each individual living unit. These drop cables meet standards set for indoor riser, plenum or indoor/outdoor applications so the appropriate cable is selected for the application. The indoor fiber drop cables are available in a variety of lengths with high performance SC connectors (APC or UPC) terminated on one or both ends. Fiber drop cables are certified to Telcordia GR-326 and are typically available in standard lengths of 50, 100, 150, 200, 250, and 300 feet. All fiber drops are packaged on convenient reels so that field deployment can be completed quickly and efficiently.

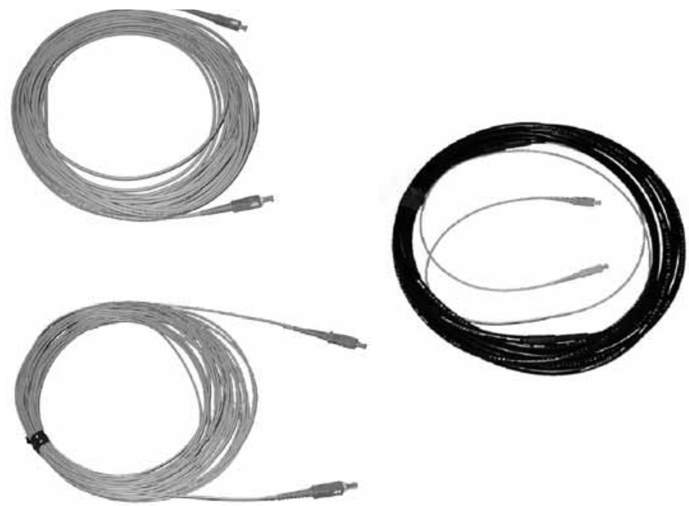


Figure 13.9   Indoor Drop Cables

Outdoor Hardened Drop Cables

Some MDU configurations such as a horizontal outdoor cabling require hardened drops for routing around the exterior of the building. These drops are often buried in the front or back yard of the structure. Rugged Optical Connectors are used to connect FDTs typically located at the street or on the side of the dwelling with Optical Network Terminals (ONTs) located at the premises. The hardened fiber drop is typically terminated with a rugged outdoor connector on one or both ends and facilitates rapid service connection. The Rugged Connector and associated Rugged Drop Cable (RDC) assemblies provide a reliable interface for fiber drop cables in the outside plant environment. The rugged optical connector is hardened to protect against extreme temperature, moisture, UV, chemical exposure and other harsh conditions typically found in the outside plant. The rugged connector is usually provided as part of a drop cable assembly and the connector is sealed using O-Rings as it is installed into a rugged adapter. The rugged connector is also normally supplied with a protective cap which seals the connector and keeps the end-face clean until it is ready for use. Upon installation the protective cap is removed and the RDC can be connected to the rugged adapter. Outdoor Fiber Drop cables are available in dielectric flat, flat with toneable wire, and in Figure 8 configurations and with connectors on one end or both ends.

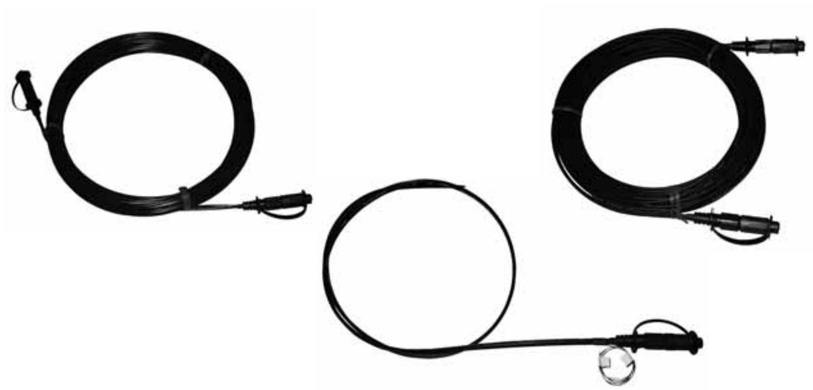


Figure 13.10 Outdoor Hardened Drop Cables

Drop Cable Installation

A wide range of cabling installation techniques may be used to route indoor drop cabling. Typical drop cables may be installed in a raceway configured along the ceiling of the MDU hallway. An extension of the raceway may be used to cover existing cabling such as voice or CATV wiring. The raceway system may be provided with a decorative cover to provide an installation that appears like crown molding. Drop cable installation can be installed in overlay configurations.

In some new or rehab construction, alternate techniques may be considered for drop cable installation. For instance drop cables may be installed along with conduit to provide a protective path from the FDT all the way to the living unit. The advantage to installing conduit is that fibers can be installed at any time after the conduit and a fiber cable can be replaced if needed. Another alternative is to utilize blown fiber techniques that involve installing micro-duct initially and then returning at a later date to blow fiber drops from the FDT into the living unit. Drop cable installation tends to be labor intensive and therefore overall efficiency and cost effectiveness will need to take individual building conditions into consideration when determining the effective drop cable installation technique.

Summary

FTTP networks increasingly include MDUs such as apartments, condominiums and townhouses as part of the network build. MDU installations require special consideration for fiber cable interconnection to terminal equipment located at the premises. Connecting MDUs into the FTTP network requires an understanding of the wide diversity of structures such as high-rise, mid-rise, garden-style and horizontal building layouts. Once the structure is fully understood the connectivity plan can be developed and optimized for the structure. MDU connection strategies may also vary considerably depending on whether the structure already exists or is under construction/rehab. A variety of solutions are required to support the many different connection scenarios. Depending on the type and size of the MDU there may be a need for extensive fiber cabling and connections within the structure or on the exterior surface of the structure. Once the architecture is specified a variety of building blocks is available to support MDU connectivity. Key building blocks include outdoor FDHs, indoor FDHs, outdoor FDTs, indoor FDTs, outdoor Drop Cables, indoor Drop cables and miscellaneous raceway and wall plate hardware. These connectivity components are designed to provide multiple solutions for connecting MDU structures.

