PLANNING GUIDE

Fiber To The Premises

A Deployment Guide for Network Managers

Welcome
to the FTTP Deployment Guide for Network Managers

There has never been more pressure on bandwidth and cable plant. The resources of cable providers and telephone companies are being stretched to the limit due to the addition of such items as second lines for children, computers, security and the advent of the "smart house." This situation is compounded by the race to offer the telecommunications "triple play" – a combination of voice services; cable TV and video on demand; and high-speed data and Internet access. Until now, phone companies have lacked the video portion, since their existing copper infrastructure has had only enough bandwidth to support broadband and voice.

For branch offices, small businesses and homes seeking such services, the traditional solutions offered by telecommunications companies have been T1 lines and DSL. T1 lines are often expensive and DSL has been plagued with performance issues. And with speeds hovering around the 1.5 Mbps, neither technology offers the ability to fully support triple play.

Enter **Fiber-to-the-Premises (FTTP)**. The new FTTP technology is expected to solve this problem—transferring data at speeds from 622 Mbps to 2.5 Gbps per second to users and 155 Mbps to 622 Mbps to the network—much faster than cable modems, T1s or DSL.

According to analysts at In-Stat/MDR, the number of FTTP subscribers worldwide will grow at a compound annual rate of 49% between 2003 and 2007, by which time the cost of deploying fiber could drop to below $500 per subscriber.

The North American rollout has begun and will reach completion over the next decade—taking place in both existing and greenfield developments.

The purpose of this guide is to provide you an understanding of the issues surrounding FTTP. What are the challenges in FTTP implementations? When does it make economic sense? What should you be doing now to take advantage of the next phase of fiber optic "roll-out" in order to optimize your telecommunications infrastructure?

If you don't have the answers to some of these questions or you lack a complete understanding of FTTP, this guide is a great place to start.

Charting the Future Direction of FTTP Deployment

The FTTP Deployment Guide is designed as a hands-on reference document. We invite you to share this guide with your staff and use the information to build your own "Blueprint for FTTP Success."

It has the potential to help you and your staff in the following ways:

- Analyze the strengths and weaknesses of your current telecommunications infrastructure.
- Explore strategies for improving operational efficiency.
- Plan for the inevitable transition to triple play service delivery.

How to Use the Deployment Guide: Sections 1 through 5

The guide is broken into five easy-to-navigate sections. While this format allows you to pick and choose which sections to view, the most effective way to use this document is to work through each section in order.

You will be asked to complete an FTTP network audit, which offers the dual benefit of allowing you to document your current situation and providing ADC with the necessary information to answer your tough FTTP questions.

The guide also provides you with insight into design choices for effective FTTP infrastructure, as well as case histories from real-world FTTP implementations.

Section 1
Auditing Your FTTP Network Deployment

Section 2
Service and Technology Considerations

Section 3
Your Blueprint for FTTP Success

Section 4
Cable and Drop Wire Selection Process (Provided courtesy of Sumitomo Electric Lightwave)

Section 5
Lessons Learned: Actual FTTP Deployment Scenarios

Section 1: Auditing Your FTTP Network Deployment

Successful FTTP deployment begins with building a solid network foundation. In Section 1, we examine the objectives of your FTTP deployment, your network infrastructure considerations, and the operational requirements you may face by asking informed questions.

After you've completed this audit and carefully examined the important aspects of FTTP deployment, call 1-866-210-1122 and let ADC answer your tough 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, outside plant (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

ADC

Section 1:
Auditing Your FTTP Network Deployment

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.

Section 1:
Auditing Your FTTP Network Deployment

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. ____________________

Section 2: Service and Technology Considerations

Today's service providers require certain service and technology considerations to be satisfied as part of deciding on the best FTTP architecture for their needs. If the resources are going to be committed to build new infrastructures or overbuild existing infrastructures, it must be done right the first time. To accomplish this, the following factors must be taken into consideration as you develop your deployment objectives:

1. Maximize Revenue Opportunity
This is achieved by delivering all services: voice, video and high-speed data. The primary driver for considering an optical access system is the need to deliver the broad range of services demanded by residential customers. This translates into carrier quality plain old telephone service (POTS), cable TV (CATV) and broadcast quality entertainment video and Internet access. All three must be provided in a manner consistent with subscriber expectations such as service quality, ease of use and support for all associated features. POTS and CATV have especially high, well-developed subscriber expectations that must be met, as opposed to Internet, where the expectations continue to evolve.

2. Align Revenue to Costs
There is extensive evidence from FTTP projects around the country how varying take-rates can impact profitability and drain capital from more productive uses, such as the creation of advanced services. The challenge is to create an infrastructure that maintains capital expenditure as close as possible to revenue generation while simultaneously reducing operating expenses so investment in new services is possible.

Any FTTP business plan should incorporate a combination of low costs, exceptional service, and leading-edge technology to increase both the number of subscribers and overall subscriber satisfaction.

3. Minimize Subscriber Impact
Minimize impact on customer premise equipment and wiring. Homes come equipped with twisted pair wiring for POTS and coaxial wiring for CATV. Most homes have several analog telephones and answering machines, RF televisions, VCRs and DVDs. There also may be pre-existing telemetry equipment for security and utility management. This set of equipment and infrastructure is not something that can be easily or cheaply replaced. Existing subscriber wiring interfaces and subscriber expectations presuppose an external optical network terminal (ONT) in which will provide a well-defined demarcation between the service provider equipment and the subscriber wiring and customer premise equipment (CPE). Installation, maintenance and upgrading of this ONT are accomplished if it is located outside the subscriber's premise, as is the case for current telephony and CATV services.

4. Provide a System Solution
Service providers cannot afford to be in the system integration business. Full service solutions encompass, by necessity, a wide range of technologies. The best solutions integrate these disparate technology components into a system solution that is easy to procure, install, operate and maintain. An implied aspect of the "system solution" is accountability on the part of the solution vendor in making the entire system work.

5. Support a "Near-Term" Business Case
Service providers are drawn to optical access solutions because they expect service demand and revenue opportunities to grow rapidly in the near future. Nonetheless, any solution needs to support a near term business case based on "today's" revenue opportunities and penetration.

6. "Future-Proof" the Network
A service provider network must evolve to satisfy future demands. Accommodating a growing subscriber base, increased penetration and expanding services is a key consideration in building an optical access network. Service providers should examine the logistical and financial implications of growing their infrastructure, as well as the additional maintenance requirements.

