Evolant® Solutions

Multidwelling Unit Engineering and Design Guide

ClearCurve® and Traditional Deployment Solutions

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Introduction to FTTH in MDU Applications

A Global Opportunity

Worldwide, it is estimated that there are about 680 million living units contained within multidwelling units (MDUs), which represent a significant share (35 percent) of total living units. In many major city centers, a majority of all subscribers live in MDU structures. Multidwelling units currently represent 25 percent of all housing units in the United States. These figures are higher in many European and Asian countries. A number of national governments have even set goals for delivering high-speed broadband services to their citizens. In Korea, MDUs are rated according to the high-speed access network capabilities available to their residents. In Europe, incumbent providers are focusing initially on larger city areas which have as many as 70 percent of living units in MDUs. And in Singapore, more than 90 percent of living units are in MDUs. Because of their density of potential subscribers, MDUs thus represent significant opportunities for communications service providers. Figures 1.1 and 1.2 show the proportion of MDUs in several major markets, as well as the increasing rate of deployments.

For building owners, the availability of high-speed triple-play-plus services over fiber represents a competitive advantage leading to higher property values, increased rents and higher occupancy rates. And, for tenants, the availability of high-speed fiber-based services represents an enhanced lifestyle.

Almost every building is unique, making the choice of products complex. Variations in building size, age, construction codes, materials, limited cable pathways, hardware locations, power location, building owner preferences, existing copper services and aesthetics are all important factors in deciding the best method to deploy service.

To advance the deployment of fiber to MDUs, Corning Cable Systems presents this guide and the associated solution set which emphasizes the following characteristics:

- Flexibility
- Low initial and ongoing operational expense
- Ease of use and compatibility with a variety of MDU building types and sizes
- Low profile, aesthetic, tamper-proof construction

The following pages contain solutions to the most common MDU scenarios. We recognize that even the most flexible solution sets will be challenged from time to time and we welcome the opportunity to understand your needs and respond by developing innovative product and service solutions.

MDU Challenges

There are two main challenges to deploying optical fiber within multidwelling unit structures. First, from an engineering and design standpoint every MDU is different. While there are common themes and corresponding product solutions, the challenge of solving the design puzzle is a unique exercise for each MDU.

Second, and perhaps the greater challenge from a construction standpoint, is that path creation and cable placement contain requirements unlike any other optical fiber application. MDU solution sets have thus far been largely adapted from other applications, such as private

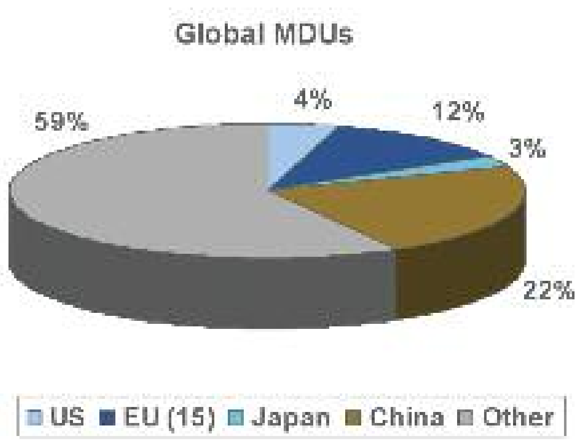

***Figure 1.1 – Estimated MDUs by Region** | Drawing ZA-3117

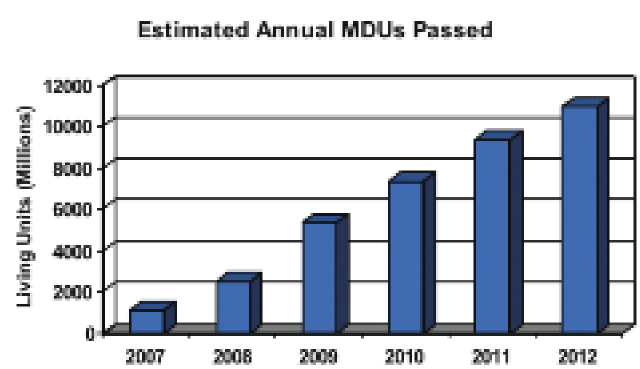

***Figure 1.2 – Total Multidwelling Living Units** | Drawing ZA-3118

**Data source: Based on internal Corning Cable Systems analysis of several external market studies in key deployment regions*

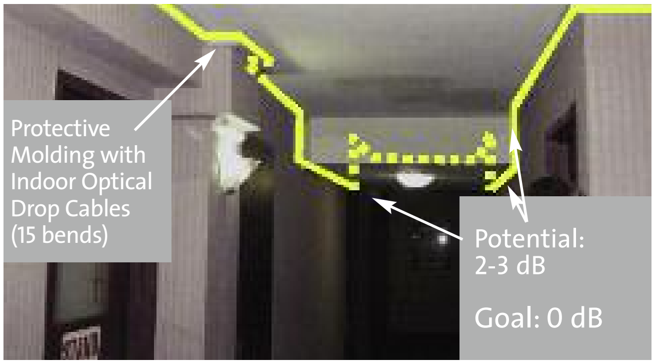

Figure 1.3 – Cable Routing in Existing MDU | Photo NS163

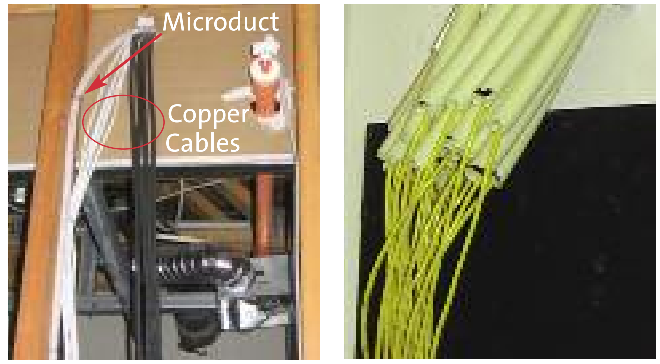

Figure 1.4 – Drop Cables to Individual Units | Photo NS161, NS160

(local area) networks and outside plant environments. Now, an MDU-specific solution has been created.

Elements unique to MDUs include:

- Lack of space for terminals, riser cables and drop cable placement.
- Spaces normally available in commercial applications are usually not accessible in MDUs. For example, hung ceilings provide access to infrastructure in commercial buildings, but ceilings in MDUs are often permanently sealed with gypsum wallboard.
- Aesthetics are very important when it comes to living spaces – owners and tenants want to use the network, but not see it.

In MDU deployments, there are attenuation and mechanical problems associated with tightly bending current generation optical cables. Because of the space limitations, as well as general installation practices for infrastructure in residential applications, the preferred pathway and installation methodology for the optical cable is the same as for copper (phone, data and electrical) and coaxial (video) cables. While all of these cables have specified minimum bend radii that must be observed, traditional optical fiber cable is more sensitive to performance degradation due to bending than are the others.

Common placement methods, which include pulling cables through and stapling to building structures (such as wooden studs, block and concrete walls), expose the cable to tight bends as low as 5 mm in radius. These conditions will induce many decibels of attenuation in small optical cables with standard fibers (or can break other elements in larger optical cables). An optical fiber that withstands very tight bends with very low signal loss – and the cable and hardware products to leverage it as a solution set – has been needed.

Figure 1.3 shows an existing MDU. In this example, cable routing along the surface, as shown, must negotiate 15 bends to pass just a few living units. There are at least two more bends before the cable reaches the terminal. Bends of this nature, if not carefully managed, will induce losses that can degrade performance in traditional fiber optic cables.

Figure 1.4 demonstrates how drop cables to individual units are often run in microduct to protect them from bending and from physical hazards, whereas copper (phone, CAT 5e) and coax (video) are robust enough to be placed as is.

Next Generation Product Preview

Through extensive research with major customers globally, Corning Cable Systems has identified the key optical MDU deployment challenges and defined a new set of requirements for MDU applications. Addressing this application, Corning's continuing innovation has resulted in ClearCurve® optical fiber, which utilizes technology within the fiber to "trap" light more effectively than other bend-optimized fibers, while remaining backwards compatible with standard single-mode fibers. ClearCurve fiber offers bending performance robust enough to enable a revolutionary suite of MDU-specific products, including both rugged and compact optical drop cables and a reduced-size MDU terminal.

Figure 1.5 – ClearCurve Rugged Drop Cables | Photo NS159

In Figure 1.5, Corning Cable Systems ClearCurve® Rugged Drop Cables are shown pulled through floor joists, just as copper cables would be pulled in a residential setting. Due to the bending capability of the fiber AND the self-bend-limiting design of the sheath, no microduct is required and tighter bending is easily accommodated.

This product suite brings unprecedented value by reducing overall material and labor, thereby minimizing total installed cost. The ClearCurve solution set is featured throughout this guide.

To the Living Unit or to the Building?

One of the key questions to arise early on in the process of taking fiber to MDUs is the question of whether to place fiber all the way to the living unit or to place fiber to a common point in the building and use copper to deliver services to each subscriber. This question stems from at least one of these vantage points:

- This is an existing building with existing wiring – why not leverage what is there and save on cost?
- The building was nearing completion when the opportunity was recognized; the builder has already placed copper – why not use that?
- The building owner(s) are opposed to running new cabling through the structure to each unit.

These are important, but not insurmountable, issues. More detail relative to each position is presented throughout this Guide, but let's look at each briefly before moving on:

Existing Building/Existing Wiring

It is certainly attractive to leverage existing infrastructure. The key concerns will be the age, and therefore *performance/quality*, of the existing wiring and the *authority* to use the wiring. Existing wiring may have been installed prior to the availability of currently recognized wiring standards. Copper twisted-pair may not have the bandwidth capacity needed. Coaxial systems may contain splitters distributed throughout the building – whereas a homerun from each living unit would be preferred. It is also important to determine who has authority to permit use of the existing cabling.

If the builder/developer installed the cabling for the owner, the owner will generally have the authority to offer use of that cable. It is therefore important to understand both the *authority* and *performance/quality* of the cabling before relying on it to deliver services.

New Building/Existing Wiring

This situation is similar to the existing building/wiring scenario, but usually offers more up-to-date wiring quality and is more promising for use with multi-subscriber electronics. Still, it is important to verify ownership and availability of the cable structure. Also, verify that the performance criteria required by the electronics to be used will be satisfied by the available wiring.

Building Owner Concerns

Building owners may prefer not to take fiber to each living unit for a variety of reasons, including disruption and security for tenants, agreements with other service providers, risk of damage to other systems and concerns over exclusivity. These concerns must be weighed against the benefits of being an all-fiber MDU. First and foremost is the value of the building and/or living units as well as the rents that they can command. As more and more MDUs offer the high-speed services available over fiber, those not able to deliver will be negatively impacted both in value and in time on the market in for sale/rent conditions.

In single-family detached housing, fiber is being taken to each home specifically to overcome the "last mile" problem caused by copper's lack of bandwidth capability.

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Using electronics designed for multiple subscribers, existing wiring may occasionally be used in MDUs, provided the optimum conditions are present. However, a choice not to place fiber all the way to the living unit today should not preclude it in the future. In fact, the bandwidth limitations of most copper systems imply that conversion to fiber will eventually be needed. Therefore, if an initial choice is made to use multiuser electronics, a migration plan should be put in place to facilitate conversion to fiber-to-the-living unit at a later date. This plan will involve placing sufficient fiber to the MDU building to support fiber to each unit.

Two Design and Deployment Philosophies

Design and deployment of fiber to living units in MDUs (and FTTH in general) can be accomplished with either of two philosophies. The ready-to-connect philosophy leverages factory-built cable assemblies and compatible hardware to create ready-to-connect network elements that install quickly. The field production philosophy assembles individual components in the field to create the network solution. Both philosophies provide high-performance, high-quality networks. Selecting one approach over the other, or combining the two in a large deployment, is an important choice that should be understood up front. The following paragraphs outline the logic behind each philosophy to aid in this decision. The design principles put forth in this guide are valid regardless of which approach is used and Corning Cable Systems products support both approaches.