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Chapter 14

Challenges and Solutions for the FTTN Service Delivery Option

Although FTTP is receiving a great deal of attention for delivering today's bandwidth-hungry triple-play services to the home, many service providers are opting for a fiber-to-the-node (FTTN) access solution. FTTN takes advantage of existing copper infrastructure to provide a cost effective alternative – and ADC has developed an entire portfolio of FTTN service delivery solutions.

These service delivery solutions cover numerous scenarios and situations, including passive stand-alone architectures and active integrated solutions whereby the service delivery frame is actually embedded into an active cabinet. There is even a "combo" solution that provides FTTN delivery using one side of the cabinet with the provision to plug in 1x32 optical splitters on the opposite side for a fast future upgrade to an FTTP cabinet network architecture. This is a unique single cabinet solution for deploying FTTN today with a migration route to FTTP tomorrow.

Each solution provides the technicians with a consistent "look and feel" approach to wiring within each cabinet, making it easy to quickly identify key components and ports. These solutions offer monitor "look-in, look-out" testing capabilities that help technicians quickly isolate any potential network problems.

Like FTTP, there are considerations and challenges to deploying successful FTTN solutions. There is no "one size fits all" solution when transforming the traditional switched approach network into a high-speed, high-capacity broadband network.

Challenges to FTTN

The first challenge facing FTTN deployers is the need to "resectionalize" the distribution areas (DA). Today, service providers are providing regular DSL or ADSL services to customers via a digital loop carrier (DLC) feeding through a cross box with a loop length, in some cases, that can have a loop length of up to 12,000 feet. But the introduction of VDSL or ADSL2/ADSL2+ technologies is now limiting distribution area (DA) loop length distances to between 3000 and 5000 feet.

Another example is the 18,000 foot CO-fed distribution area. The copper outside plant (OSP) that serves customers within this DA will have to be resectionalized to shorten all loops to within 3000 to 5000 feet. In this CO DA, the digital subscriber line access multiplexer (DSLAM) may require to be replaced or require an upgrade to support the new services. Additionally, the CO DA will have to be resectionalized by using existing plant and rearranging it to create smaller loop links. In essence, the CO will only serve an area approximately 3000 to 5000 feet from its location.

At the remote terminals (RTs), the same challenges must be addressed. Depending on whether each RT is copper or fiber fed, the distribution areas, which were probably 12,000 feet, must now be rearranged to support customers within a 3000- to 5000-foot area.

When providing new services, there are also the low density areas – those beyond 5000 feet from the last cross box – that must be considered. These are areas that traditionally "do not qualify" for new services – mainly due to the cost involved with distributing services to these sparsely populated areas. However, at some point, providers must acknowledge the demand for the same new services they are providing to customers in more densely populated areas. Thus, when reconstructing the FTTN network for new services, this is a valid consideration.

Low density areas may be the most challenging part of deploying the FTTN network. New remote terminal installations will be required to reach these customers, as well as additional fiber and cabinets. Additionally, pair counts may not be available for bonded DSL strategies.

Sub-dividing the DA

Sub-dividing, or resectionalizing, the DA will be a major consideration as service providers reduce coverage areas from the traditional 12,000 feet to smaller loops of 3000 to 5000 feet. Different requirements in different areas of the network will demand customized solutions. For example, an existing cross-box will now be limited to 5000 feet of coverage, making it necessary to add additional cabinets at the edge of the 5000-foot boundary to service customers beyond that limit.

Other challenges include finding ways to accommodate various existing designs of the OSP portion of the network. Subdivisions may require different size solutions, depending on customer density and distances. Right-of-way issues must be considered where new cabinet placements are required. The existing fiber feeder distribution interconnect (FDI), also known as a cross-box, may have no spare binding post to support a direct terminated method for delivering new service. Providers must also consider the fact that not all customers will want to switch from basic DSL services, such as from ADSL service to ADSL2+.

Service delivery challenges

There are also several service delivery challenges associated with this new FTTN broadband technology. The most significant challenge is in pair bonding. Although pair bonding doesn't actually refer to physically tying two pairs together to provide more copper, it accomplishes a similar objective. It enables the electronic bonding, inside the DSLAM, of two output DSLAM ports to provide twice the bandwidth. However, for successful pair bonding, there must be two continuous copper pairs available to the customer premises and the service delivery platform, such as the cross-box or interface, must support pair bonding.

It is common to run voice over the low frequency part of the circuit, while running data over the high frequency portion. This enables voice and data to run over a single copper pair. The same can be accomplished for the new DSL services. A second pair can be run into the home and electronically bonded back to the DSLAM terminal to provide twice the capacity to the customer plus a voice channel. However, pair bonding presents new challenges to the phone companies.

For example, to deploy these adjunct DSLAMs – such as placing a small cabinet next to an existing cross-box and injecting the services – there may not be enough spare binding posts inside the cross-box. For 100 circuits of DSLAM, only 200 pairs of binding posts are available required in a traditional cross box. This could make pair bonding a complicated and expensive initiative.