The FTTP passive optical network (PON) architecture solution allows for seamless scalability with minimum cost while still supporting a near-term business case.

Section 3:
Your Blueprint for FTTP Success

Based on the data gathered in Section 1, and the service and technology considerations discussed in Section 2, you are now able to begin a blueprint for successful FTTP deployment in your own network. Creating an infrastructure that defers capital expenditures as close as possible to revenue generation, while reducing operating expenses, will enable you to invest in new services for your customers and new revenue streams for your company.

Along with the addition of FTTP architecture comes a new set of complicated issues and concerns to challenge network engineers. Large-scale service distribution networks require providers to rethink their traditional methods of building, operating and maintaining the outside plant (OSP) network. Which overall design, particularly in terms of which splitter approach to use, will be most cost-efficient in a particular deployment scenario? Which will provide the necessary flexibility – connectorization, splicing or a combination of both? Which components will provide the best performance? How many access points will be needed for testing and maintaining the system? How much training will technicians need to ensure proper cable management and slack storage? How does one deal with the new implications posed by FTTP for the central office (CO)?

In this section, we will show you how the network infrastructure choices you make today will impact your success tomorrow. We'll guide you through the architectural decisions and equipment selections that impact the short-term and long-term success of your FTTP network.

Acronym Key

You will encounter many acronyms throughout this document. And while they will be defined along the way, the following acronym key is provided as an ongoing reference tool.

AT	Access terminal
BDCBB	Battery distribution circuit breaker bays
BDFB	Battery distribution fuse bay
CATV	Cable television
CO	Central office
CPE	Customer premise equipment
FDH	Fiber distribution hub
FDT	Fiber distribution terminal
FITL	Fiber in the loop
FTTB	Fiber to the building
FTTP	Fiber to the premises
Gbps	Gigabits per second
HDT	Host digital terminal
LEC	Local exchange carrier
Mbps	Megabits per second
ODN	Optical distribution network
OLT	Optical line termination
ONT	Optical network termination
ONU	Optical network unit
OSP	Outside plant
OTDR	Optical time-domain reflectometer
PON	Passive optical network
POTS	Plain old telephone service
UPS	Uninterruptible power supply
VAM	Value added module
WDM	Wavelength division multiplexor

Section 3:
Your Blueprint for FTTP Success

Choosing the Right Fiber Architecture for the OSP Networks
OSP networks, particularly those deploying fiber, were designed primarily with transport and backhaul in mind—they are a means to carry telecommunications traffic on and off a larger transport system—typically over long distances. In the past, there was little demand for actual service delivery to multiple end users, although an occasional large business customer might require as much as an OC-3 or OC-48 connection.

Times have changed. Today, fiber is being deployed much deeper into the network, both for business and residential consumers. The demand for high-speed voice, data and video services is escalating and new distribution architectures must be added to OSP networks to reach these customers. However, serving the small business and residential customer requires architecture that can efficiently connect thousands to millions of users onto a local network.

FTTP systems based on PON architecture, like the one detailed in Figure 1, provide the access piece to traditional OSP networks for bringing multiple services to multiple business and residential customers.

The FTTP PON shares an optical transceiver system across a set of subscribers by use of a passive optical splitter. This allows multiple users to share the transceiver and fiber without active electronics or optics.

There are many different fiber architectures being implemented. Some place various transmission components into the infrastructure while most are passive in nature. As technologies evolve, they are replaced by improved versions. Today, it is expected that electronic transmission components will have an average installed life of seven years. In the PON, components have an expected installed life of thirty years. By selecting the PON architecture, you save the costs of prematurely replacing your infrastructure as new technologies are implemented.

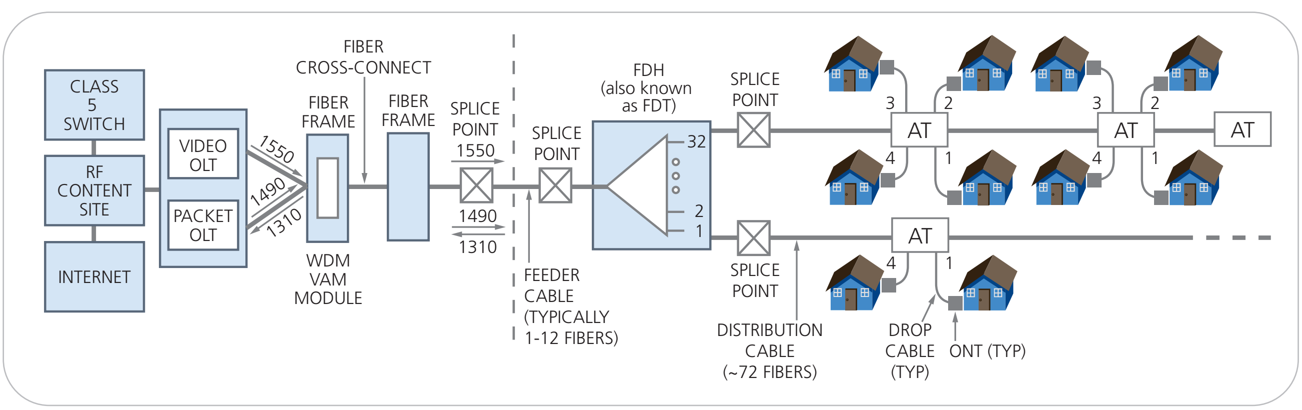

Figure 1: ADC Schematic Diagram of the PON Architecture.

Section 3:
Your Blueprint for FTTP Success

Using the FTTP PON architecture, the fiber infrastructure remains intact and is compatible with new technologies, thereby reducing the cost of upgrading your network. FTTP PON architectures are optical transmission systems designed to carry transmission signals via fiber-optic cable from the CO directly to the end user—either business units, multi-tenant units or to individual homes. The optical distribution network (ODN) is passive because once the signal leaves the central office, there are no powered electronics or optical components involved. The signal is guided through the fiber to the end user by connecting and splitting components, traveling up to, and in some cases, exceeding 20 km. At the end user, the optical signal is converted back to an electrical signal by an ONT for use as voice, data, or video.