Ready-to-Connect Philosophy

This approach requires the engineering of each cable route, including distances, terminal locations, fiber counts, slack cable needs, etc. This information is then supplied to the factory so that optical cable assemblies can be built to the defined requirements. The cable assemblies, or terminal distribution system (TDS), are shipped to the job site ready to place. All terminal locations have a factory-installed and tested multi-fiber connector to which prestubbed terminals are connected during the initial installation or as service is required. Because each terminal location is factory prepared, splicing is only required at the central office/headend (CO/HE) side of the assembly, where it is spliced to a main distribution cable or local convergence point ("hub" with splitters). This approach can support accelerated MDU deployments. It can be a strategic business tool to position a provider to quickly capture market share. It works very well in regions with high labor rates or where adequately skilled labor for splicing is in short supply. It also offers the benefit of building a large part of the network in factory clean conditions, where environmental factors and work site conditions do not affect production. The designer must also evaluate the suitability of the MDU building to this type of a solution. If the building has an available riser duct, consistent distances between wiring closets and clear pathways, this approach can be easily adapted. These attributes are often the case in larger MDUs, particularly in greenfield applications. This means even greater value can be obtained from the inherent advantages of this deployment approach.

If high labor rates, a shortage of qualified talent, the need for accelerated deployment, and/or favorable MDU building configurations are present, the ready-to-connect philosophy may be appropriate.

Field Production Philosophy

This approach integrates discrete components into the network onsite. Instead of factory made-to-order assemblies, bulk cable, closures and terminals are spliced in the field using traditional placement and construction techniques. This approach offers a great deal of flexibility, especially where it may be necessary to make design changes at the last minute or "on the fly." It leverages readily available and reasonably priced labor as well. Since it is more labor intensive than the ready-to-connect approach, the construction phase, from ground breaking to system turn-up, will be longer. For some MDU structures, particularly older and smaller MDUs with existing copper plant, the field production method is not only preferred, it is required. It is important to note that most operators using the field production philosophy do so for the riser (if required) and terminal portions of the MDU building network. Drop cables, the last link to the customer, can also be field spliced, but are typically preconnectorized on one or both ends.

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If your project has an ample time horizon, reasonably priced labor is available and the building is not conducive to the ready-to-connect approach, the field production method may be the right choice for your deployment.

Corning Cable Systems' Products Support Both Approaches

Whatever the need, Corning Cable Systems has a solution that will enable you to deliver fast, easy and reliable high-capacity broadband services to your customers. Whether you follow the ready-to-connect philosophy, field production philosophy or leverage aspects of both, Corning Cable Systems offers a full solution set from the living unit to the CO/HE. Corning Cable Systems Evolant® Solutions for Access Networks offer factory-terminated and field-installable solutions that reduce installation time and deployment costs for MDU optical access networks. Our Premier solutions support the ready-to-connect philosophy, while our Classic and Advantage solutions support the field production philosophy. We have the experience and innovation it takes to deliver scalable solutions that accommodate any MDU configuration. Corning Cable Systems is pleased to brings our decades of experience in public and private networks hardware, cable, high performance connectors and plug-and-play solutions to this exciting application.

Typical MDU Scenarios

MDUs come in many sizes and shapes. Following are some generic examples of MDU layouts and how cabling might be addressed. Note that cabling solutions can be deployed on the *inside* or *outside* surface of a building to connect the subscribers within, depending on the pathways and spaces that are most favorable for the network.

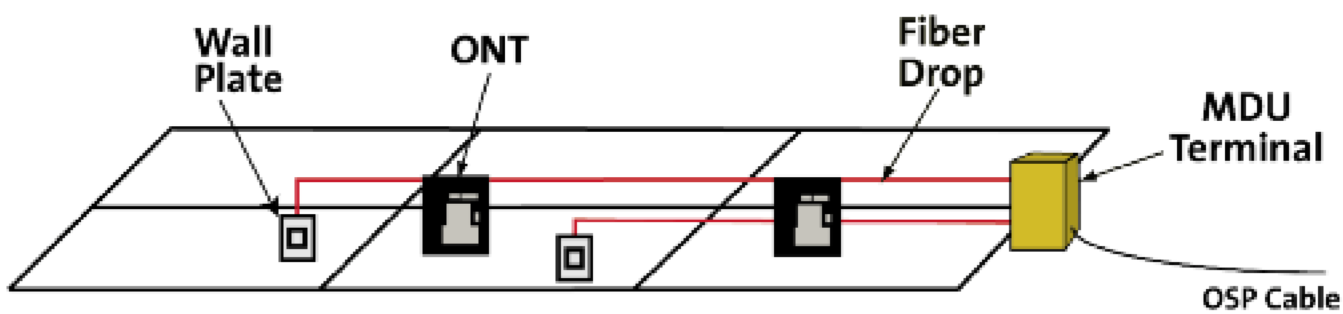

Figure 1.6 – Single-Level MDU | Drawing ZA-3102

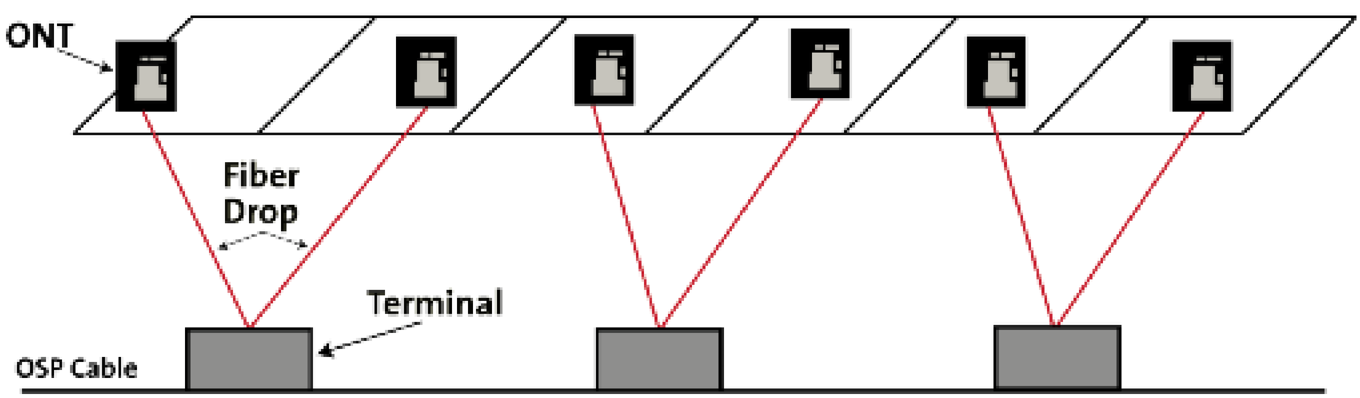

Figure 1.7 – Single-Level MDU | Drawing ZA-3240

Single-Level MDUs

The first example (Figure 1.6) illustrates a deployment where cabling is run within the building. In this case, cabling is run in common areas and is therefore unaffected by whether the building is owned by one entity or the units are owned individually. This scenario also shows the drop cable going to a wall plate instead of directly to the ONT.

In the second example (Figure 1.7), the structure is laid out as town homes (single-family *attached*) with small backyards. In this case, the units and yards are assumed to be individually owned. Because of the physical layout and ownership, the living units are often connected using the same techniques as single-family *detached* housing, with external terminals and individual drops to each unit. Depending on what is acceptable to building owners, it may be necessary to use this external approach or, when permitted, cables may be run through the structure, connecting living units as a true MDU. Figure 1.7 also shows the option of running the drop cable directly to the ONT.

Multi-Level MDUs

In this scenario, an MDU terminal is placed on each floor and individual drops are run from the MDU terminal to the optical network terminal (ONT) at each living unit. Riser cabling connects the MDU terminals back to a central piece of hardware at the building point of entry (PoE). For larger MDUs, a hub with splitters may be located at the PoE. For smaller MDUs, a standard splice location may connect an outside plant cable that leads to an external hub (where splitters may be located).

In Figure 1.8, the riser cabling may be spliced to the MDU terminals onsite or factory prestubbed assemblies may be used. If factory prestubbed assemblies are used, the terminal has a cable already installed which can be pulled down a riser or other pathway to be spliced to a main distribution cable or to the PoE or hub.

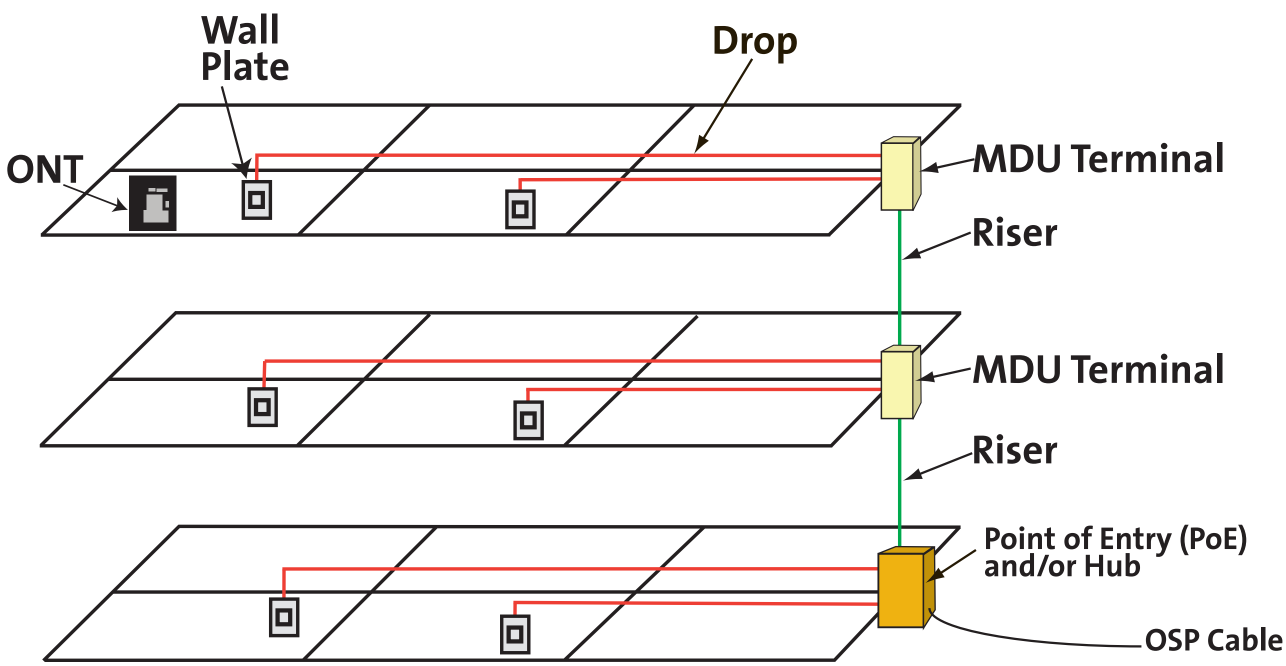

Figure 1.8 – Multi-Level MDU | Drawing ZA-3101

Chapter Two:

Transport Technology, Standards and Requirements

This section provides an overview of network architectures, industry standards and electronics-related topics that impact the engineering and design of fiber-to-the-home (FTTH) networks in general. It then applies these topics to MDUs, specifically. As described in this section, there are two primary approaches to FTTH networks, one based on passive optical network (PON) standards and one based on Ethernet standards. It is important to note that fiber supports both technologies. In most cases, with proper planning, the same optical fiber infrastructure can support either technology.

This section will cover:

- Point-to-Point (P2P) and Point-to-Multipoint (P2MP) Optical Networks
- Architectures
- Topologies
- Electronics Overview
- Access Standards (BPON, GPON, EPON/Ethernet)
- Alternatives to Fiber-to-the-Living-Unit Deployment (Multi-Unit ONTs)
- Complementary Solutions

***NOTE**: If you are familiar with FTTH architectures and transport technologies, you may wish to skim this chapter and move quickly to the next chapter on Design Considerations.*

P2P and P2MP Optical Networks

Both point-to-point and point-to-multipoint optical solutions are in use today for access networks. It is important to understand the basic definition of these two approaches and how they will relate to the discussions that follow. Point-to-point networks use a dedicated optical fiber to each subscriber from the central office where that fiber is connected to its own dedicated optical electronics port. In P2P networks, no splitting of the signal or bandwidth, optical or electrical, takes place between the CO/HE port and the subscriber equipment (Figure 2.1).

In point-to-multipoint networks, a one-to-many relationship is created, either by splitting the optical signal or by using electronics. This allows a single CO/HE electronics port to serve more than one subscriber, which can reduce electronics cost and space requirements. The splitting may be located in the CO/HE or in the outside plant (Figure 2.2).