Provisioning new ADSL, ADSL2+, or UDPSL2 services at places where two pairs are required may not always be possible. Some homes may not have a second continuous pair available. Thus, service providers will end up rolling customers from their existing platform to the new platform that is closer to the subscriber – all at additional expense. There may also be multiple voice-grade lines needed if pair bonding is used to create necessary additional wiring requirements.

Other considerations include having clean copper pairs – there cannot be any bridge taps on the line. Load coils or other means of stretching POT service must also be eliminated. Today's new services require a clean copper plant.

Solutions? You bet!

ADC offers FTTN solutions that address copper pair bonding challenges and provide streamlined service delivery alternatives to binding post issues within existing cross-boxes. The company's passive service delivery solution can operate as a stand-alone unit or be integrated into active deep fiber broadband cabinets for easily resectionalizing the existing DA. New deep fiber broadband cabinets are available in several sizes that address DA rezoning. These cabinets make possible a copper service delivery platform that manages pairs easily and supports pair bonding. Every ADC product provides the same look and feel – as well as monitor "look-in, look-out" testing capability – to give technicians a more reliable, user-friendly CAT-5 connection.

There are multiple approaches to deploying FTTN, so multiple solutions should be available. One approach is using passive cabinets to upgrade DSLAMs at the remote terminal or where an existing cross box may lack capacity. There will also be a need for medium and small integrated cabinets – active, fiber-fed units for resectionalizing the existing network infrastructure.

At the CO, the objective is to serve all customers within 3000 to 5000 feet. Copper-fed remote terminals, with or without DSLAMs, can be used to resectionalize the DA to serve customers within 5000 feet. Fiber-fed remote terminals, with or without DSLAMs, that are already present in the network can also service a 5000 foot area. Finally, new DAs will require brand new solutions, such as an all-in-one fiber- fed broadband cabinet with built-in copper distribution.

A new FTTN architecture is shown in the figure below using one of ADC's OmniReach FTTN2P solutions. This solution enables service providers to migrate to FTTP or offer both FTTP and VDSL/ADSL2+ out of the same cabinet. All FTTP components are modular and can be added at a later date.

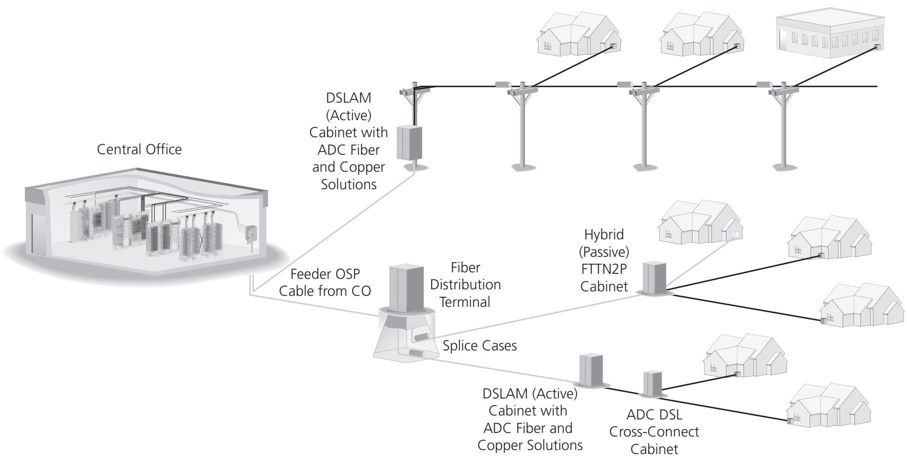

Figure 14.1 FTTN Architecture Diagram

FTTP migration and DSLAM protection

Each DSLAM input/output and feeder/distribution section in ADC's NCX Passive Service Delivery Cabinet has a unique monitor look-in/look-out testing capability. This feature enables technicians to easily turn up services and provide troubleshooting operations.

One of the keys to ADC's FTTN solution is its ComProtect™ protection components. The voice circuit is actually run into the input block through the ComProtect unit to protect the DSLAM circuit. It is then run out of the DSLAM through the input/output block to protect the output, and then tied directly to the distribution pair. ComProtect replaces the 5-pin protector, and saves a great deal of space in the cabinet.

The ComProtect unit provides over-voltage and over-current protection for the network element. A key feature of the ComProtect solution is to provide crossconnect capability and protection in a single footprint, thus reducing space in the cabinets. The unit passes or exceeds all Telcordia requirements for protection devices.

ADC provides two basic FTTN application technologies. The first one is a cabinet that combines the cross-box and DSL inputs/outputs into one footprint. The other is the distribution intercept (DI) that provides a built-in cut-through for the terminal block.

Using a DI application offers a low-cost, quick-to-market solution for operating companies. With this application, the existing dial tone services pass through a special terminal block that simply relays the service out of the cabinet. When a customer requests DSL services, the technician only has to run a four-wire crossconnect jumper to deliver voice and DSL. The DI application is spliced into the network downstream from existing cross boxes and RT sites. This means there is no investment required to existing plant. Simply place the new broadband cabinet in a location within 3000 to 5000 feet of the subscribers, half tap into the OSP plant, and turn up the new broadband services.

FTTN, FTTP or Both?

As service providers make major decisions regarding the most cost effective, reliable method of delivering today's new voice, video and data services to customers, both FTTP and FTTN solutions should be thoroughly investigated. Individual circumstances surrounding each individual deployment will dictate how far to push fiber towards the customer premises.