The following points are key assumptions and definitions being proposed by Telcordia (see Figure 2), as well as several critical issues that are slated for approval in Q3/2004:

- Application Environment: Residential and small business (large multi-dwelling unit and multi-tenant unit applications may be added in future.)
- ONT Definition: An ONT is an optical network unit (ONU) located on customer premises that serves a single LEC customer.
- ONT Ownership: ONTs are network equipment owned by the LEC, but in the future, may become part of the customer-owned equipment.
- ONT Powering: Primary and backup powering of ONTs is provided by the customer.
- Digital Video Support with an Analog Video Overlay: If an analog video overlay is supported, when digital video services will by provided via sub-carrier multiplexing on the AM-VSB system and not using base band digital video transport on the fiber in the loop (FITL) system.
- FTTB Definition – fiber to the building, here the ONU is either attached to or located within a building and serves multiple LEC customers. Applications include residential multi-dwelling unit (MDU) and business multi-tenant unit (MTU) buildings.

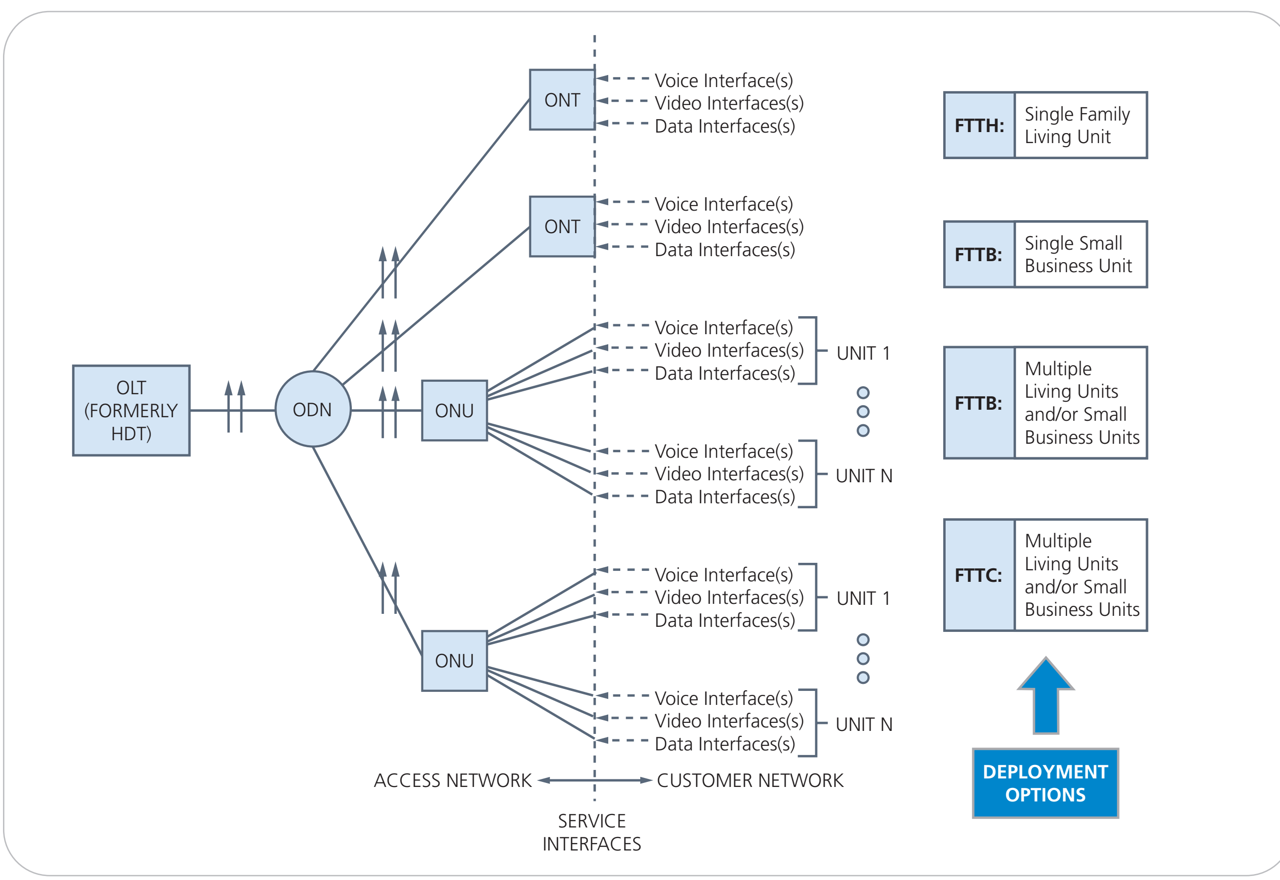

Figure 2: Reference Architecture from Telcordia GR-909 Release 2004

Section 3:
Your Blueprint for FTTP Success

Information from the end user flows from the premise back through the PON ODN to the CO, using wavelength division multiplexing (WDM) equipment, which enables different wavelengths of light to be transmitted over a single fiber in either direction. PON offers distinct advantages over competing technologies because of its passive nature, eliminating the need for any electrical power unit. The PON can function in the OSP under environmental extremes, and its low maintenance and data-independent nature provides significant operational and upgrade cost benefits to telecom providers.

Achieving High OLT Efficiency: Centralized vs. Distributed/Cascaded Splitters
The two primary configurations for high OLT efficiency are centralized splitter and the distributed/cascaded splitter arrangements. Choosing the right one can streamline the budget and boost performance. So which one is right for you?

Through research, statistical data, and lessons learned, ADC has concluded that in many cases, a 1x32 centralized splitter configuration provides distinct advantages over the distributed splitter approach. The first reason for choosing a centralized approach is to obtain the highest possible efficiency of the OLT cards. On each OLT card, the PON port services a maximum 32 end users, providing an optical signal to each ONT.