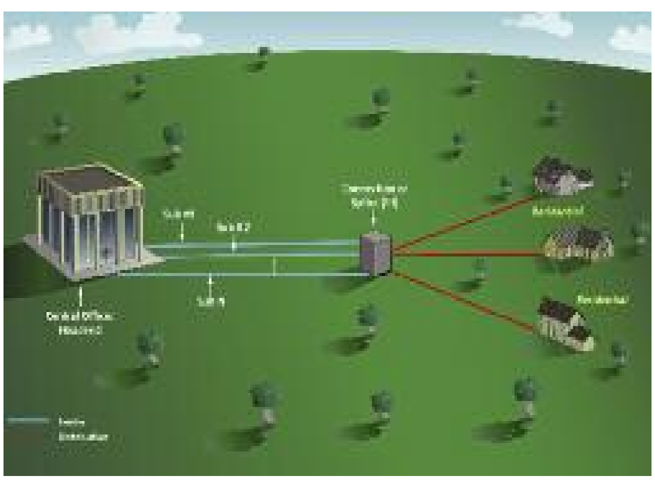

Figure 2.1 – Point-to-Point Optical Network | Drawing ZA-3125

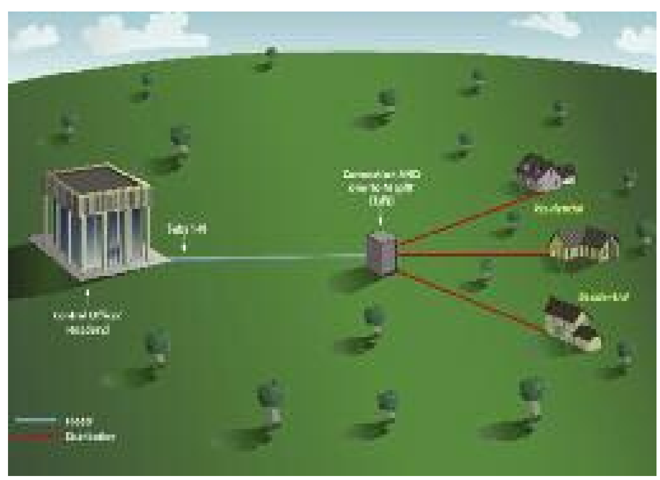

Figure 2.2 – Point-to-Multipoint Optical Network | Drawing ZA-3126

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Note, too, that the term passive optical network (PON) implies that all components between the CO/HE and the subscriber premises are passive (non-powered) devices. P2P optical networks would be considered passive between CO/HE and subscribers. P2MP optical networks can be passive unless active electronics are placed in the field, between CO/HE and the subscribers. The architectures described below can support both P2P and P2MP, though some combinations are more favorable than others.

Architectures

Today's FTTH networks utilize a range of PON designs. There is no standard PON design that will work for all systems. Fortunately optical fiber enables delivery of voice, video and data regardless of the electronics technology selected. To better understand network design for MDUs, a brief overview of the entire network is beneficial.

The ***architecture*** defines the logical or theoretical view of the network. It shows how the components (cable, hardware, splitters and electronics) must relate, operate and connect to allow data to flow. The architecture serves as the model around which the network is designed. Architecture selection is driven by both the goals of the business model, as well as the choice of network electronics.

The business model will determine cost, performance, future-proofing and technological adaptability requirements for the network. The electronics will determine basic requirements such as the use of splitters, the split ratio required and placement in the network. Even if a point-to-point network is being designed (such as Ethernet solutions without splitters), there is usually a one-to-many relationship created in electronics rather than splitters. Either way, considerations are similar.

There are three key architectural models, each having its own advantages. The three architectures are the central switch homerun (CSH), the local convergence homerun (LC) and distributed splitting (DS) (Figure 2.3).

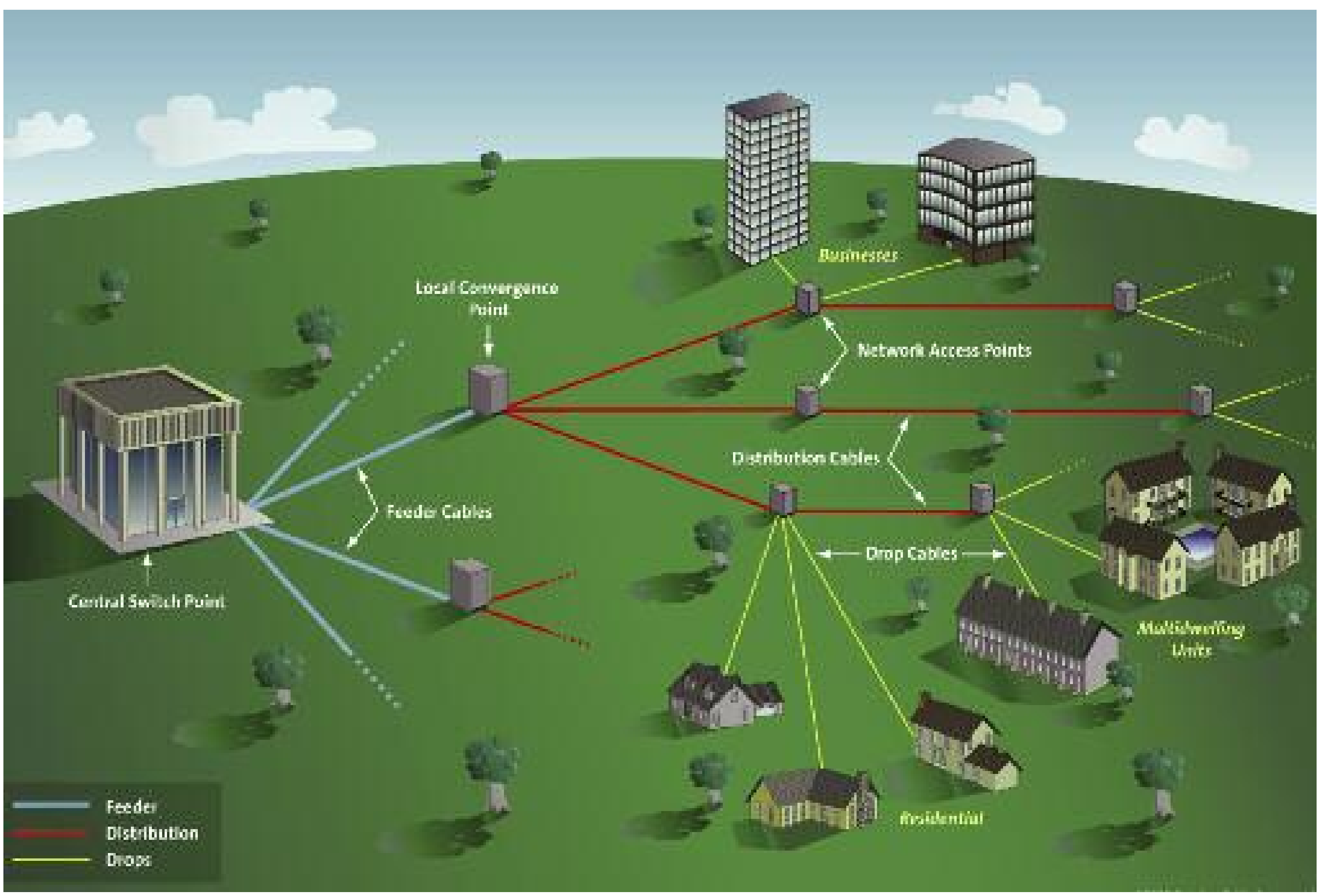

Figure 2.3 – Access Solutions Generic Architecture | Drawing ZA-2301

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Central Switch Homerun

In the central switch homerun, each living unit has a dedicated fiber path all the way back to the central office/headend (CO/HE). All electronics and any splitters, if used, are at the CO/HE. This is highly robust in terms of information capacity and technological insensitivity, but is also very rich in fiber, splices, connectors and hardware. This solution also consumes significant space in the CO/HE. It is the most robust architecture, from a performance and adaptability perspective, but carries a cost premium. It can support both P2P and P2MP networks; any splitting within a P2MP network would take place within the CO/HE.

Local Convergence Homerun

The local convergence approach moves all splitting (passive or electronic) to or near the neighborhood being served. A local convergence point (LCP), usually a cabinet, is placed in the neighborhood where subscribers will be served — any and all splitting takes place at this point. The technical benefits are similar to the CSH model, but with less fiber in the feeder segment, less congestion in the CO/HE and lower cost. This is the most popular architecture in use today. It, too, can support P2P and P2MP networks; where used for P2P, the local convergence point becomes a cross-connect rather than a splitter location.

Distributed Splitting

The distributed split approach uses multiple tiers of splitting, one feeding the next, so that the amount of fiber in the network is minimized. It is limited in application because it does not support easy changes in split ratio, and at low take rates, it is not efficient at aggregating subscribers into the least amount of CO/HE electronics cards, requiring added investment. On the other hand, it does have applications in very rural areas, where low population densities make it nearly impossible to determine a common location for the local convergence point. Distributed splitting is better suited for passive P2MP networks. If actives are used to create the one-to-many relationships at the various "splitting" points, the quantity, powering and maintenance of so many devices would become unfavorable.

Topologies

In each architecture, the hardware locations (CO/HE, LCP, etc.) are connected via optical cabling. The cable from the CO/HE out to the first splitter (or electronics) location is considered *feeder cable*. A large feeder cable may serve multiple LCPs by "dropping" sufficient fibers at each LCP it passes. The cable from the LCP to the terminal that serves a home or living unit in a building, is known as *distribution cable*. The cables that run from the last terminal (usually single-fiber cables) and make connections to individual homes or living units are called *drop cables*. The functional parts of the architecture that are contained within or on the walls of the MDU can range from as little as the drop cables inside and the MDU terminal just inside or on the exterior wall, to the entire distribution and drop (including the LCP with splitters) being in the MDU. How the network architecture is mapped into the MDU structure is determined by the selected *topology*.

The *topology* is the physical layout/configuration of the network that establishes where components are physically located as well as the physical routes for cables. It specifies how the architecture is physically mapped onto streets and into the building structure and supports the logical relationship dictated by the architecture. Topologies must often be tailored to the specific MDU under consideration – a testament to the fact that *every MDU is different*. A standard topology for a multi-level building uses one or two risers that are tied in to a single point of entry – whether one or two risers are present, the model is basically the same (Figure 2.4).

While one architectural model is usually standardized throughout the network, the physical layout – the *topology* – can vary significantly. The choice of topology will vary according to the size and layout of the building being cabled.