For greenfield deployments, the cost parity between copper and fiber has made FTTP a viable choice. However, overbuilding existing networks with pure fiber may prove to be cost-prohibitive for many providers, making FTTN a very attractive alternative solution – particularly if it provides an easy migration to FTTP in the future. Whatever the choice, ADC offers custom products that adapt to any deployment scenario to provide the most reliable, flexible, and cost effective long-term solutions.

Glossary of Terms

Below is a glossary of terms that are frequently used within the PON environment. It contains many of the terms also associated with various parts of the Access Network of which PON is one type.

Access Network
The method, time, circuit, or facility used to enter the network. The service provided by local exchange carriers or alternate access providers, which connect an interexchange carrier with its customers. The Access Network today is predominantly passive twisted pair copper wiring.

ADM
Add/Drop Multiplexer capable of extracting or inserting lower-bit-rate signal from a higher-bit-rate multiplexed signal without completely demultiplexing the signal.

ADSL
Asymmetric Digital Subscriber Line transmits data asymmetrically meaning the bandwidth usage is much higher in one direction than the other. Typical ADSL applications transmit 8 Mbps downstream and 768Kbps upstream, depending on the length of the local twisted pair loop. This is particularly beneficial for residential Internet access, remote access and video on demand because downstream usage far exceeds upstream usage.

APC
Acronym for Angle Polished Connectors

APON
An Asynchronous Transfer Mode (ATM) based Passive Optical Network (PON).

ATM
Asynchronous Transfer Mode is a connection-oriented service that segments data into a succession of small units called cells. Data transmitted from multiple sources is segmented into cells by the ATM network device, and the cells are then interleaved onto a single transmission media. It is asynchronous in the sense that the recurrence of cells depends upon the required or instantaneous bit rate. See also TDM and packet switching.

Attenuation
The decrease in power of a signal, light beam or lightwave, either absolutely or as a fraction of a reference value.

Backbone
The part of a network used as the primary path for transporting traffic between network segments. A high-speed line - or series of connections - that forms a major pathway within a network.

Bandwidth
The throughput, or ability to move information through or from a device, system or subsystem, usually measured in quantities of data per second. A measure of the information-carrying capacity of a communications channel; range of usable frequencies that can be carried by a system, corresponding to the difference between the lowest and highest frequency signal that can be carried by the channel.

BLEC
Building Local Exchange Carrier

B-PON
Broadband Passive Optical Network (PON)

CAPEX - Capital Expenditure
Expenditures used by a company to acquire or upgrade physical assets such as equipment, property, industrial buildings. In accounting, a capital expenditure is added to an asset account (i.e. capitalized), thus increasing the asset's basis.

Cascaded Architecture

The cascaded architecture approach is normally configured with a 1x4 splitter residing in the OSP enclosure, usually an FDT, and is connected directly to an OLT in the CO. Each of the four fibers leaving the 1x4 splitter is routed to an access terminal housing another splitter, eith a 1x4 or 1x8. Optimally, there would eventually be 32 fibers reaching the ONTs of 32 homes.

CATV

CATV (originally "community antenna television," now often "community access television") is more commonly known as "cable TV." In addition to bringing television programs to those millions of people throughout the world who are connected to a community antenna, cable TV is an increasingly popular way to interact with the World Wide Web and other new forms of multimedia information and entertainment services.

Cell

A unit of transmission in ATM. A fixed-size frame consisting of a 5-octet header and a 48-octet payload.

Cell Delay Variation (CDV)

CDV is a component of cell transfer delay, induced by buffering and cell scheduling. Peak-to-peak CDV is a QoS delay parameter associated with CBR and VBR services. The peak-to-peak CDV is the ((1-a) quintile of the CTD) minus the fixed CTD that could be experienced by any delivered cell on a connection during the entire connection holding time. The parameter “a” is the probability of a cell arriving late.

Centralized Architecture

The centralized architecture approach typically uses a 1x32 splitter in an OSP enclosure, such as an FDT. In the case of a 1x32 splitter, each device is connected to an OLT in the CO. The 32 split fibers are routed directly from the optical splitters through distribution panels, splice points and/or access point connectors to the ONTs at 32 homes. This is the approach recommended by ADC.

CLEC (Competitive Local Exchange Carrier)
In the United States, a CLEC (competitive local exchange carrier) is a company that competes with the already established local telephone business by providing its own network and switching.

CO (Central Office)
The Central Office is where communications common carriers terminate customer lines and locate switching equipment that interconnects those lines. Also, considered a location where Switching, Transmission and Power equipment that provide telephone service is centralized.

Coaxial Cable
A type of cable with a center conductor, an insulator, a solid or braided shield around this insulator with a tough jacket on the outside. The inner insulation provides a constant distance between the center conductor and the shielding, providing a superior quality signal over longer distances, which gives higher bandwidth and better immunity to external interference than simple twisted pair cable provides.

Connection Admission Control (CAC)
The set of actions taken by the network during the call setup phase (or during call renegotiation phase) in order to determine whether a connection request can be accepted or should be rejected (or whether a request for re-allocation can be accomplished).

Constant Bit Rate (CBR)
An ATM service category, which supports a constant or guaranteed rate to transport services such as video or voice as well as circuit emulation that requires rigorous timing control and performance parameters. QoS Parameter typically used for voice traffic.

Core Network
See backbone

Coupler
Fused fiber device that optically splits and multiplexes signals. The couplers used in the PON outside plant network are basically power splitter

wherein the power from the OLT is sent into different branches of the network to feed the ONTs based upon their distance from the OLT. Another type of coupler/splitter is used to separate the incoming and outgoing signals into their respective wavelengths at the OLT and ONT. This is a WDM coupler/splitter and is sometimes referred to as an optical multiplexer/deplexer.