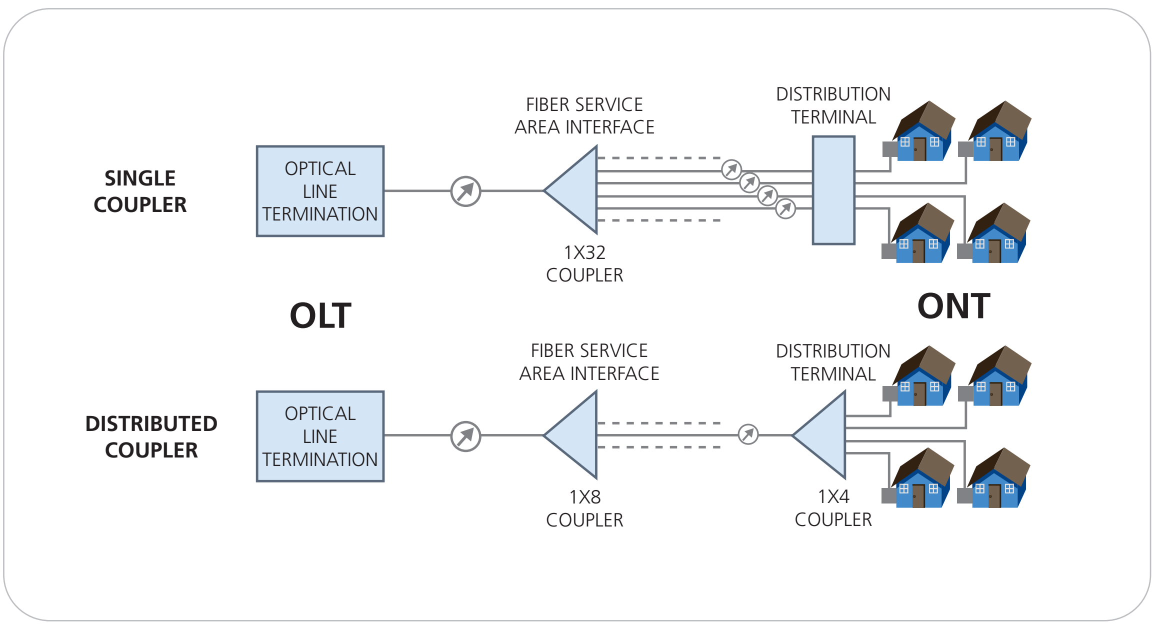

Figure 3: OLT Efficiency Diagram

Section 3: Your Blueprint for FTTP Success

The distributed/cascaded approach requires the dedication, or "hard-wiring" of fibers to certain locations, leaving a real possibility of stranding physical connections whenever take-rates are not high – making additional OLT cards a necessity. A centralized approach makes use of all 32 connections on each OLT PON port, resulting in maximum efficiency and the need for fewer OLT cards.

Testing can also become a challenge with the distributed or cascaded approach. To use an optical time domain reflectometer (OTDR), each fiber must be characterized with certain identifiable traits for recognition by the OTDR. From a centralized point, it is difficult to see through an array of splitters down individual fiber lengths. In a centralized system, all troubleshooting is done from a single, centralized point. A centralized splitter also provides better overall loss measurements compared to the distributed/cascaded approach, which can lead to increased technician time and expense. The centralized approach also requires less optical devices in the field, minimizes the chances of network outages.

One argument for a distributed/cascaded splitter approach has traditionally been that it makes more sense in a very high take-rate situation. Cable costs may be less since a 12-fiber cable may substitute for the 32-fiber cable used in the centralized architecture. However, since the price differential is probably not excessive (glass is fairly inexpensive today) and holes are being dug to bury the cable anyway, why not put the higher fiber count in case future upgrades or additions become possible? The luxury of gaining simpler testing will likely outweigh any cost savings realized in using smaller fiber counts.

Connectors vs. Splicing

Another major consideration in building a cost-efficient, yet flexible, distribution network is deciding when to splice and when to use connectors. Splicing is the physical process of joining fibers permanently together, typically via mechanical splicing or fusion splicing. Traditionally, OSP networks used splicing exclusively as a means of interconnecting cables. However, where a distribution network is involved, splicing could be a very expensive and time-consuming operation. It requires highly skilled labor and sometimes the cable to be spliced is in an inconvenient location. Quality can also be an issue with splicing. Poor quality splices can impede transmission quality and are subject to damage.

A simple rule of thumb is to splice connections that will remain permanently and use connectors wherever a need for access may occur. Still, there are other factors to consider. Splicing may be preferable for distribution cables to achieve reasonable distances that can be easily and efficiently managed. Connectors, on the other hand, provide easy access for testing and troubleshooting. They also provide the network with considerably more flexibility in terms of making adjustments or changes during services provisioning. Since distribution networks typically require numerous connections for quickly turning up services to thousands of homes and businesses, connectors offer more flexibility and less personnel training to accomplish. The number of technicians and equipment required for multiple splicing operations should also be considered.

Finally, connectors enable easier access for troubleshooting and maintenance operations. They provide access at multiple points along the network and are certainly simpler than cutting into the cable to perform these same operations. The mythical "seamless" network may have appeared as a good solution for transport and backhaul operations, but with an access network, the ability to easily test and monitor is essential. Without seams provided by connectors, there is no access or ability to physically restore a network outside of cutting into the optical cable.

The risk of inadvertent failure also increases when cutting and splicing cables, creating the possibility of service interruption or failure to other customers while troubleshooting a problem in another area of the network. To most service providers, this is an unacceptable risk.

Factory Termination vs. Field Termination

Because most budgets are tight, fiber connectorization methods are under intense scrutiny. Network operators have long faced the decision of terminating fiber panels in the field or purchasing pre-connectorized fiber panels from the manufacturer. **A simple cost analysis reveals pre-connectorization at the factory encourages quick deployment, minimizes operational expenses and ensures network integrity.**

Section 3: Your Blueprint for FTTP Success

Field connectorization requires a dedicated labor force to load, install and terminate panels onsite. For instance, you must pay technicians to load the pigtails and do the work in the field. Compared to having the work done in the factory, labor costs can accrue quickly during field connectorization. In addition, reliability may be jeopardized as technicians—unfamiliar with the intricacies of the manufacturer's equipment—attempt to integrate the panels into the network. Field connectorized panels may be less expensive at the time of purchase, but extraneous expenses encountered in the field mount rapidly.

Factory connectorization, on the other hand, minimizes installation expenses and maximizes network performance by eliminating additional labor costs and termination gaffes in the field. The manufacturer understands the complexities of its panels and the optimal methods for termination. Pre-connectorized panels are terminated correctly the first time, eliminating "do-it-again" costs.

Cost Analysis

The following cost analysis presents an ADC 72-termination fiber panel as the example for all comparisons. The factory connectorized fiber panel features 100-foot IFC cable with 72 terminated multimode SC connectors at one end and a stub at the other end. Two diverse examples of field connectorization methods are provided—field-polished terminations and pre-polished crimp terminations. Field-polished terminations are connectors that are manually attached to the fiber, often with epoxy, before being field-polished to remove the glue so it does not inhibit the passage of light. Pre-polished crimp terminations, on the other hand, are already prepared by the manufacturer and ready to use in the field. In reality, field-polished terminations are less reliable and do not perform as well under extremes of heat and cold.