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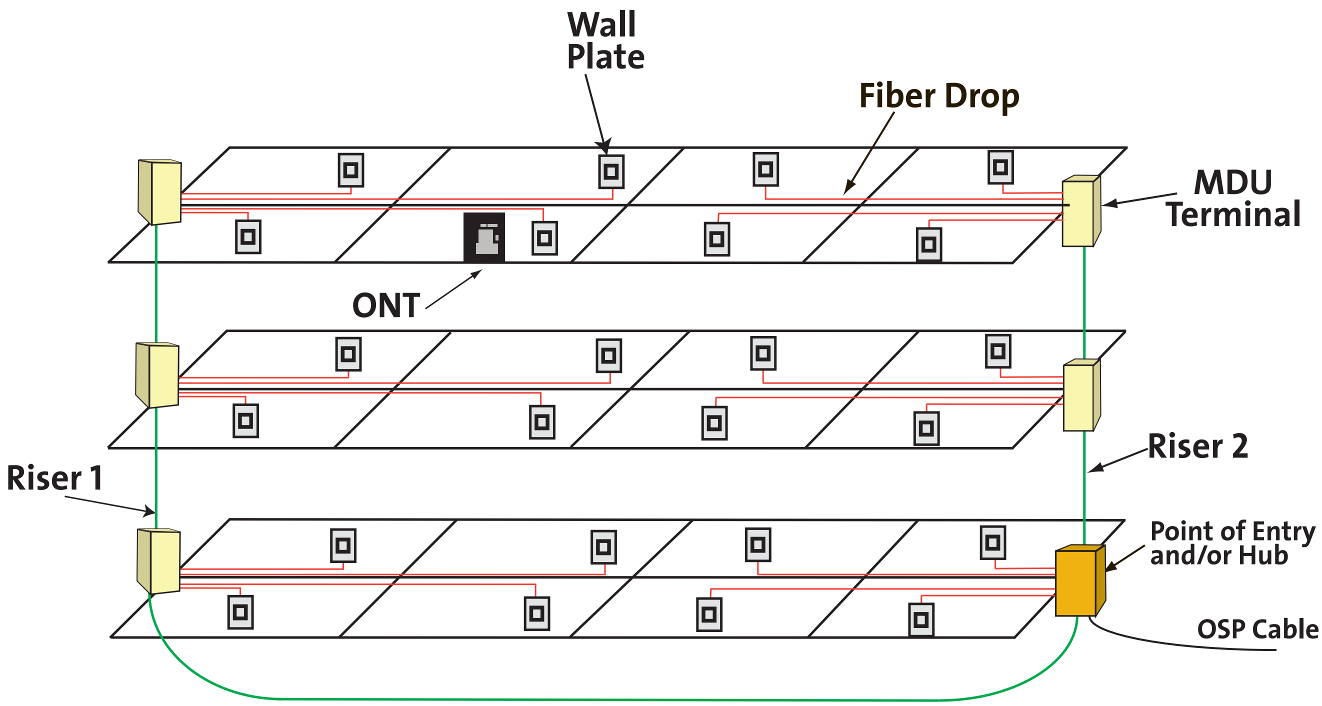

Figure 2.4 – Multi-Level Building Topology | Drawing ZA-3104

Large, multi-level MDUs with 72 or more tenants in one building may be best served by placing the LCP cabinet in the building basement. Smaller MDUs can be served from an LCP cabinet placed in the neighborhood or in the complex, for multi-building facilities. The LCP may service one or more MDUs as well as single-family residences. The MDU is therefore located in the distribution segment of the network, and it contains subscribers, their electronics (ONTs), drop cables and distribution cables (such as the building backbone). It may or may not contain the splitters.

In the Design Considerations chapter, choices focused on the topology are treated in greater detail as it relates specifically to MDUs. Each MDU building must be analyzed to determine which model elements to apply to a particular structure.

Electronics Overview

The electronics (active) portion of the network consists of equipment placed at the CO/HE and at the customer premises. Passive optical networks (PONs) are those which have no active devices between the CO/HE and the subscriber living unit. Some solutions, such as Ethernet technology, may use active devices at the local convergence point to aggregate upstream traffic and separate downstream traffic to individual subscribers. The CO/HE equipment is modular in nature, with a chassis that holds cards for various functions such as data and voice services. Video may be delivered by either an RF overlay (similar to conventional CATV delivery and using a separate wavelength than the voice and data), or it may be delivered over the same technology as the voice and data using Internet protocol television (IPTV). RF video solutions are common today, as they place less demand on the data link and use readily available electronics. Because IPTV delivers video over the same link as voice and data, it requires higher data bandwidth capacity in the link. IPTV is a newer technology (compared to the RF overlay) and is gradually being adopted. One benefit of migrating to IPTV is the elimination of separate electronics for video delivery. Networks that deliver voice, video and data (known as triple-play services) can generate the greatest revenues.

It is important to understand the relationship between the choice of electronics and the choice of architecture. Access networks that use optical splitters create a point-to-multipoint (P2MP) relationship between the CO/HE and the subscriber's electronics. In this case, a single port at the CO/HE serves 16, 32 or 64 subscribers. Any of the three architectural models can be used to construct a P2MP network. When no splitters are used, a point-to-point (P2P) relationship exists between the CO/HE and subscribers, meaning that each subscriber has a dedicated port at the CO/HE. In this case, only the central switch model can support the network. Note that networks with all splitting at the CO are still P2MP networks and those with electronics in the field are not PONs.

The following sections describe the basic building blocks for FTTH PON networks. A variety of equipment vendors offer the necessary ONTs, OLTs and video electronics. Figure 2.5 shows the relationships among the various network elements, including the components for RF video overlay. A system using IPTV would not require the 1550 nm elements.

Optical Line Terminal (OLT)

Located in the CO/HE, the OLT distributes signals throughout the PON and is typically a modular chassis with a number of cards. It is controlled/configured using software on a connected computer. The OLT is responsible for controlling signaling to/from the ONTs that are located at each subscriber's living unit. Services are provisioned through the OLT.

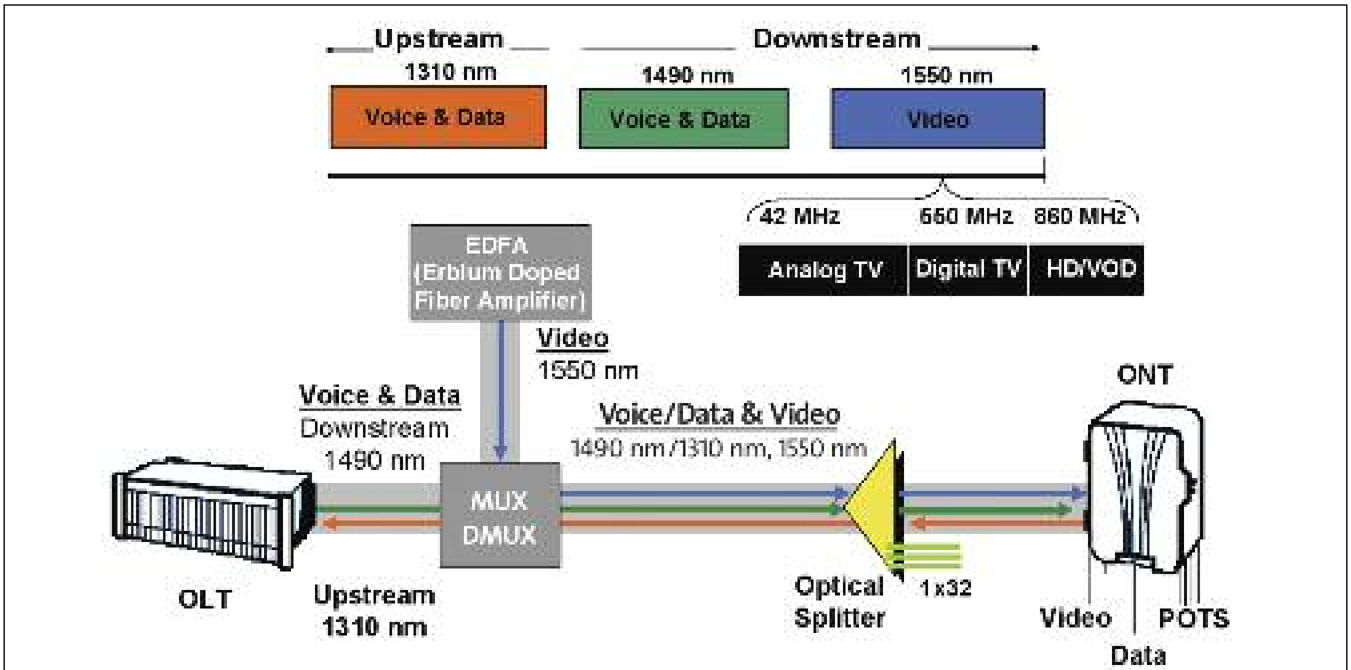

Figure 2.5 – Electronics Overview | Drawing ZA-3119

OLT Line Cards

OLT line cards are the actual interface between the CO/HE equipment and the subscriber ONTs. Cards are available in one, two and four PON interfaces (each interface being 16, 32 or 64 subscribers). Cards transmit at 1490 nm and receive at 1310 nm for voice and data.

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Erbium Doped Fiber Amplifiers
Erbium doped fiber amplifiers (EDFAs) are used for RF video transmission systems. RF video signals (similar to broadcast cable television) are amplified and split in the CO/HE before being sent out over the PON fibers at 1550 nm. The amplifiers are placed between the one original video feed and the wavelength division multiplexers (WDMs) that are used to combine the video with the voice/video signals. Each PON (containing 16, 32 or 64 ONTs) requires sufficient optical power for video to ensure each ONT will provide acceptable video picture quality after the signal has experienced the attenuation due to the fiber, connectors, splices and splitters in the fiber network. Optical power outputs leaving the CO/HE for RF video are typically 15-20 dBm.

Optical Network Terminals
The optical network terminals (ONT) are the customer premises equipment which decodes the optical signals, converting them to the twisted-pair, CAT 5 and coax formats used by devices in the living unit. It also serves as the service provider demarcation point between the carrier network and the customer wiring. Transmissions back to the CO are likewise converted to optical signals at 1310 nm to be carried upstream on the same fiber. The ONT itself is bundled with equipment to provide back-up power, ensuring basic service availability in the event of a power outage. Figures 2.6 through Figure 2.9 show examples of wall-mountable and flush-mountable ONTs.

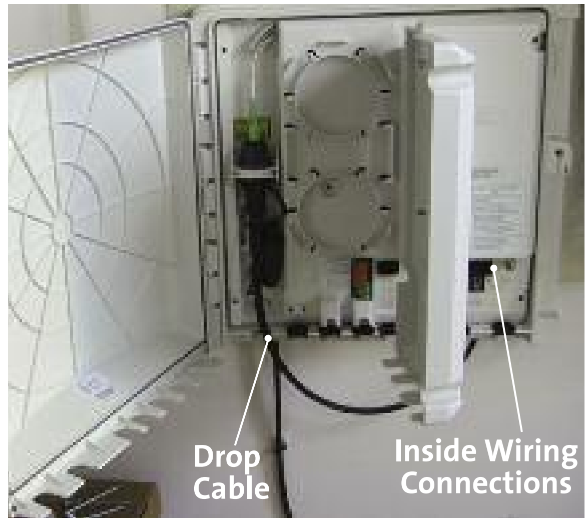

Figure 2.7 – Wall-Mounted ONT Showing Connections | Photo NS115

Figure 2.8 – ONT for Mounting Between Studs | Photo NS116

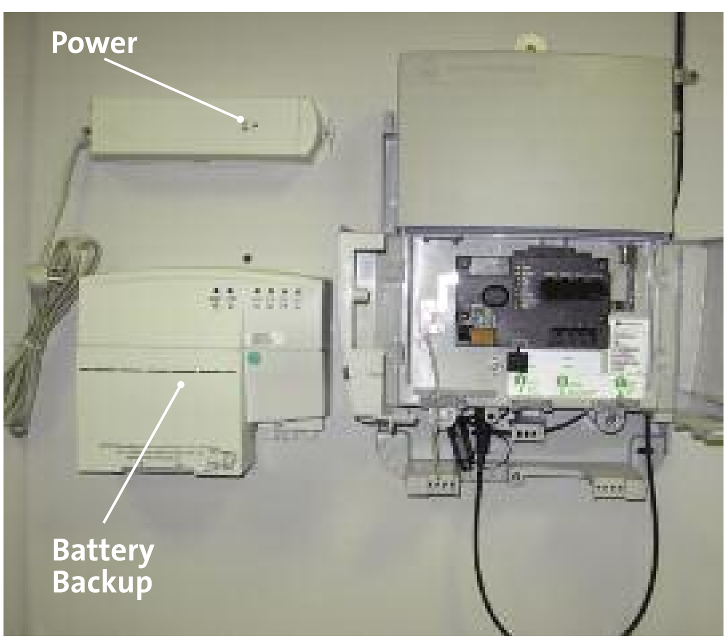

Figure 2.6 – Wall-Mounted ONT with Power Supply and Back-Up Power | Photo NS114

Figure 2.9 – ONT for Mounting Between Studs | Photo NS117

Access Standards

Standards provide a common foundation for multiple equipment providers to be able to design and sell equipment that will interoperate within the same network. They minimize a great concern of equipment buyers by avoiding vendor-proprietary solutions. Standards set up clear specifications for service providers', component vendors' and end-users' building access networks using this developing technology. Standards address service provider equipment (SPE), customer premises equipment (CPE) and network architecture and components.

There are currently two industry organizations promoting optical fiber access standards. The International Telecommunications Union (ITU-T) supports the Full Service Access Network (FSAN) group, which has developed standards for ATM-based networks. The IEEE (Institute of Electronic & Electrical Engineers), through the Ethernet in the First Mile (EFM) group, promotes access standards using Ethernet.