CWDM
Coarse Wave Division Multiplex

Cyclic Redundancy Check (CRC)
A mathematical algorithm commonly implemented as a cyclic shift register that computes a check field for a block of data. The sender transmits this check field along with the data so that the receiver can either detect errors, and in some cases even correct errors.

Dark Fiber
Dark fiber refers to unused fiber-optic cable. Often times companies lay more lines than what's needed in order to curb costs of having to do it again and again. The dark strands can be leased to individuals or other companies who want to establish optical connections among their own locations. In this case, the fiber is neither controlled by nor connected to the phone company. Instead, the company or individual provides the necessary components to make it functional.

DA - Distribution Area
A physical area defined by a number of homes, served by an FTTX network.

DLC
Digital Loop Carrier

DS0
Digital Signal level Zero: One 64 Kb channel

DS1
Digital Signal level 1: 24 data channels (64 Kb) and 8 Kb for signaling; total data rate of 1.544 Mbps

DS3
Digital Signal level 3: 28 DS1s encapsulated; 44.736 Mbps data rate.

DSL
Digital Subscriber Line is a method of providing high-speed data services over the twisted pair copper wires traditionally used to provide POTS. Types of DSL include ADSL (asymmetric digital subscriber line), HDSL (high data rate digital subscriber line), SDSL (single line digital subscriber line), and VDSL (very high data rate digital subscriber line).

DSLAM
Digital Subscriber Line Access Multiplexer Provides high-speed Internet or Intranet access over traditional twisted-pair telephone wiring through the use of ADSL technology. Provides simultaneous high speed digital data access and POTS analog service over the same twisted-pair telephone line. Can be installed in the CO or at and ISP adjacent to the CO

DWDM
Dense Wave Division Multiplexing is an optical multiplexing technique used to increase the carrying capacity of a fiber network beyond what can currently be accomplished by time division multiplexing (TDM) techniques. Different wavelengths of light are used to transmit multiple streams of information along a single fiber with minimal interference.

DWS
DWS (Dynamic Wave Slicing™) extends WDM (Wave Division Multiplexing) by "slicing" each wavelength so that it can serve multiple end points (customers). This provides a division of available bandwidth over a PON by enabling a single fiber segment to allocate bandwidth to multiple customers according to their particular needs (from 1.7 to 100 Mbps in 1.7 Mbps increments). This provides effective utilization of the total capacity of the fiber optic media.

EPON
Ethernet based Passive Optical Network (PON).

Erbium-Doped Fiber Amplifier (EDFA)
A key enabling technology of DWDM, EDFAs allow the simultaneous amplification of multiple signals in the 15xx nanometer region, e.g. multiple 2.5 Gbps channels, in the optical domain. EDFAs drastically increase the spacing required between regenerators, which are costly network elements because they (1) require optical/electrical/optical conversion of a signal and (2) operate on a single digital signal, e.g. a single SONET or SDH optical signal. DWDM systems using EDFAs can increase regenerator spacing of transmissions to 500-800 km at 2.5 Gbps. EDFAs are far less expensive than regenerators and can typically be spaced 80-120 km apart at 2.5 Gbps , depending on the quality of the fiber plant and the design goals of the DWDM system.

Ethernet
A LAN used to connect devices within a single building or campus at speeds up to 10 Mbps. Within the OSI model, Ethernet is defined at layer one (physical) and layer two (data link). Based on Carrier Sense Multiple Access/Collision Detection (CSMA/CD), Ethernet works by simply checking the wire before sending data. Sometimes two stations send at precisely the same time in which case a collision is detected and retransmission is attempted.

F&T - Forest and Trees
A term coined by Sharon Stober, Editorial Director of Outside Plant Magazine. Refers to the need to take into account not only the larger strategic vision, but also the many details that accompany any deployment project.

Ferrule
A component of fiber optic connection that holds a fiber in place and aids in its alignment.

Ferrule Rotation
When the ferrule moves, or rotates, air gaps develop between mated pair fiber cores. This results in significantly degraded, if not interrupted services.

Fiber Access Terminal (FAT)
A fiber optic access point sometimes referred to as a network access point (NAP). This may be in the form of an above ground pedestal, and aerial or buried splice closure.

Fiber Distribution Terminal (FDT)
A fiber optic distribution point sometimes referred to as a fiber service area interface (FSAI), service area interface (SAI), or local convergence point (LCP). This is an area where the primary optical feeder fibers and secondary optical distribution feeders are facilitated or combined.

Fiber Optic Cable
A fiber optic cable consists of a bundle of glass threads, each of which is capable of transmitting messages modulated onto light waves. Fiber optics has several advantages over traditional metal communications lines: Fiber optic cables have a much greater bandwidth than metal cables. This means that they can carry more data. Fiber optic cables are less susceptible than metal cables to interference. Fiber optic cables are much thinner and lighter than metal wires. Data can be transmitted digitally (the natural form for computer data) rather than analogically.

Fibre Channel
Fibre Channel is an industry standard technology for transmitting data between computer devices at up to 1.0625 Gbps and over 10 km in distance. Fibre Channel is optimized for connecting servers to shared storage devices and for interconnecting storage controllers and drives. Fibre Channel utilizes either an optical fiber or copper connection.