The cost analysis below is based on the following assumptions:

- Hourly cost of a technician is $40
- All labor includes 30% factor for unproductive time due to delays and access restrictions
- Material costs are a compilation gathered from various industry sources
- Panels feature single-mode connectors
- IFC cable used with all fiber panels

Field Polished Termination	
Labor (45 hours)	$1800
Materials	$2618
Total Costs	$4418

Pre-Polished Crimp Termination	
Labor (35 hours)	$1400
Materials	$2888
Total Costs	$4288

Factory Pre-Connectorized Termination	
72-termination fiber panel with 100 feet of IFC cable (costs include labor and associated expendable termination materials)	$3600
Total Costs	$3600

With many operators asked to deliver more with less, factory pre-connectorization provides a key advantage over the competition. You can increase the flexibility, reliability and functionality of your FTTP network … and save money!

CO Considerations

The optical ONT and node PON electronics implement access protocols to insure appropriate quality of service (QoS) for carrier grade telephony, CATV and various Internet access service packages. Element management system (EMS) applications provide integrated configuration, provisioning, monitoring and fault management for node and ONT equipment. The EMS also provides interfaces to higher-level network management systems for network wide control of subscribers.

While much of the focus on FTTP is OSP, there are some CO considerations that can have a direct impact on broadband service delivery. There are approximately 23,500 COs in the U.S. and installed equipment varies widely. Unless the CO is optimized to support FTTP requirements, it can become a network bottleneck.

Section 3:
Your Blueprint for FTTP Success

As FTTP is deployed, it can create critical issues within the CO that include:

- Upgrades to passive and active network equipment elements
- Space reclamation as higher-density fiber frames and WDM equipment require a larger footprint than POTS equipment
- Infrastructure build-out to support high-density equipment
- Changes in primary and secondary power demands

In addition, there are issues in the CO related to the separation of assets for regulated verses unregulated business. FTTP and the delivery of triple play services will require carriers to take a close look at how their assets are segregated in a common CO.

Network Element Upgrades

Depending on the state of a given CO, it may require significant modifications, including the addition of higher-capacity active and passive network elements. Most telco switching centers were designed primarily for low-bandwidth switching. The addition of optical elements and FTTP will transition the CO to a broadband environment and introduce or increase fiber requirements. Ultimately, the transition from circuit-switched to packet-switched services will require more fiber in the CO. The CO is the critical link between the core and the edge in this migration.

As a result, high-speed transport and switching equipment will likely need to be deployed in many COs to deliver speeds of 20 megabits to 25 megabits per second. Depending on the network architecture, carriers may also need to upgrade or replace their existing DSLAMS, DLCs and NGDLCs.

Space Reclamation

As noted, higher-density fiber frames and WDM equipment require a change in space allocation as compared to traditional POTS equipment. Typically, most existing COs have little unclaimed space. Low capacity equipment, inactive network elements that are retired-in-place, improper cable management and equipment overcrowding make new technology deployment unnecessarily difficult.

Space planning using visualization of a CO based on asset-management records may be a risky proposition. For example, a recent test audit on one CO found 235 discrepancies between the asset-management database and the actual inventory, including:

- Six pieces of equipment removed but still recorded in the database
- Nine incorrect equipment location records
- One active equipment shelf not listed in the inventory
- 12% of the circuits either out-of-date or cabled to equipment that was not longer in service
- 30% of the tie-pair blocks in each bay empty in the rear

FTTP deployment should include a top-to-bottom reassessment of space, assets and facilities to create an ideal CO environment. All decommissioned equipment will likely need to be removed and active equipment may need to be consolidated or relocated in the CO to make room for new equipment. Low-capacity equipment may also need to be decommissioned and removed to free up space for newer elements. A cable mining process should be used to identify unused or significantly under-utilized cable, allowing for removal and consolidation.

Space reclamation not only makes room for FTTP, it can help improve overall service quality by improving physical access for preventive maintenance and repairs.

Additional WDM Considerations

There are definite advantages to placing the WDM inside the fiber distribution frame lineup. These include easy integration into the cross-connect system, better management of the video OLT and voice OLT ports, the fact that collocation of video feeds, etc. is simpler at the headend than out in the field, and costs tend to be lower when placing the WDM inside the fiber distribution frame lineup. There are also new considerations for fiber raceways and connector performance within this environment that will revolutionize the CO of tomorrow for FTTP.

Infrastructure Build-outs

Besides more space, optical and fiber elements need a different infrastructure than that found in most COs. Larger shelves will require changes in the ironwork as well as new cable management systems to protect both copper and fiber cabling.

New equipment will also place new demands on the HVAC systems. Optical components, fiber frames and relays produce more heat than copper components. It's likely that there will still be a fair amount of copper elements in the CO as well, and this combination will create more temperate stress.

Section 3:
Your Blueprint for FTTP Success

Power Requirements

Optical and fiber equipment requires more power than their copper counterparts. While some COs will have enough of a power budget to support this new equipment, our experience to date in FTTP shows that a number of COs will require modifications to both their primary and secondary power systems. Affected components include:

- Power boards
- Batteries
- Battery distribution fuse bays (BDFBs)
- Battery distribution circuit breaker bays (BDCBBs)
- Uninterruptible power supply (UPS)
- Rectifiers, inverters and converters

Managing Cables in the CO and OSP

ADC solutions consist of four time-tested elements that have already ensured long-time reliability and plenty of flexibility within the CO. Now, ADC has evolved these elements into the OSP cabinet environment with the craftperson in mind to ensure that field products will perform with equal efficiency.

These four specific elements, directly impacting the reliability, functionality, and operational cost of the network, are: Bend radius protection, intuitive cable routing, easy fiber/connector access and physical protection.

1. **Bend radius protection** – Fibers bent beyond the specified minimum bend diameters can break, causing service failures and increasing network operations costs. Adding new fibers on top of previously installed fibers can easily bend the bottom fiber beyond its minimum bend radius and suddenly cause an increased level of attenuation and a shorter service life (see Figure 4). By emphasizing fiber cable management, ADC provides bend radius protection at all points where a fiber cable is making a bend—preventing micro- and macrobending losses. This practice increases long-term reliability of the network, reduces down time and ultimately reduces the operating cost of the network.