The ITU-T is backed by the telecom industry. Standard G.983 (Figure 2.10) provides standards for BPON (broadband passive optical networks), while G.984 (Figure 2.11) provides definition for GPON (gigabit passive optical networks). Both are based on ATM and offer a range of upstream and downstream data rates. Both forms support 1x32 and 1x16 passive splits. The G.984.2 standard also supports a 1x64 split and several electronics vendors are now supporting this ratio. On the horizon, 1x128 split ratios are under consideration within the industry.

BPON (G983) Line Rates	Upstream	Downstream	
Network Line Rates	1F: 1310; 2F: 1310 nm	1F: 1550; 2F: 1310 nm	Unit
Option 1: Symmetric	155.52	155.52	Mb/s
Option 2: Asymmetric	155.52	622.08	Mb/s
Option 3: Symmetric	622.08	622.08	Mb/s
Option 4: Asymmetric	155.52	1244.16	Mb/s
Option 5: Asymmetric	622.08	1244.16	Mb/s

Figure 2.10 – BPON Line Rates | Drawing ZA-3120

GPON (G984) Line Rates	Upstream	Downstream	
Network Line Rates	1F: 1310; 2F: 1310 nm	1F: 1490; 2F: 1310 nm	Unit
Option 1: Asymmetric	155.52	1244.16	Mb/s
Option 2: Asymmetric	622.08	1244.16	Mb/s
Option 3: Symmetric	1244.16	1244.16	Mb/s
Option 4: Asymmetric	155.52	2488.32	Mb/s
Option 5: Asymmetric	622.08	2488.32	Mb/s
Option 6: Asymmetric	1244.16	2488.32	Mb/s
Option 7: Symmetric	2488.32	2488.32	Mb/s

Figure 2.11 – GPON Line Rates | Drawing ZA-3121

Chapter Two:
Transport Technology, Standards and Requirements

The IEEE supported network, backed by the Ethernet community, is described in the 802.3ah standards documents. It resembles an Ethernet WAN and is referred to as EPON. It typically is a point-to-point optical path between active components but the standard also supports a 1x16 passive split. Both 100 Mbs and 1 Gbs (GEPON) speeds are defined, as well as 1- and 2-fiber solutions. Ten Gbs systems are under consideration.

Both the ITU and IEEE standards support 20 km maximum ranges between OLT (in the CO/HE) and the ONT (at the subscriber). This includes the total length of the feeder, distribution and drop segments of the network. Some vendors may offer proprietary solutions with greater ranges.

A note on split ratios: Higher split ratios are being enabled by both the standards and availability of electronics to support higher data rates in the PON. This allows the higher rate to be split more ways with fewer splitter modules and OLTs. However, two things must be kept in mind when designing the network. First, higher ratios mean a larger system loss budget (so it is important to make sure the choice of electronics and splitters will not compromise the distance requirements of the network). Second, most of the deployments to date have used RF video overlay as the means to deliver broadcast video services, so that the BPON or GPON is not burdened with video, except for special services such as pay-per-view and video on demand. In the future, a transition to IPTV (Internet Protocol Television) is highly likely. This change will eliminate the RF video overlay, moving video into the same data stream used for voice and data. This significantly increases the bandwidth needs on the PON itself. The network designer should plan fiber counts in the feeder portion of the network (between CO/HE and the splitters in the field) to accommodate a 1x16 split ratio. Higher ratios can be used to better utilize capital investment in electronics and splitters. The higher fiber counts, which are inexpensive in the broad network picture, provide the flexibility to use a wide range of ratios to support a variety of technologies in the future.

With the proper choice of architecture and topology, it is possible to create physical layer networks that will support equipment for both sets of standards. Within the ITU standards, BPON and GPON can be supported by the same physical layer network, making migration from one to the other extremely easy. The optical fiber itself is protocol independent, as both work using standard single-mode fibers. Today, nearly all FTTH networks use one fiber per residential subscriber, with traffic moving in both directions. In cases where multiple fibers to one subscriber are deployed, it is generally intended for use by other network applications (such as security) or provisioned for future use.

Alternative Solutions

While the most common method is to use single-subscriber ONTs and deploy them at each living unit, alternatives are currently being used or considered in the industry. One alternative method uses a multiuser ONT which deploys individual subscriber services using copper and/or coax that runs through the building to each living unit. This method's primary attraction is to be able to utilize existing copper wiring in the building. In some cases, the building owner may simply prefer this approach. Before this technology is considered, it is critical to verify that the existing wiring in the building meets the required bandwidth and distance specifications for the multiuser ONT being used. Substandard wiring will result in poor network performance requiring rewiring with new copper or a complete upgrade to an optical fiber solution.

Multiuser ONTs (mu-ONTs)

Multiuser ONTs (mu-ONTs) offer the ability to connect more than one subscriber per fiber input. Depending on the manufacturer, these service eight or more living units over existing copper in the building. Both Ethernet and VDSL versions are available. The Ethernet solutions work over CAT 5e, and the VDSL solutions are used where older and/or lower performance grade copper wiring is present. The coax output is split and can provide signal to several televisions per living unit.

Mu-ONTs connect to the same OLTs at the CO/HE as do single-unit ONTs and are generally subject to the same ratio of ONTs per OLT port. For example, a system using a 1x32 split ratio could service four multiuser ONTs, each in turn serving eight subscribers. In this case an optical ratio of only 1x4 is needed. Some vendor platforms permit mixing of both single- and multiuser

ONTs on the same OLT. Figures 2.12 and 2.13 show a typical mu-ONT and its backup power supply mounted in a telecom closet.

Multiuser ONTs are used for a variety of reasons, the most common being:

- The building owner(s) will not permit optical cabling to be installed to each living unit in the building, OR
- The building or business case is not currently favorable to a full-fiber deployment at this time, but it is attractive as a high-bandwidth customer and has sufficient existing wiring to support mu-ONTs as a means of offering more services than can currently be delivered. This MDU may also become more lucrative in the future so that a full-fiber deployment can be justified.

It is important to understand that while mu-ONTs bring fiber to the building, they do not bring fiber to each living unit and therefore re-create the "*last mile*" problem all over again, albeit on a somewhat smaller scale.

Ultimately, a fiber overbuild should be both the goal and the inevitable solution. To avoid future last mile problems, mu-ONTs should be used on a limited basis, with optical fiber to the living unit being the lead solution.

Figure 2.12 – Multiuser ONT for Eight Subscribers | Photo NS148

Figure 2.13 – Battery Backup for mu-ONT | Photo NS149

Chapter Two:
Transport Technology, Standards and Requirements

Complementary Solutions

Several technologies are in use today to facilitate use of the existing wiring within individual living units and buildings:

MoCA – Multimedia over Coax Alliance

This technology leverages existing coax in the living unit to provide services to computers, televisions, phones and other devices. Coax splitters in the units may require replacement to be compatible with this technology. *The attraction of MoCA is that it prevents the need to install new CAT 5e cabling for data, saving time and money in connecting a subscriber.* ONTs are available both with and without MoCA capability. MoCA-capable ONTs can be located in a common area for a small MDU and use existing building wiring to connect living units, provided a dedicated coax cable is available to each unit.

HPNAv3 – Home Phone Network Alliance

This technology can use either existing telephone or coax lines to deliver service. It follows a philosophy similar to MoCA for leveraging existing wiring inside or directly to a living unit.

Wireless

Wireless routers also offer a solution for providing data connectivity where appropriate wiring is not present and the installation of new wiring would be costly. Wireless solutions are generally lower costs than providing new or rewire solutions and are faster to install. One caution in using wireless is the potential for others, besides the intended subscriber, to access the service; therefore, appropriate security safeguards should be considered to prevent unintended usage.

Future-Proofing

Future-proofing means taking steps to ensure the network installed today is compatible with current and future transport technologies *and* is capable of additional bandwidth needed for future service offerings. The easiest way to future-proof the passive network is through (a) careful choice of architecture and (b) proper fiber count planning. While the CSH architecture is the most robust, the LC model offers nearly the same benefits with lower cost. Both models put the splitters (one-to-many relationship) in one location, making it easier to perform future split ratio changes or technology upgrades (compared to distributed splitting). A single fiber in the distribution network (from splitter to living unit) is sufficient because it is a dedicated link per living unit with very high bandwidth capacity. The feeder portion should have sufficient fiber to support split ratios from 1x16 and up (requiring at least double the fiber needed for a 1x32 ratio). This extra fiber can also support future substitution of electronics in place of splitters.

Migration

Migration means changing from one technology to an improved technology. An example would be bringing fiber to the MDU and using existing copper in the building today. The migration path would be to eventually take fiber to each living unit as bandwidth and business demands it. As with future-proofing, the key is to plan for the migration. For *medium* and *large MDUs* that require an LCP to be placed in the building, sufficient fiber should be placed to the building to support as low as a *1x16 split ratio in the building*. For *smaller MDUs* that would share an external LCP, at least *one fiber per living unit* should be brought to the building from the LCP. While some of the fiber will be dark initially, its low material cost and near zero additional installation cost will ensure an easy migration path for the future.

Chapter Three:
Design Considerations

This chapter covers key design considerations for MDUs and offers a design process describing the required design steps and typical order of execution.

Greenfield and Brownfield Installations

Greenfield installations are defined as new construction into which telecommunication cabling infrastructure has not previously been placed. New construction offers the opportunity to design in and provide adequate space to route fiber optic drop cables and or ducts from a main consolidation point to each individual living unit. Fiber can be brought to a pre-designated location in each living unit and terminated in a network interface device, which designates the demarcation point between the service provider and the end customer.

Brownfield installations include all structures which are served by some type of voice, data and/or video services. These services can be provided via copper cables, via wireless, or some combination. In this case, fiber replaces all or part of the existing infrastructure to each living unit. Within the living unit, the existing infrastructure is maintained and connected to the ONT. Brownfield applications are noted for their diversity in building age and configurations. Space is frequently an issue in brownfield MDUs. Often "creative" pathways must be identified to enable routing of the fiber drop cable to each living unit. Inside wiring, discussed in detail later, is a special consideration for deployment in brownfield MDUs.

New construction, in which copper has been placed and the walls/ceilings have already been covered by drywall or other finishing materials, should be treated as brownfield installations because the in-wall pathways are now limited, difficult to access or unavailable. MDUs undergoing total renovation, where wall and ceiling spaces are accessible, should be treated as greenfield installations.

Building Types and Sizes

Buildings come in a variety of types and sizes, according to the number of units served and the style of construction. The following examples serve as guidelines. Note that there is intentional overlap in the sizing of the MDUs to accommodate the wide variety of actual building structures. Also note that in small MDUs, the cabling may have a larger horizontal component, whereas medium and large MDUs will have a more significant vertical (riser) component.

Small MDU: 2-24 dwelling units per structure

Townhomes, duplexes and small apartment clusters are the best examples of small MDUs. The size of the building does not require a dedicated LCP, rather it is shared by multiple buildings of this type or even with single-family homes. A terminal is mounted to the side of the building and serves ONTs located in the dwelling units' utility rooms and/or garages.

Network Element	Product Examples
LCP	Outdoor LCP 72-864
Distribution Cable	ALTOS® Loose Tube or ALTOS Ribbon Cable
Distribution Terminal	Outdoor MDU Terminal
Drop	Riser-rated indoor/outdoor drop; rugged drop and compact drop in raceway, SST Flat Drop for single family attached
Wallplate / ONT	OptiWay® Wall Plate, OptiWay NID

Medium MDU: 12-48 dwelling units per structure

Medium MDUs are typically low-rise structures with limited conduit space or utility space on each floor. While a structure like this *may* warrant a small dedicated indoor LCP, generally it makes sense to deploy a shared outdoor LCP. If space is not available on each floor for fiber distribution terminals, drops may be run to a central distribution terminal located in a central utility area or basement. Drop cables are riser or plenum rated per application and serve ONTs located in dwelling unit closets or utility areas.

Network Element	Product Examples
LCP	Outdoor LCP 72-864 or Indoor LCP-72
Distribution Cable	ALTOS® Loose Tube or Ribbon or MIC® Riser/Plenum Cable
Distribution Terminal	Indoor MDU Terminal - 12 or 24
Drop	Single-fiber rugged drop and compact drop in raceway
Wallplate/ ONT	OptiWay® Wall Plate, OptiWay NID

Large MDU: 48+ dwelling units per structure

High-rise structures in city centers may contain hundreds of dwelling units and often warrant a dedicated indoor LCP. Space for cable and hardware is still at a premium but not nearly as constrained as in the medium MDU, allowing fiber distribution terminals on each floor. Drops typically terminate at a distribution terminal on their floor but may extend one or two floors up or down. The LCP is located in a central utility area or basement. ONTs are located in dwelling unit closets or utility areas.