FTTB
Fiber to the Business/Basement

FTTC
Fiber to the Curb/Cabinet

FTTN
Fiber to the Node

FTTP
Fiber to the Premises

FTTX
Fiber to the "x" c/b/h/k

FSAN
Full Service Access Network. is a forum for the worlds leading telecommunications services providers and equipment suppliers to work towards a common goal of truly broadband access networks. For more information visit http://www.fsanet.net

Gigabit Ethernet
Another variation of the Ethernet protocol, is capable of transmitting data at one billion bits per second. This standard may eventually challenge ATM and Frame Relay as the high-speed LAN topology of choice, but, at present, ATM and Frame Relay still offer Quality of Service (QoS) guarantees that Gigabit Ethernet cannot match. Gigabit Ethernet can use high-quality copper wire at distances of less than 25 meters and optical fiber cabling for greater distances.

Headend
MSO (CATV) telecommunications office

Header Error Control (HEC)
A 1-octet field in the ATM cell header containing a CRC checksum on the cell header fields, HEC is capable of detecting multiple bit errors or correcting single bit errors.

HDSL
Unlike ADSL, High Bit Rate Digital Subscriber Line (HDSL) is a symmetric method of transmitting data at rates up to 1.5 Mbps in both directions. Because of the symmetric properties, the highest transmission rates can only be supported at lengths of 15,000-foot distances of two or more twisted pair lines.

ICP
Integrated Communications Provider (e.g. ATG)

Insertion Loss (IL)
The difference in the amount of power received before and after something is inserted in the circuit or a call is connected.

Internet Protocol (IP)
A set of rules for how data gets transmitted from one place to another on the Internet. IP is a connectionless protocol, in which data gets broken down into a number of small bundles known as packets, and each packet gets transmitted to the destination separately, possibly along a different route than other packets from the same message.

IOT
Intelligent Optical Terminal

ISP
Internet Service Provider

ITU
International Telecommunications Union

IAD
Integrated Access Device

Lambda (l)
Greek symbol used to signify wavelength.

Last Mile
The last mile is the local access network that extends from the Central Office (CO) to the end-user subscriber. Also called the local loop network, it is traditionally copper-based and suffers from the bandwidth limitations of that media.

Leased Line
A physical line that a single subscriber leases from a carrier, giving the subscriber exclusive rights to the line's capacity.

Line (SONET)
A transmission medium, together with the associated Line Terminating Equipment (LTE), required to provide the means of transporting information between two consecutive line terminating network elements, one of which originates the line signal and the other terminates the line signal.

Metro Network
A network spanning a geographical area greater than a LAN but less than a WAN (Wide Area Network). IEEE 802.6 specifies the protocols and cabling for a MAN.

MDU/MTU
Multiple Dwelling Unit/Multiple Tenant Unit - a building with more than one residence or business.

MSO
Multiple Systems Operator (i.e., CATV company)

Multi-mode Fiber
Optical fiber supporting propagation of multiple modes of light. Multimode fibers have a larger core diameter than single mode fibers.

Multi-Cast
The ability of one network note to send identical data to a number of end-points. (Usually associated with multicast video techniques where the source will send a single stream and multiple end-points will accept the stream.)

Multiplex
A general concept that refers to combining independent sources of information into a form that can be transmitted over a single communication channel. Multiplexing can occur both in hardware (i.e., electrical signals can be multiplexed) and in software (i.e., protocol software can

accept messages sent by multiple application programs and send them over a single network to different destinations).

NGDLC
Next Generation Digital Loop Carrier

OAN
Optical Access Networking

OAS
Optical Access Switch

OC-#
Short for Optical Carrier, used to specify the speed of fiber optic networks conforming to the SONET standard. The table shows the speeds for common OC levels.

OC-1 = 51.85 Mbps
OC-3 = 155.52 Mbps
OC-12 = 622.08 Mbps
OC-24 = 1.244 Gbps
OC-48 = 2.488 Gbps

ODN
The Optical Distribution Network is the optical fiber access network usually used to describe the PON Network. The ODN consists of but is not limited to the optical fiber, optical distribution cabinets, splitters, and optical access points.

ODSI
Optical Domain Service Interconnect is an open, informal initiative comprised of service providers and networking vendors. ODSI represents a coalition of networking professionals with a common interest in selecting, applying and promoting the open interfaces and protocols that will allow higher-layer service networks to effectively interoperate with the intelligent optical network core.

OLT
The optical line termination is the PON controller card or unit located at the CO. The terminal at the subscriber's end of the network is the ONT or optical network terminal. Several OLTs may be located in a single chassis. The laser at the OLT is frequently a DFB (distributed-feedback laser) transmitting at 1490nm and is always on. Signals from the OLT tell the ONTs when to send upstream traffic to it.

ONT
The optical network termination resides at the subscriber's end of the PON. It provides the interface between the network and the subscriber's equipment. Frequently the laser used at the ONT is a Fabry Perot type and operates at 1310nm and only transmits when given permission by the OLT.

Operations Administration and Maintenance (OAM)
A group of network management functions that provide network fault indications, performance information and data and diagnosis functions.

OPEX - Operational Expenditure
An expenditure for the purpose of operating a network. Labor expenses are typically the largest component of OPEX.

OTDR - Optical Time Domain Reflectometer
A test and measurement device often used to check the accuracy of fusion splices and the location of fiber optic damage.

OSP - Outside Plant
The part of the telephone system that is physically located outside of telephone company buildings.

Path (SONET)
A path at a given bit rate is a logical connection between the point at which a standard frame format for the signal is assembled, and the point at which the standard frame format for the signal is disassembled.