2. **Intuitive cable routing** – Intuitive cable routing provides a very clear path to route a particular cable, leaving fewer options and virtually eliminating the chance for human error. In addition, having defined routing paths makes accessing individual fibers much easier, quicker and safer – reducing the time required for reconfigurations. Well-defined routing paths also

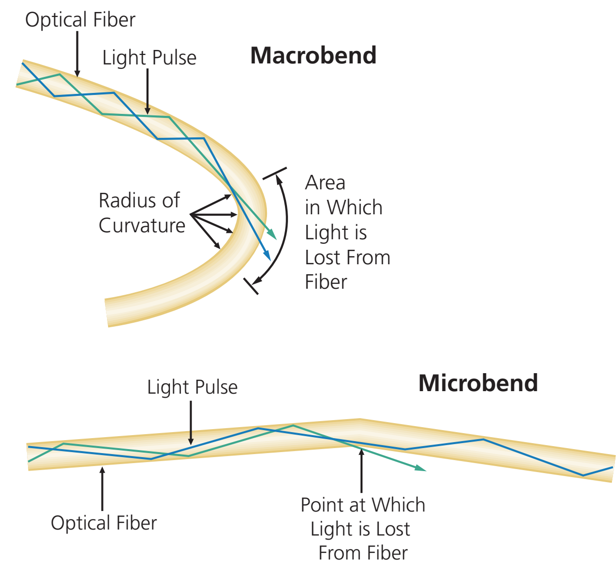

Figure 4: The Importance of Maintaining Proper Bend Radius

reduce the training time required for technicians and make patch cord routing and re-routing a simpler operation.

3. **Easy fiber/connector access** – ADC FDTs provide the ability to store unmated connector pairs in a "parking lot." This parking lot is a huge benefit to maintaining connector cleanliness. The practice of scoping every single fiber as it is being cleaned can be both cumbersome and expensive. Because ADC places individually accessible connectors on both front and rear without the need for removing an entire panel, technicians have much easier access for cleaning operations to ensure optimal connector performance. From the time each unit is shipped from the factory, a dust cap protects every connector's end face while it is plugged into the parking lot. Superior fiber cable accessibility ensures that any fiber can be installed or removed without inducing a macrobend or otherwise damaging an adjacent fiber.

4. **Physical protection** – Physically protecting every fiber and connector from inadvertent damage is a major concern in cable management. ADC's cabinet design ensures maximum protection for every optical cable and component. Fibers that are routed between pieces of equipment without proper protection are very susceptible to damage. A fiber cable management system should ensure the physical protection of every fiber.

Section 4:
Cable and Drop Wire Selection Process

SUMITOMO ELECTRIC LIGHTWAVE

Provided courtesy of Sumitomo Electric Lightwave, excerpted from the Lightwave Product Guide to the Cable and Drop Wire Selection Process

The launch of FTTP initiatives has prompted fiber optic manufacturers to broaden cable offerings, which has led to the ongoing development of new and better cable designs. Sumitomo is committed to bringing to the forefront the latest fiber and cable innovations that decrease the cost of deployment in the access network. Throughout the PON, it is essential that the fiber optic cables be carefully selected in order to reduce costs, increase productivity, and meet the objectives of your FTTP network.

Cable Design Considerations
In order to select the correct fiber optic cable design for one's planned application, the following should be considered:

- Does the planned infrastructure call for an aerial or buried installation; or a combination of both?
- Is there a concern regarding locatability and lightning and/or rodent protection?

If so, you must consider the following when making your choice between a dielectric or armored constructed cable:

- The dielectric cable requires no protection from foreign voltages, lightning strikes, etc., plus the sheath preparation time is much less than for the armored.
- The armored cable design requires the application of bonding and grounding hardware to provide a field of safety for those who work on these cable sheaths, as well as protection of the electronic equipment that the cable connects to on each end. The amount of rodent protection offered will decrease with the diameter of the cable and with a non-corrugated steel tape. Armored cable is locatable using standard techniques.

The next section details the selection process for feeder backbone/trunk, distribution cables, and the connecting drop wire.

Feeder Cable
In making the first step toward selecting the proper feeder cable design, what are the key considerations?

- When high-count fiber cables are required (such as 144f to 864f) the DriTube ribbon cable design will provide high productivity when applied with the mass fusion splicing method. It will also utilize minimal splice closure space.
- Fiber requirements below the 144f count can be packaged in a DriCore loose-tube design. The benefits of mass fusion splicing can still be attained in using this cable, by applying the ribbonizing method to the indi vidual fibers contained within the buffer tubes.
- The CO or head-end patch panel terminations are best served by being equipped with DriTube ribbon cables, in both an FT-4 cable design (OFNR) and an Indoor/Outdoor cable design. The use of this cable design will enhance productivity of labor through the mass fusion splicing method.

Backbone/Trunk Cable
As one goes deeper into the network, the use of backbone/trunk cables (96 fibers to 288 fibers) are utilized to distribute the feeder fibers. This cable can serve as a combination backbone/trunk cable and a distribution cable. When selecting the correct cable design for this application, the following should be considered.

When deploying any type of cross-connect housing, splitter housing, etc., most stubs from these types of apparatus are equipped with ribbon cable. Again, the benefits of mass fusion splicing are achieved when the backbone/trunk cables meet the stubs of these units. The design of the distribution terminals that are being deployed in concert with the stubbed products will also have an impact on selecting the cable design to use in the backbone / trunk application. Those terminals with ribbon fanouts will mate well with ribbon cables, while those terminals equipped with single fusion pigtails (when less than four pigtails) will mate well with loose-tube cables.

Section 4:
Cable and Drop Wire Selection Process

Provided courtesy of Sumitomo Electric Lightwave, excerpted from the Lightwave Product Guide to the Cable and Drop Wire Selection Process

Distribution Cable
Within the deepest area of the network lies the distribution area, where fiber counts of 12 to 72 fibers are typical. In determining which cable design to apply, ribbon DriTube®, Loose-Tube DriCore®, or filled central tube Bundle cable, the design of the terminal and its splicing method should be considered. The following information should be relevant in selecting a cable product.