Network Element	Product Examples
LCP	Indoor LCP 72, 144, 216 or 432
Distribution/ Riser Cable	MIC® Riser/Plenum Cable either stubbed to the distribution terminal or on reels
Distribution Terminal	Indoor MDU Terminal - 12 or 24
Drop	Single-fiber with rugged drop and compact drop in raceway
Wallplate/ ONT	OptiWay® Wall Plate, OptiWay NID

Topology Elements for MDUs

The previous chapter described architectures and topologies from an overall network view. To make a design choice regarding the network topology, or the physical network layout, the following concepts and guidelines will be helpful. Keep in mind that networks may utilize more than one topology and that the topological choices are driven by building structure, initial and target take rates, brownfield or greenfield application, active electronic requirements, cost and splitter placement strategy. While many combinations can be created, these concepts illustrate the key topology elements:

Self-Contained Distribution

The entire distribution system, including splitters, is physically located in the building. This is more common for medium to large MDUs which have living unit entries on the inside of the building.

Shared Distribution

The splitters and part of the distribution system are shared by more than one MDU. The splitters are located in a cabinet (usually independent of the MDU) or the CO/HE. The distribution cabling is both outside (to the building) and in the building. This is more common for small MDUs, where it makes sense to share resources further "up" in the network. The LCP may be placed in one building and then shared with one or more additional MDUs, which is still considered shared distribution.

Chapter Three:
Design Considerations

Intermediate Terminals

Multi-level MDUs, especially those with three or more floors, benefit by placing intermediate terminals on every floor, every second or every third floor. Drops (horizontal cabling) are then placed between living units and MDU terminals. The terminals are then consolidated to a hub or splice point in the basement, telecom room or outside.

Building Homerun

All drops are homerun to a common point for the entire building. The common point may be in a telecom room, basement or on the outside of the building. This approach is useful for MDUs with three or fewer floors.

Figure 3.1 summarizes these approaches to choosing a topology for a given building. Overlap is intentionally built into this diagram to reflect the fact that each MDU is different and solutions must be ultimately tailored to that building. Splitter placement (for example, the LC model, where all splitting occurs in one field location for each PON) is governed mainly by the chosen architectural model. However, whether splitters always reside in a cabinet or are sometimes located in a smaller "mini-LCP" (such as a terminal that also contains a single 1x16 or 1x32 splitter), they may vary as part of the topological design choices to create the best fit for an MDU.

	Small MDUs	Medium MDUs	Large MDUs
Distribution/ LCP Strategy	• Shared	• Shared or Self-Contained	• Self-Contained
Terminal Strategy	• Building Homerun • Single Terminal • Two Terminals • Indoors/Outdoors	• Intermediate Terminals • Building Homerun • Generally indoors	• Intermediate Terminals • Indoors
Splitter Placement Strategy	• In Shared LCP	• In Shared LCP or in Terminal	• In Self Contained LCP
Building Types and Sizes	• 2-24 Units • Garden Style • Du-, Tri-, Quadplex • Includes some multi-level	• 12-48 Units • Multi-level	• 48+ Units • High-Rise

Figure 3.1 – Topology Element Matrix | Drawing ZA-3122

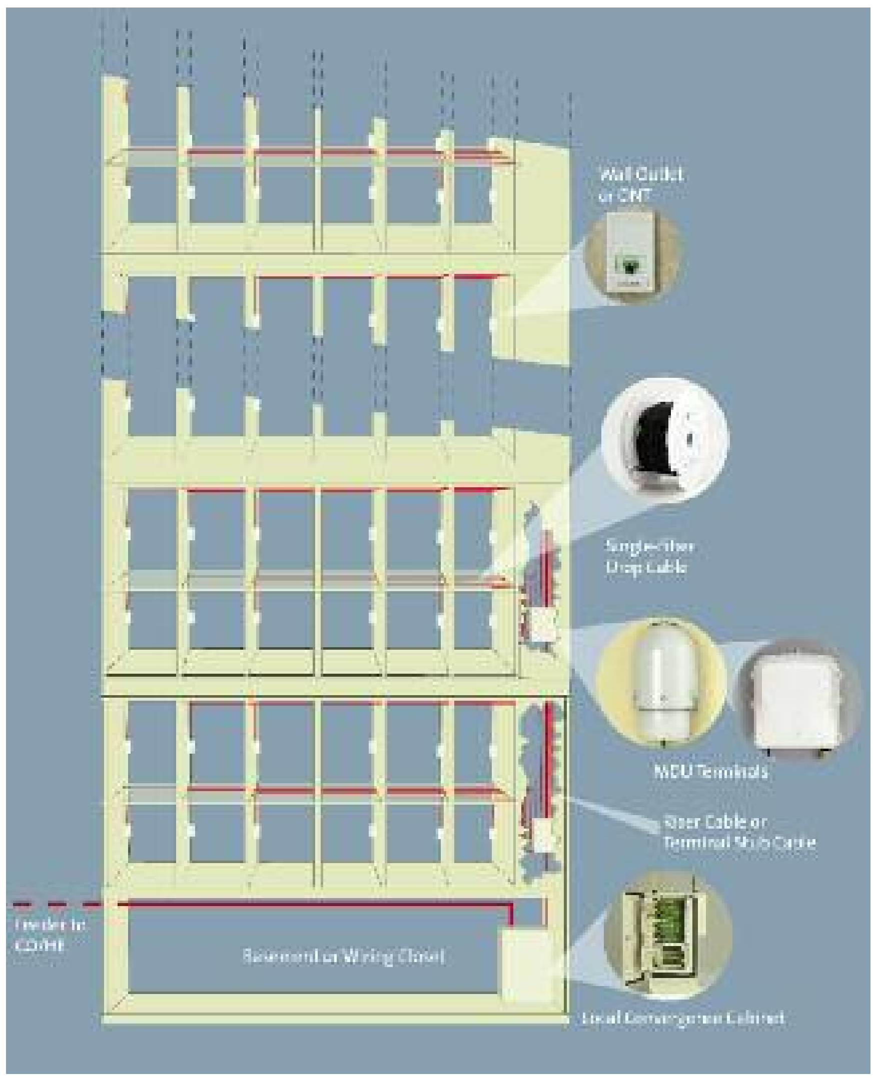

Figure 3.2 – Self-Contained Distribution - Multidwelling Unit with Intermediate Terminals | Drawing ZA-3439

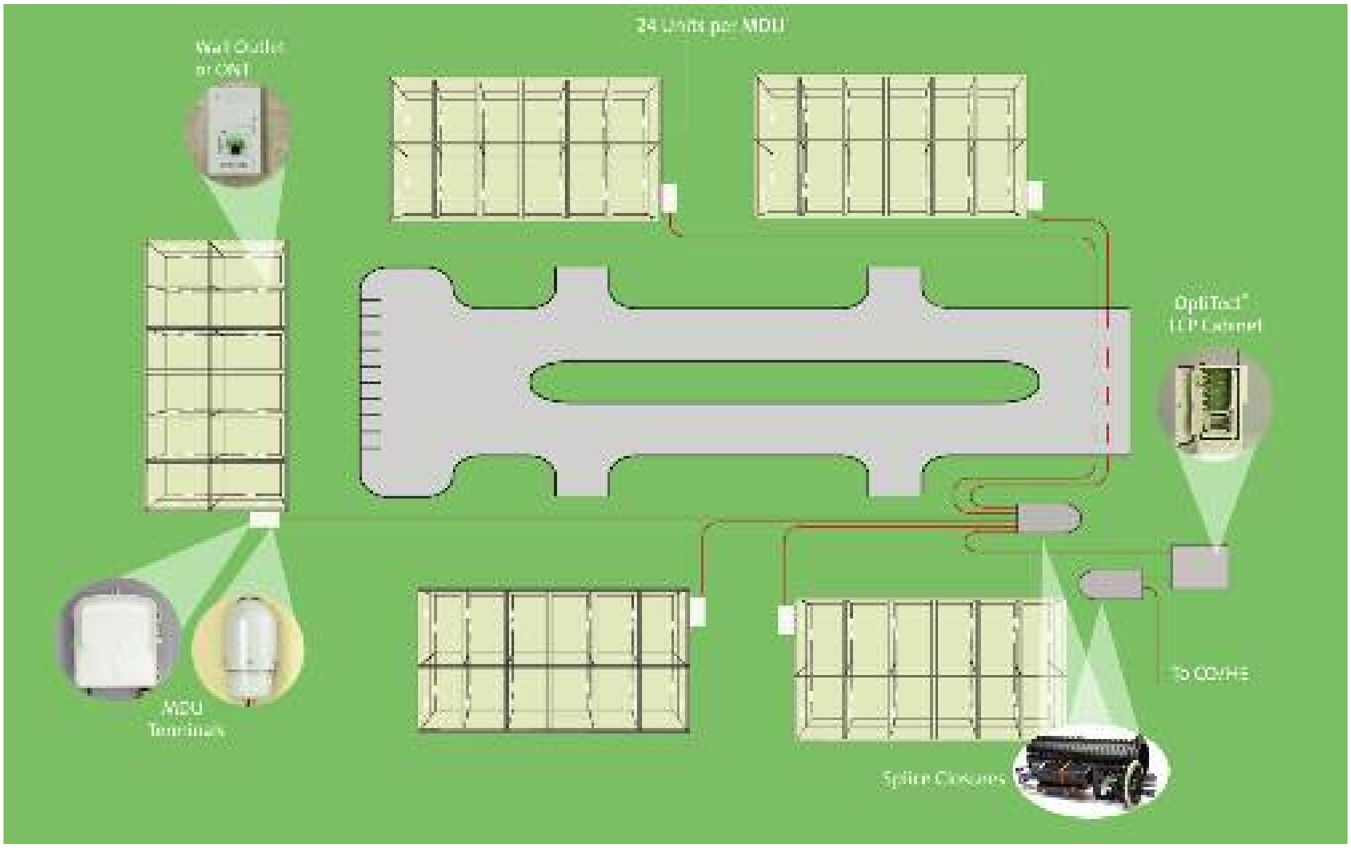

Figure 3.3 – Shared Distribution - Multidwelling Unit Community | Drawing ZA-3441