Payload
The data in an ATM cell or IP packets that subscribers want to access (the message, conversation, file, etc.). The term payload is used to distinguish the subscriber's data from the "overhead," which is data in an ATM cell or IP packet that network equipment tacks on to the payload to help guide its transmission across the network.

PBX
Private Branch Exchange

PON
A Passive Optical Network (PON) is made up of fiber optic cabling and passive splitters and couplers that distribute an optical signal through a branched "tree" topology to connectors that terminate each fiber segment. Compared to other access technologies, PON eliminates much of the installation, maintenance, and management expenses needed to connect to customer premises. Per the FSAN specifications PON is a point to multipoint system with one OLT at the central office servicing up to 32 ONTs. The system is single fiber with downstream traffic sent in the 1550 nm wavelength window and upstream traffic being sent in the 1310 wavelength window. This is an example of Bi-directional transmission on a single fiber. Sometimes the PON is called B-PON, which indicates it is a Broadband PON. Also it can be an APON, which is an ATM based PON or an EPON, which is an Ethernet based PON.

Point of Presence (POP)
A facility used by a network access provider to house physical equipment that enables subscribers to access the network. The term is used to describe the location where a long distance carrier connects to a local service carrier, and also the location where an Internet service provider houses equipment that enables dialup subscribers to access the Internet.

Public Switched Telephone Network (PSTN)
The traditional voice network infrastructure, including both local service and long distance service that has been in use in various parts of the world for up to a century or so.

Quality of service (QoS)
The concept of applying and ensuring specific, quantifiable performance levels on a shared network. Performance can be assessed based on physical measurements of the network, the methods by which network traffic is prioritized, and on how the network is managed.

RC
Acronym for Ruggedized Connector

RT
Remote Terminal

Regional Bell Operating Company (RBOC)
One of six telephone companies created after AT&T divestiture. Also, the acronym for the local telephone companies created in 1984 as part of the break-up of AT&T. (The six RBOCs are Ameritech, Bell Atlantic, Bell South, NYNEX, Southwestern Bell and U.S.West. Some of the six have and/or are merging.)

Return Loss
A measure of the similarity of the impedance of a transmission line and the impedance at its termination.

Router
A computer that directs bundles of data being transmitted between nodes on different networks.

Scalable
The ability to add power and capability to an existing system without significant expense or overhead.

Simple Network Management Protocol (SNMP)
A set of protocols for managing complex networks. SNMP works by sending messages, called protocol data units (PDUs), to different parts of a network. SNMP compliant devices called agents, store data about themselves in Management Information Bases (MIBs) and return this data to the SNMP requesters.

Single Mode Fiber
Used to describe optical fiber that allows only one mode of light signal transmission

SONET
Synchronous Optical Network - Standards for transmitting digital information over optical networks. It defines a physical interface, optical line rates known as Optical Carrier (OC) signals, frame formats and a OAM&P (Operations, Administration, Maintenance and Provisioning) protocol. The base rate is known as OC-1 and runs at 51.84 Mbps. Higher rates are a multiple of this such that OC-12 is equal to 622 Mbps (12 times 51.84 Mbps)

STS-1
Synchronous Transport Signal 1 - electrical SONET signal at 51.84 Mbps.

T1
Refers to a networking standard capable of transmitting data at a rate of 1.54-Mbps. This protocol is commonly employed by very large enterprises such as telecommunications companies, the Internet backbone and connections from Internet service providers to the Internet backbone

T3
A faster implementation of T1. Using coaxial cable, T3 allows for data transmission rates of 45 Mbps and is used for WAN backbones , the Internet backbone and connections from Internet service providers to the Internet backbone.

TDM
Time Division Multiplex - A method for transmitting multiple calls over a single line; each call is assigned a recurring timeslot on the line, and a small portion of that call gets transmitted over the line each time its assigned timeslot is available.

TDMA
Time Division Multiple Access

Twisted pair cable
A form of wiring in which a pair of wires are wrapped around one another again and again. Twisting two wires reduces their susceptibility to electrical interference.

UBR
Unspecified Bit Rate - a QoS parameter typically used for data transmission.

Unicast
The transmit operation of a single PDU (protocol data unit) from one source to a single destination. In Unicast video, this is one channel delivered to a single interface device. (See multicast.)

Variable Bit Rate (VBR)
An ATM Forum defined service category which supports variable bit rate data traffic with average and peak traffic parameters. A generic term for sources that transmit data intermittently. The ATM Forum divides VBR into real-time and non-real-time service categories in terms of support for constrained Cell Delay Variation (CDV) and Cell Transfer Delay (CTD).

Vault
Outside plant enclosure used to house telecommunications equipment.

VDSL
Very high-speed Digital Subscriber Line is a scheme to boost transmission speeds to as much as 52 Mbps for very short distances (up to 1000 ft.) on copper wire, or longer distances in fiber-optic networks.

Virtual Private Network (VPN)
A network service that employs encryption and tunneling to provide a subscriber with a secure private network that runs over public network infrastructure.

Wavelength
A measure of the color of the light for which the performance of the fiber has been optimized. It is a length stated in nanometers (nm) or in micrometers (um).

Wavelength Division Multiplexing (WDM)
A type of multiplexing developed for use on optical fiber. WDM modulates each of several data streams onto a different part of the light spectrum.

Appendix A
Auditing Your FTTP Network Deployment

Successful FTTP deployment begins with building a solid network foundation. It is crucial that you have a clear picture of the objectives for your FTTP deployment, your network infrastructure considerations, and the operational requirements you may face by asking informed questions.