- Aerial Taut Sheath Splicing. In selecting a loose-tube cable for this application, the spacing of and the identification method for the ROL (reverse oscillation lay) of the buffer tubes, is important. The unraveling of the buffer tubes at the ROL will provide the maximum in fiber slack during the splicing operation.
- In using the ribbon product in this scenario, there is no need to locate a ROL-type location. When compared to the buffer tube accessing operation, the ribbon design yields less fiber slack. The access time to reach fibers in the loose-tube and ribbon cable is about the same.
- When selecting the filled central tube bundled cable, here again there is no need to locate a ROL-type location. There is also no need to spend time accessing packaging such as a buffer tube or ribbon, to get at the individual fibers. The fiber slack yield is comparable to that of loose tube cables.
- Slack Available in Aerial, Buried, and Underground Splicing Operations. Where cable slack is provided during the placing operation, the choice of loose-tube, ribbon, or bundled cables is influenced by the following.
  - Splice closure or terminal design. Fanout or pigtail, plus storage capacity.
  - Single fusion or mass fusion (4, 8 and 12 fibers)
  - The need for fiber access tools.

Fiber Drop Wire, 1-12 Fibers
The final step in building an FTTP / FTTH connection is to select the proper drop wire for use in this application which brings the customer to the service structure. The choices are as follow:
- Aerial self-supporting drop wire
- Aerial dielectric drop wire
- Buried dielectric drop wire
- Locatable buried drop wire

The termination methods of pre connectorized; raw-end splice to fiber; raw-end splice to pigtail; are all common with the four designs listed above.

For aerial drop wire applications, the following information must be known:
- What storm loading area applies? Heavy, medium, or light?
- What span lengths are there to be met?
- What flammability standard is required?
- What is the attachment hardware preference?
- What sheath access tools are required?
- What are the bonding and grounding requirements of the area?

For aerial spans, the following applies:
- Heavy storm loading area, self-supporting span maximum is 300 feet, and the dielectric maximum is 75 feet.
- Medium storm loading area, self-supporting maximum is 500 feet, and the dielectric maximum is 150 feet.
- Light storm loading area, self-supporting span maximum is 750 feet, and the dielectric maximum is 250 feet.
- Self-supporting drop wire design requires a wire-vise type attachment hardware along with insulation hardware.
- Dielectric drop wire requires a clamping-type device for attachments.

For the buried drop wire application, which can be plowed, trenched, or pulled into conduit, the following is information that should be known when selecting between the two designs:
- Is the drop wire required to be locatable?
- If the drop wire is not required to be locatable, the standard dielectric drop should be selected.
- For locatability, consider Sumitomo's "Zip Cord" Locatable Dielectric Drop Cable, which provides customers with a superior solution over existing armored-type cable by facilitating both increased cost savings and improved efficiency when installed as a low fiber count distribution cable and as the final drop to the premise. With Sumitomo's locatable drop cable, the time-consuming process of grounding one or both ends of the cable — one to the premise and the other at the termination pedestal — is eliminated. Technicians simply zip or peel back the metallic locator by hand, separating it from the dielectric optical cable, saving hardware costs and installation time for quicker, easier, and more efficient FTTP/FTTH deployment.

Section 4: Cable Selection Guide

	Fiber Count	Cable Family	Cable Type	Cable Design	Features	Considerations and Benefits
Feeder	144 to 864	Ribbon Cable	Flooded Central Tube Ribbon	Armored Dielectric	Rodent Protection Lightning Protection	• Uses less duct and closure space than loose tube cable
			DriTube Ribbon Cable	Armored Dielectric	Rodent Protection Lightning Protection	• Improved termination productivity • Uses less duct and closure space than loose tube cable
	72 to 144	Loose Tube Cable	Outside Plant Loose Tube Cable	Armored Dielectric	Rodent Protection Lightning Protection	
			Indoor/Outdoor Loose Tube Cable	Dielectric	Lightning Protection	• Eliminate the OSP/OFNR cable transition splice
		Ribbon Cable	Outside Plant Ribbon Cable	Armored Dielectric	Rodent Protection Lightning Protection	
			Indoor/Outdoor Ribbon Cable	Dielectric	Lightning Protection	• Eliminate the OSP/OFNR cable transition splice
Backbone/ Trunk	96 to 288	Ribbon Cable	DriTube Ribbon Cable	Armored Dielectric	Rodent Protection Lightning Protection	• Distributing feeder fibers • Deploying cross-connect or splitter housing products • Stubbed distribution terminals products • Splicing to fanouts - ribbon
		Loose Tube Cable	Loose Tube Indoor/Outdoor	Armored Dielectric	Rodent Protection Lightning Protection	• Stubbed distribution terminal products • Splicing pigtails - single fiber
Distribution	12 to 72	Loose Tube	Round or Figure 8 Round	Armored Dielectric	Rodent Protection Lightning Protection	Taut sheath splicing considerations • ROL Identification required • Maximum fiber slack • Optimal for single fiber splicing
		Central Tube Bundle	Armorlux	Armored Dielectric	Rodent Protection Lightning Protection	Taut sheath splicing considerations • No required ROL Identification • Sufficient fiber slack • Optimal for single fiber splicing
		Central Tube Ribbon	DriTube Ribbon Cable	Armored Dielectric	Rodent Protection Lightning Protection	Taut sheath splicing considerations • No required ROL Identification • Sufficient fiber slack • Optimal for single fiber splicing
Drop Cable	1 to 12	Single Tube	Aerial self-supporting	Figure 8	Flame Resistance Sheath	Storm loading/Span • NESC Heavy / 300 feet • NESC Medium / 500feet • NESC Light / 750 feet
		Single Tube	Dielectric aerial/buried	Dielectric	Flame Resistance Sheath	Storm loading/Span • NESC Heavy / 75 feet • NESC Medium / 150feet • NESC Light / 250 feet
		Single Tube	Locatable buried dielectric	Dielectric with copper zip wire	• Flame Resistance Sheath • Copper zip wire provides locatable feature	Storm loading/Span • NESC Heavy / 75 feet • NESC Medium / 150feet • NESC Light / 250 feet Zip-away copper wire from NID to protect electronics

About Sumitomo Electric Lightwave

Sumitomo Electric Lightwave, located in Research Triangle Park, NC, is the North American operation within the global network of Sumitomo Electric Industries, Ltd. (SEI). Established in 1984, the company is dedicated to tailoring the fiber optic networks of major telecommunications companies through the manufacturing of optical fiber cable, ribbon-configured network solutions, interconnect assemblies, fusion splicers, FTTH products, and its FutureFlex® Air-Blown Fiber® Cabling System. First to introduce peelable ribbon fiber to the U.S., Sumitomo Electric Lightwave is the industry's leader in ribbon-configured solutions that increase the bandwidth opportunities of its customers. For more information, please call 800-358-7378, email us at info@sumitomoelectric.com, or visit us at www.sumitomoelectric.com.