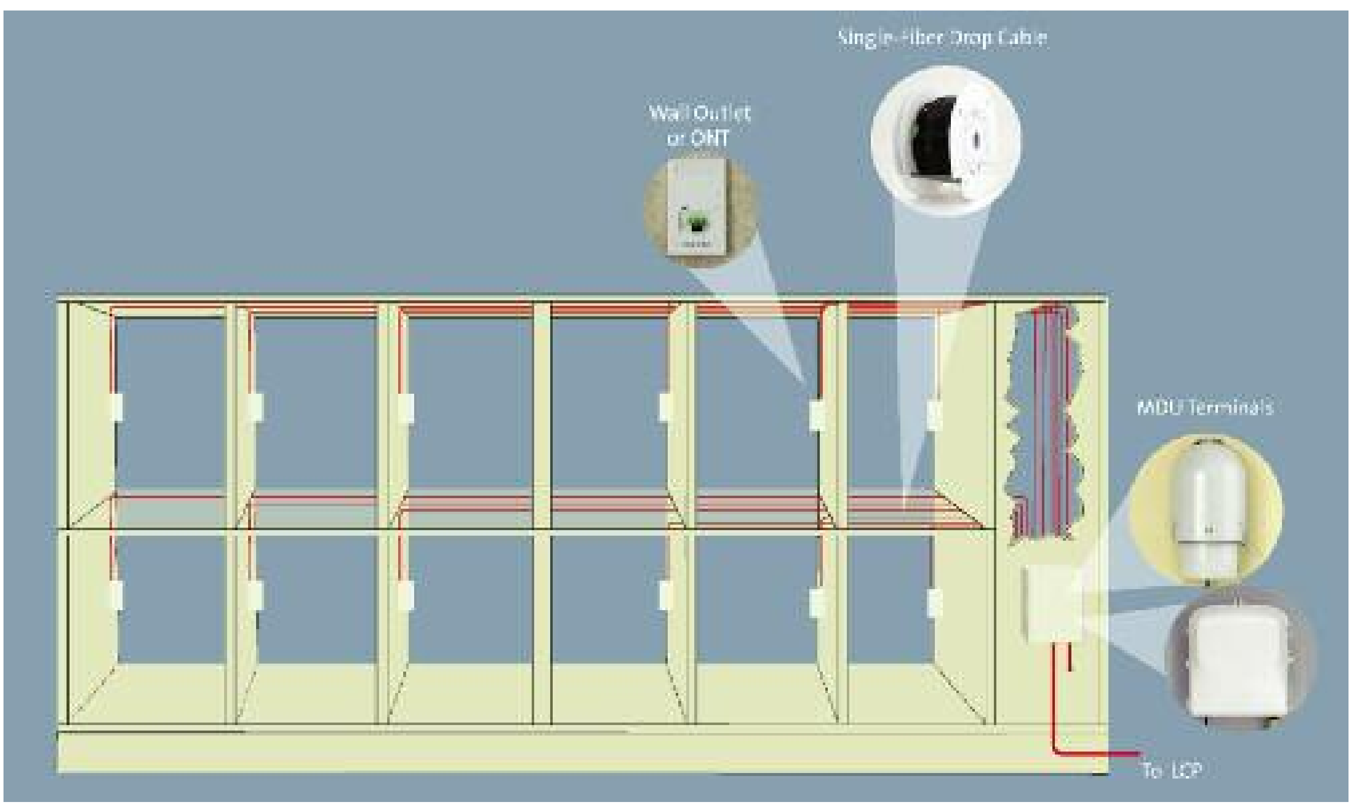

Figure 3.4 – Homerun Architecture - Multidwelling Unit | Drawing ZA-3440

Chapter Three:
Design Considerations

Building Access and Ownership

Building access is a critical issue when provisioning fiber optic cables within an MDU. The service provider must identify and contact the owner(s) of the building for permission to place infrastructure in the building. In greenfield applications, the owner is usually the developer. Permission is straight-forward and access is typically during the construction phase. This requires coordination with the general contractor. Construction timelines may offer only a short "window" of time to complete network path creation. The network design must utilize resources, processes and products that will lead to successful deployment within the allotted time frame.

In brownfield applications, the issue becomes more complex. Units that are individually owned, such as condominiums, will require contacting each individual unit owner, although this typically can be handled through the homeowner's association. Apartments and other leased units require permission of the lessor and the lessees for access into each unit.

Ownership of the infrastructure can also vary. The service provider usually will own all the facilities to the demarcation point, which for FTTH is at the network interface device in the individual living unit. In this case, the service provider will place the infrastructure. However, in some cases, the building owner may choose to own the telecommunication facilities within the building and only grant the service provider permission to use the infrastructure to provide services. This can be true for both greenfield and brownfield applications. For brownfields, where cable paths are difficult to determine, further complications can occur when the best path to serve one unit may be through a unit leased or owned by someone else. This has to be addressed on a case-by-case basis.

Economic Considerations

When planning an FTTH installation in an MDU, the fiber cabling infrastructure is not the only consideration. Space and power must be available for active components. This often requires additional expense, particularly in brownfields. In addition, items such as conduit, ducts, raceway and molding must be budgeted. While individual situations vary, the cost of providing FTTH service to an MDU is typically less than that of provisioning to an SFU on a per home connected basis due to the concentration of subscribers within a small area.

Living Unit Cabling (IW), Power and Security

Each living unit will have or require proper inside wiring (IW) in the form of phone, data (CAT 5e or CAT 6) and video (coax) cabling for the delivery of services to phones, computers, televisions and other devices within the living unit. In new construction, ample cabling, running from communications outlets in each room, work space and entertainment area, must be homerun back to one central location in the living unit, where everything can be tied into the ONT. This "star" topology provides great flexibility over time for changing and adapting to the needs and lifestyle of the tenants. Where the IW converges, a common hardware box is used to manage it and provide a demarcation point for the service provider(s). From this common box, cabling can be passed directly to the ONT or jumpers can be run to the ONT to complete connections.

Existing deployments may or may not have all the desired wiring ready to connect to the ONT. Copper phone lines and, in most cases, coax, will be present. Data (CAT 5e or CAT 6) are less likely to be available. There are three possible solutions to accommodate triple-play services where existing IW is insufficient:

- **Rewire the living unit**

While this is the best technical solution, it may be the most costly solution, too. In this case, data cable is pulled from the ONT to the desired outlet location(s). Phone lines and coax cable can also be installed, as needed.

- **Leverage the existing wiring with additional technology**

As mentioned earlier, MoCA or HPNAv3 can be used to leverage existing wiring, usually coax, to deliver services in the living unit. ONTs are available with this functionality built in for a small added cost. A small router with MoCA capability may be required. Video and data are delivered over the existing coax by the addition of set-to boxes, modems and splitters that attach to the ends of the existing coax cable. While there is a cost for this technology, it avoids the added disruption time and cost of rewiring the unit.

• Supplement with a wireless solution
Where the existing wiring and coax are sufficient for voice and video, a wireless router can be used to extend the Ethernet port of the ONT to computers and other wireless-equipped devices in the living unit. This solution may allow non-subscribing living units to utilize the service without paying for it. Wireless may also present security concerns, unless the network is carefully configured. It may or may not have the same consistent bandwidth available over a wired network.

Power is required at the ONT location, which is often in a closet. It must be provided by the builder in new installations via a dedicated 15 amp branch circuit. In existing facilities, power may be provided by adding an outlet to an existing circuit. Adding a new outlet generally requires a licensed electrician, so an alternative is to place the ONTs power supply at the closest available existing outlet and run its low-voltage output along a ceiling or baseboard to the ONT. ONT manufacturers typically allow for up to 50 feet from power supply to ONT, which should be verified for the model being used.

Security for wiring in the living unit and the ONT itself must be addressed to avoid physical damage or tampering that can cause service outages. Optical cables should be protected in raceway or by routing them out of reach of children, pets, furniture or stored items in closets. The ONT and connections to it should be protected by placing in a proper housing. Power supplies and cabling should also be protected against accidental damage and disconnects.

Deployment Velocity (speed and efficiency)

Deployment velocity is the time required to provide service to the living unit. Rapid installation requires minimized interruption to occupied living units as well as an optimized path from deployment decision to service turn-up. Product selection should facilitate the quickest overall deployment with the lowest overall cost. Because of the competitive market for service providers, maximum deployment velocity becomes a strategic tool for both capturing market share from competitors in brownfield environments, as well as adding new subscribers in greenfield MDUs before competing offers become available.

Basic Design Process

This section provides a systematic approach to designing fiber to the living unit for MDU deployments. It is assumed that pre-work such as site surveys, gaining rights-of-way and signing contracts has been completed, and that the full and final network design is ready to commence. The sections that follow provide added detail to assist in finalizing the design and selection of products.

Step One: Determine if the deployment will be greenfield (new construction) or brownfield (existing buildings). If the project is still in the planning process, it is possible to ensure sufficient space in greenfield deployments for riser and horizontal cabling, as well as for fiber distribution terminals, hubs and splice points. Greenfield projects can be most effectively done by pulling rugged drop cable directly through walls to the living units. They may also involve deploying microduct within walls and ceilings to create a cable pathway. Brownfield deployments can also be cabled with rugged drop cable, using raceway or conduits where desired in public spaces for aesthetic purposes. Rugged drop cable is every bit as robust as CAT 5e and coax cable, so the decision as to whether to provide physical protection should be made in the same way.

Step Two: Evaluate the number of living units in the building and select either a shared or self-contained distribution topology. Large MDUs (48 living units or more) will often be best served with a self-contained topology, putting splitters in the building. Small (2-24 living units) and medium (12-48 living units) MDU deployments will usually be best served by a shared topology, where splitters are outside and shared with other buildings. An exception occurs where a small- or medium-sized MDU is somewhat isolated from other MDUs or falls in a mostly single-family area. In this case, a terminal capable of connecting drops AND containing splitters may be used. The terminal's CO/HE side cable is simply spliced into the main feeder, possibly at the same location as an LCP.

Step Three: Evaluate the physical size of the building and determine if intermediate terminals will be used on each floor (or every two to three floors) or if drops will be homerun to a central location in the building. Larger MDUs will benefit from use of intermediate terminals, while smaller MDUs may be best served by homerunning every drop to a central location. *Note that no more than three floors should be aggregated to a single terminal to balance hardware costs with construction simplicity.*

Step Four: Evaluate age-related attributes of the building. While the physical size of the building may suggest a particular approach to cabling, the age and type of construction may restrict the options or present unique opportunities for cabling. For example, a larger building may require a homerun approach because there are no locations for intermediate cabinets *or* it may offer existing conduit, abandoned dumbwaiters or other options for running drops and/or riser cables. In these cases, some adaptation is required; where necessary, use concepts from other building sizes and types to develop a cabling solution.

Step Five: Evaluate the building for pathway options.

- ONT location – ONTs should be located where the living unit wiring (copper, coax, CAT 5) converges. Ideally this will be in/on the wall opposite a hallway, where the drops can penetrate into the living unit (for inside entry MDUs). Other locations, depending on the style of MDU, may be closets, kitchens, pantries, master bedroom closets and storage rooms. For townhome style units, a basement or garage location, or the outside rear wall near the power entry, are all potential sites. In new construction, both in-wall and surface-mount options can be planned, with rough housings installed during construction and ONTs installed in those boxes later, when the unit is complete and service is required. Look or plan for locations where power for the ONT is available.
- Inside wiring – Existing inside wiring (IW) within MDUs may converge at a common point in the living unit, where connections can be made to the ONT. Depending on the MDU style and age, the IW may continue on to a basement or other common point in the building. When ONTs are being placed in living units, the IW will have to be intercepted for connection to the ONT. Additional wiring may be required if the existing wiring is insufficient or missing. IW can be connected directly to the ONT or connected to a separate demarcation box first, then routed or patched to the ONT. In greenfield applications, all inside wiring (phone, video, data) should be brought to one location where the ONT will be placed.
- Horizontal (drop) pathway – In existing buildings, look for existing raceway or molding that can be used, provided permission can be obtained to use them. Generally, a new raceway will be required to run drops down hallways and into living units. Existing MDUs are often built with "stacked" floor plans, where a closet on one floor is directly below the same type of closet on the floor above. Stacked designs offer the ability to create vertical cable paths and ONT locations in out-of-sight places where only minimal protection is required. In new construction, ClearCurve® Rugged Drop Cable can be run directly through walls and ceilings by drilling and stapling to structural members in walls or through ceilings. Traditional cable can be run in microduct in walls or through ceilings. Depending on building size, new construction may best be served by homerunning drops to a common building point that may be one floor up or down.
- MDU terminal locations (indoor/outdoor) – For medium and large structures, it is generally beneficial to locate terminals on each floor or every two to three floors so that drops can be kept short and separate from the building riser/backbone. Look for telecom closets on each floor, or other closets, such as garbage disposal and storage facilities. In small- and medium-size MDUs, the best location may be on an outside wall or in a basement.
- Riser (distribution) pathway – Look for riser spaces, stacked closets, abandoned shafts and (especially in brownfields) stairways in the building. The best place could be on the outside of the building, running up to a closet or attic space. Greenfields are somewhat easier, since telecom risers can be planned and conduits installed during rough-in, for simple installation once the building is finished.
- LCP location (if applicable) – Where dedicated distribution is being installed, an LCP can be installed in a basement or telecom closet.
- Building entry – Cable entry to the building can be accomplished via penetration into a basement or closet wall, using standard techniques. Where a pre-stubbed LCP is installed in the building, the splice to the LCP can be made inside the building, or performed outside in a handhole or vault.

Step Six: Where applicable, evaluate multi-building complexes. Groups of MDUs in a complex, whether high-rise structures or smaller garden-style units, often present opportunities for sharing interbuilding network elements, such as feeder and distribution cabling, terminals and hubs (splitters). An LCP may be placed in one building and shared with an adjacent building. Shared elements should be used to reduce cost and complexity whenever possible.