Do you have plans to deploy FTTP, or are you considering deploying FTTP?

- ☐ Deploying now
- ☐ In the next 6 months
- ☐ In the next year
- ☐ Considering

Have you chosen a "Design Engineering" consultant?

- ☐ Yes (Name: ____)
- ☐ No
- ☐ Need assistance

Is your FTTP deployment...

- ☐ Greenfield
- ☐ Overbuild
  - ☐ Own overbuild
  - ☐ Competitor
- ☐ Refurbish
- ☐ Unknown

Have you chosen an active component supplier?

- ☐ Yes (name supplier)
  - ☐ APON (________________________________)
  - ☐ EPON (________________________________)
  - ☐ BPON (________________________________)
  - ☐ GPON (________________________________)
  - ☐ P2P Ethernet (____________________________)
- ☐ No
- ☐ Need assistance

Have you chosen a passive, OSP component supplier?

- ☐ Yes (Name: ________________________________)
- ☐ No
- ☐ Need assistance

What business challenges lead you to consider FTTP?

- ☐ Increasing revenue/sales
- ☐ Retaining subscribers
- ☐ Supporting community quality of life
- ☐ Minimizing long-term maintenance costs by retiring copper plant
- ☐ Other ________________________________

Have you built a business plan for FTTP? If so, what metrics do you target? (list metrics)

- ☐ Revenue/subscriber (____________________________)
- ☐ Cost/homes passed (____________________________)
- ☐ MTTR- Mean-Time-To-Repair (______________________)
- ☐ Cost/truck roll (______________________________)
- ☐ Provisioning (________________________________)
- ☐ Other ________________________________

Are you actively deploying other access technologies? Please check all that apply.

- ☐ DSL
- ☐ Video
- ☐ Data services
- ☐ Voice services
- ☐ TI/T3
- ☐ Wireless
- ☐ Satellite
- ☐ Other ______________________________

At what stage are your FTTP projects?

- ☐ Activating service
- ☐ First office application and/or field trials
- ☐ Vendor selection
- ☐ Collecting information from vendors
- ☐ Securing funding/budgets
- ☐ Other ______________________________

What process will you use to select vendors?

- ☐ RFI
- ☐ RFP/RFQ
- ☐ Sole source

(Audit continued on next page)

What services will you offer over your FTTP network?

- ☐ Voice
  - ☐ TR008/GR303
  - ☐ Multiple lines
  - ☐ T1/T3 (fractional T1)
  - ☐ VoIP
- ☐ Video
  - ☐ Video overlay with On-Demand/Pay-Per-View
  - ☐ Video overlay without On-Demand/ Pay-Per-View
  - ☐ QAM 256
  - ☐ Switched digital video
  - ☐ HDTV
  - ☐ IPTV
- ☐ Data (tiered service levels)
- ☐ Security
- ☐ Meter reading (municipalities and utilities)
- ☐ Interactive gaming
- ☐ Other ______________________________

Which architecture type are you deploying?

- ☐ Passive Optical Network (PON)
  - ☐ Point-to-Multipoint
  - ☐ Point-to-Point Ethernet
  - ☐ Point-to-Point ATM
- ☐ SONET Ring
- ☐ Other ______________________________

Which overall approach do you favor for your OSP network?

- ☐ Aerial
- ☐ Direct burial
- ☐ Above ground cabinet
- ☐ Above ground access terminal (pedestal)
- ☐ Unknown

Which additional considerations do you favor for your OSP network?

☐ Splicing
☐ Connectorization
☐ Combination of both
☐ Unknown
☐ Other ____

Have you chosen a splitter architecture?

☐ Distributed/Cascaded
☐ Centralized
☐ Unknown

How many “homes passed” does your FTTP network serve when fully deployed?

☐ 100 or less
☐ 101 to 500
☐ 501 to 1000
☐ 1001 to 5000
☐ 5001+

What initial “take-rate” is expected?

☐ 0%
☐ 1% to 25%
☐ 26% to 50%
☐ 51% to 75%
☐ 76+

How many total subscribers do you expect your FTTP network to serve when fully deployed?

☐ 100 or less
☐ 101 to 500
☐ 501 to 1000
☐ 1001 to 5000
☐ 5001+

If “currently deploying,” what percent of your potential subscribers are currently “turned up?”

- ☐ 0%
- ☐ 1% to 25%
- ☐ 26% to 50%
- ☐ 51% to 75%
- ☐ 76+

How would you rate the current state of fiber expertise among your technicians?

- ☐ Excellent: They are thoroughly trained in FTTP and understand the nuances of fiber optic cable management and slack storage.
- ☐ Fair: While some are experienced in FTTP, many technicians lack familiarity with the technology.
- ☐ Poor: We need to thoroughly train most of our staff in FTTP.

If you could offer FTTP now, what take-rates would you anticipate?

- ☐ Less than 10% “homes passed”
- ☐ 10% to 24% “homes passed”
- ☐ 25% to 49% “homes passed”
- ☐ 50% or greater “homes passed”

What environmental extremes will your network face?

- ☐ Temperature extremes
- ☐ Flooding
- ☐ Earthquakes/seismic activity
- ☐ Snow/ice
- ☐ Unknown

What would you say are the most critical FTTP challenges for you to overcome?

1.

2.

3.

What right-of-way constraints or community covenants impact your infrastructure options? (i.e. moratorium on "above ground" facilities, ROW federally mandated)

1.

2.

3.

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