Section 5:
Lessons Learned - Actual FTTP Deployment Scenarios

These scenarios are a series of real-life situations where organizations just like yours are challenged with FTTP-related issues. By reviewing each of these cases, you may find your own situation played out in the networks of others, providing you the opportunity to learn from their experiences.

Scenario #1 - Maximizing Electronics Efficiency to Defer Capital Outlay
FTTH Communications is an integrated provider of voice, video and Internet services in Minneapolis. Delivering services to residential and business customers on an all-fiber network, the FTTH Communications business plan depends upon a combination of low costs, exceptional service and leading-edge technology to increase both the number of subscribers and overall subscriber satisfaction.

Company managers had seen from other fiber-to-the-home projects around the country how varying take-rates can impact profitability and drain capital from more productive uses, such as the creation of advanced services. The challenge was to create an infrastructure that maintained capital expenditure as close as possible to revenue generation while, at the same time, offering reduced operating expenses, so that investment in new services is possible.

Solution
The solution was based in both architecture and supporting products. FTTH Communications found that the optimum architecture was a PON with passive splitters centralized in FDTs. Splitters were specified 1x32 to mirror port capacity on OLT cards in the headend datacenter. With no splitters at Access Terminals (AT) closer to the homes, FTTH Communications has been able to maximize port usage on expensive OLT cards.

To illustrate, the company uses four-port OLT cards in the data center. Each port supports 32 homes, each OLT card supporting a total of 128 homes. Each neighborhood is supported by its own FDT—up to 1,152 homes. The first 32 subscribers in the neighborhood are connected to the same 1x32 splitter in the FDT. This splitter is supported by OLT card #1 in the data center. When the thirty-third subscriber is added, the next splitter in the FDT is put to use, which then makes use of port two on OLT card #1. Only when the 129th subscriber signs up for service is there a requirement to purchase and turn-up service on the OLT card #2 in the data center.

This architecture of centralized splitters effectively defers capital expense closer to revenue generation. The alternative architecture—placing splitters in both FDTs and ATs—is an expensive proposition. In the above example, 128 subscribers from 1,152 homes are served with one OLT card when splitters are centralized in the FDT. Yet with splitters in both FDTs and ATs, additional OLT cards are required in the data center than would be needed for the customer count. In fact, with any take-rate below 100%, there would always be underutilized and stranded ports on expensive OLT cards when splitters are placed in both FDTs and ATs.

The FDT also offers the added benefit of lower costs for service turn-up because connectors, not splices, are used to add subscribers and services. As the business grows, FTTH Communications will realize operational savings because service turn-up can be done faster and with less skilled, less expensive technicians.

Section 5:
Lessons Learned - Actual FTTP Deployment Scenarios

Scenario #2 – Maintaining Reliable Service Levels While Speeding Service Turn-up
Home Town Cable is an integrated service provider operating in the City of Port St. Lucie as well as the County of St. Lucie in Florida. Just three years ago, the new company embarked upon its plan to build a PON to link homes and businesses in its service area to the company data center. Home Town officially opened for business in September 2003 with a bundle that includes standard POTS as well as alarm and monitoring services. In addition, Home Town offers 217 channels of switched digital video and gigabit Ethernet high-speed Internet service over the advanced IP-based network.

As Home Town management drew up its business and operating plans, it was clear that offering highly competitive pricing and operating profitably was going to require long-term cost containment. In addition, as a pioneer in delivering services over an FTTP network, it was also clear that Home Town's PON architecture was unique. It was going to require a different approach in the outside plant and more than off-the-shelf solutions to maintain reliable service levels and speed service turn-up.

Solution
The Home Town network was conceived as a two-fiber system – one fiber for voice and data, and one for video. In addition, planners elected to aggregate drop cables in fewer points in neighborhoods, a design resulting in far fewer above ground terminals that would appeal to both builders and homeowners.

This design for the OSP was future-thinking. With splitters in the PON rather than centralized in the headend, the company was able to reduce fiber count and construction costs. Upfront costs were also reduced by use of guide tubes and blown fiber for drop cables. By investing an additional 1% to 2% of total project costs in a cross-connect architecture for the PON, Home Town expects to generate long-term operational savings by reducing the time required for activation and troubleshooting. This small investment reduced capital investment by full utilization of PON ports in the headend, which would not be possible with an all-spliced PON. With an innovative design in hand, the task turned to finding a vendor to supply the components.

It quickly became evident that no products existed that met Home Town's unique needs. However, the company knew first-hand of ADC's track record for innovation and service in both the headend and the OSP. ADC customized ACE100, ACE200 and ACE400 OSP cabinets retrofitted with VAM (value-added module) splitter modules as well as distribution panels, splice wheels and cable storage modules from the OMX™ line of optical distribution frames.

PLANNING GUIDE

About ADC

Successful FTTP deployment requires a new approach to the outside plant—ADC answers your tough questions.

As fiber is deployed deeper into the network to enable broadband service delivery, the outside plant is undergoing significant change. ADC is a proven partner and global network infrastructure solutions leader that delivers real-world expertise and measurable success.

Offering a comprehensive line of connectivity products, ADC systems are designed and built with innovation and flexibility at the forefront. And these products are surrounded with responsive service and support.

ADC's OmniReach™ FTTP Infrastructure Solutions are the industry's first platforms designed from the ground up to meet the unique requirements of FTTP networks. By building network infrastructures upon ADC's OmniReach solutions, service providers nationwide are accelerating deployment and maximizing operational efficiency from the central office to the outside plant.

Based in Minneapolis, ADC had annual sales of $773 million in 2003. Over 7,700 employees develop and support ADC's network equipment, software and systems integration services in over 100 countries. These products and services make broadband communications a reality worldwide by enabling communications service providers to deliver high-speed Internet, data, video, and voice services to consumers and businesses.

Now that you've carefully examined the important aspects of FTTP deployment and optimization of your network, call 1-866-210-1122 and let ADC answer your tough questions.

ADC is a member of the FTTH Council.
For more industry information visit their website at www.ftthcouncil.org or visit ADC's FTTP portal at www.adc.com/fttp

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