The following flow chart integrates the steps listed on Pages 23-24:

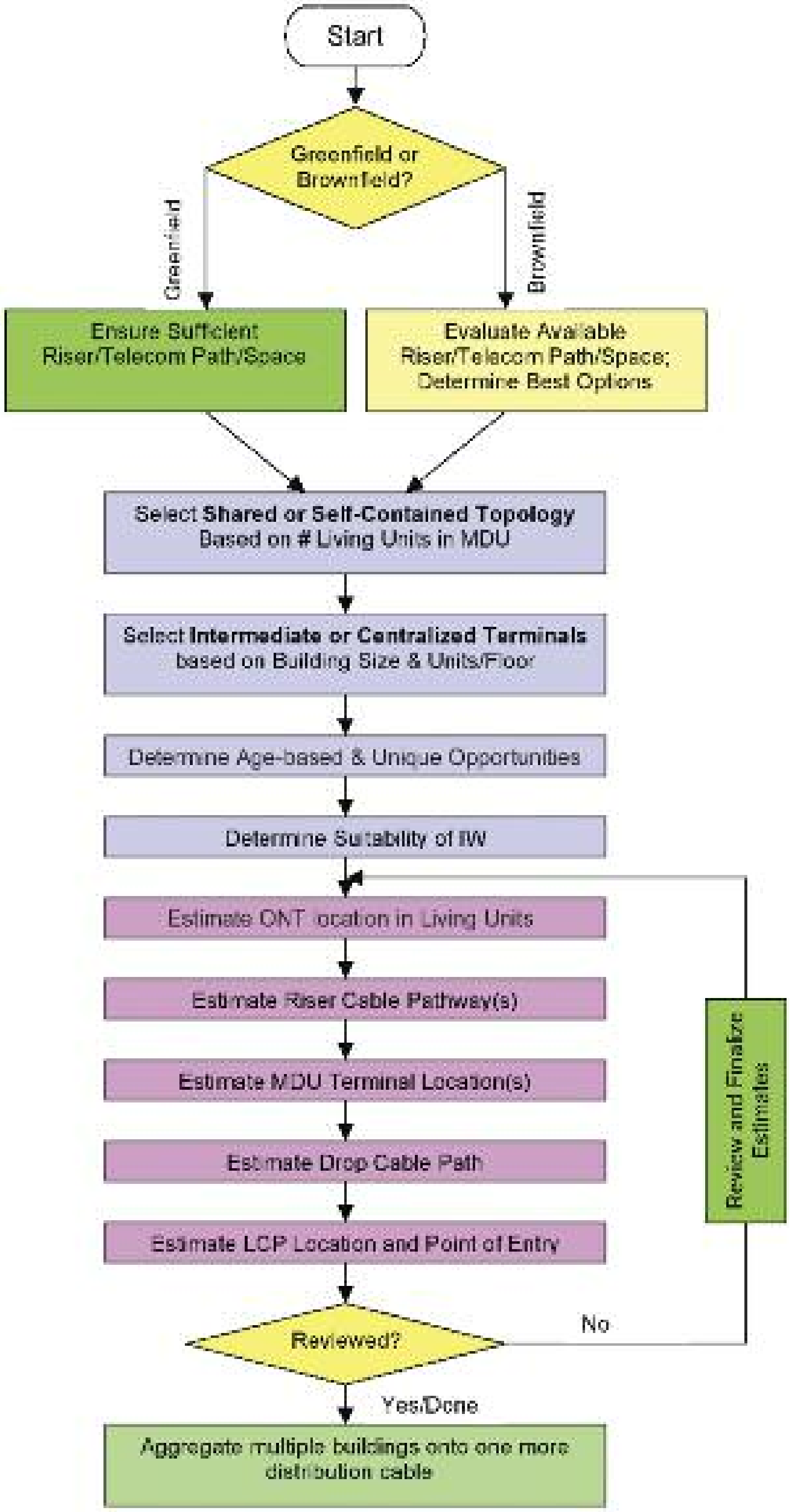

Figure 3.5 – Design Process Flowchart | Drawing ZA-3123

Chapter Four:
Passive Optical System Components for MDUs

Introduction

Once the key design choices have been mapped out, component selection can begin. The choices for components will be driven by two factors.

- The unique characteristics of the building being cabled will determine the amount of space available for hardware and cable placement, and thus the choice of products. Industry trends have clearly moved toward smaller, easier-to-deploy components, as exemplified in the ClearCurve® solution. However, traditional deployment technology is still a viable solution and is described as well.
- Total installed cost, which includes the net results of labor, materials and any secondary impacts such as building/homeowner acceptance and faster revenue generation through quicker deployment. These costs are directly influenced by the component and installation method choices discussed in detail in the paragraphs that follow.

The main objectives in component selection are:
- to deploy a reliable, robust network,
- with low optical attenuation,
- at the lowest possible cost,
- in the least amount of time,
- with a minimum of interruption to tenants (for occupied MDUs).

To address these objectives, Corning's® ClearCurve Optical Fiber has been developed with very tight bend radius capabilities. This has enabled a revolutionary set of rugged, yet smaller, cable and hardware products that meet the specific needs of the MDU environment. This chapter of the Guide will step through the various component choices, comparing and contrasting the latest state-of-the-art products with traditional approaches. The discussion begins with the underpinning optical fiber technology and steps through cable types, cable protection, hardware and connectors.

Optical Fiber

The choice of optical fiber will determine the amount of bending that cables, especially living unit drop cables, can withstand. It also influences the size of the hardware needed to connect a given number of drop cables. ITU recommendations G.652 and G.657 define three levels

Figure 4.1 – ClearCurve Indoor/Outdoor Rugged Drop Cable | Photo NS165

of bending performance, described below. Corning Cable Systems' extensive customer and application research has defined a fourth, more stringent level of bending performance, as well.

Standard Single-Mode Fibers (ITU G.652.D)
ITU G.652.D recommendations cover standard, low-water-peak fibers used in FTTH feeder and distribution applications today. Corning's SMF-28e® Optical Fiber, which meets G.652.D requirements, will continue to be the workhorse for the feeder and distribution parts of the access network. However, with a minimum bend radius of 30 mm, it does not offer the optimum bending capability for MDU drop cable applications.

Bend-Improved Fibers (ITU G.657.A)
Bend-improved fibers are typically defined by the ITU-T recommendation G.657, type A (or simply "G.657.A"), which was published in late 2006. This ITU-T recommendation requires the fibers to be backwards compatible with standard low-water-peak single-mode fibers and defines the minimum bend radius to 10 mm. "Backwards compatible" means that the key fiber parameters as defined by ITU-T recommendation G.652.D are met, specifically optical transmission parameters such as mode-field diameter, cut-off wavelength, attenuation spectrum, chromatic dispersion, and polarization-mode dispersion, but also geometric parameters such as core-clad concentricity. This guarantees interoperability with an embedded base and with

other network segments (e.g. feeder and distribution) that may use standard single-mode "G.652.D" fibers. The minimum bend radius of 10 mm comes with a penalty, however, as up to 0.75 dB of loss is permitted for one 360-degree turn at this radius. At smaller radii, the loss increases significantly. While these early bend-improved fibers have been used for MDU drop cable deployment, their greatest contribution has been to enable major density improvements for key FTTH hardware components. The benefits for fiber optic hardware, when combined with improved fiber management, can be significant. As an example, Corning® SMF-28e®XB fiber enabled a reduction in weight and size of local convergence cabinets by approximately 40 and 75 percent, respectively.

Bend-Tolerant Fibers (ITU G.657.B)

The ITU-T also recognized the challenges of fiber installation and defined a second class of bend-tolerant fibers in compliance with recommendation G.657, type B (or simply "G.657.B"). G.657.B fibers are not required to be backwards compatible, but are defined by a minimum bend radius reduction to 7.5 mm. However, as described earlier, evolving practices in MDU installations require an even further reduction in bend radius to bring fiber cable installation practices on par with copper installation in terms of speed, ruggedness and flexibility or to enable further density improvements for fiber hardware. Although these fibers are more tolerant of bending, they still are limited by an attenuation of up to 0.5 dB per 360-degree turn at this radius, which, with just a couple of turns, could exceed the normal loss of an MDU drop link. The resultant combination of significant bending loss and lack of a backward compatibility requirement places these fibers in a weak position for MDU applications.

Bend-Insensitive Fibers

The challenges of MDU applications call for a truly bend-insensitive optical fiber, yet one that remains compatible with ITU G.652.D fibers used in the feeder and distribution segments of the network. There are a variety of technologies for further improving bending performance in optical fibers. However, these are either limited in achieving performance to the bend-improved or bend-tolerant levels only, or suffer from strong incompatibility tradeoffs that render them incompatible with legacy fibers. Extensive customer and application research has shown that a functional radius of 5 mm with a maximum attenuation of 0.1 dB per 360-degree turn, while still maintaining backward compatibility, is the standard that fully addresses the "handle like copper" nature of MDU deployments. Corning's ClearCurve® Optical Fiber meets all of these requirements and, when placed in a rugged, self bend-limiting cable sheath, creates an MDU drop cable that can be pulled through and stapled to building structures more quickly and at lower installed cost than conventional solutions.

Because of the extensive benefits of bend insensitive fibers, it is recommended that ClearCurve Optical Fiber be used for all drop cable segments in MDUs. However, traditional deployment options are discussed later in this chapter. These fibers may also be used in the riser segment, as hardware stub cables, to enable smaller hardware footprints. For feeder and distribution segments, standard single-mode (ITU G.652.D) fiber is recommended.

Cable Information for ClearCurve® solution Deployment Technology

Because the drop cable pathway is the most challenging part of MDU deployments, careful component choices must be made. Conventional practices make widespread use of microduct into which a single-fiber 2.9 mm interconnect cable is pulled. Greenfield deployments have been using microduct almost exclusively, and many brownfields use it as well, to protect cables in walls, ceilings, attics and through stacked closets. This approach is robust, but requires extra labor cost for the handling of the microduct followed by the pulling of the cable, as well as the extra material cost of the microduct itself. Microduct requires careful bend radius management to avoid kinking (which would prevent cable placement). In addition, its rigid nature and bulky shipping reels usually require multiple technicians during placement and may be difficult to handle in tight work spaces. Cable-in-conduit, where the microduct is extruded around the drop cable at the factory, reduces the labor needed to install the drop but still requires the same handling cautions and added material costs as for empty microduct. Nonetheless, use of microduct and a small interconnect cable as the drop remains a viable technique for its one key benefit: it creates a reusable path, should the drop cable ever need to be replaced.

Chapter Four:

Passive Optical System Components for MDUs

A new approach which is fast gaining acceptance, taking lessons learned from copper cables, is to put a bend-insensitive fiber inside a rugged, self-bend-limiting sheath, to create an optical cable that can be handled and secured just like these competitive technologies. Corning Cable Systems ClearCurve® Rugged Drop Cable does just that. With this cable, the labor and material costs associated with microduct are completely eliminated. Cables can be pulled directly through holes drilled into studs, joists and masonry structures as well as through standard metal stud openings. Experience in actual field deployments is demonstrating that this method can achieve cable installation in as little as half the time compared to a microduct-based installation.

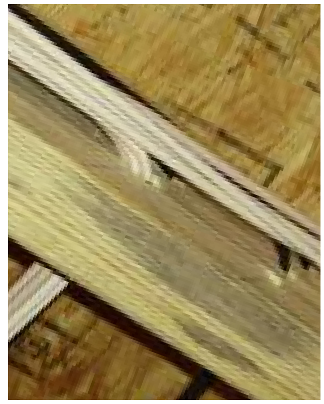

Figure 4.2 – ClearCurve Rugged Drop Cable Installed Through Joist | Photo NS159

Figure 4.3 – Sweeping Bends of Microduct in Joist | Photo NS157

In most cases, a single technician can pull in a drop cable, whereas multiple technicians are required to manage and install microduct. The 4.8 mm diameter of this cable is smaller than typical microducts, allowing the use of smaller, faster-to-drill holes in structures. Where raceway or conduit is used to protect groups of drop cables, smaller raceway, conduit and core drills can be used at lower cost. The cable may also be stapled using conventional, off-the-shelf staplers. Wherever and however copper cables can be installed, ClearCurve Rugged Drop Cable can also be installed. Further savings are realized by eliminating the transition boxes and conduit often used to bring drop cables from microduct into the MDU terminal.

Figure 4.4a – ClearCurve Rugged Drop Cable Wrapped Around Mandrel | Photo CCV010

In Figure 4.2, ClearCurve Rugged Drop Cable is installed directly through a joist. The cables' self-limiting nature requires no bend radius management. In Figure 4.3, larger holes and large sweeping bends are required for these microducts.

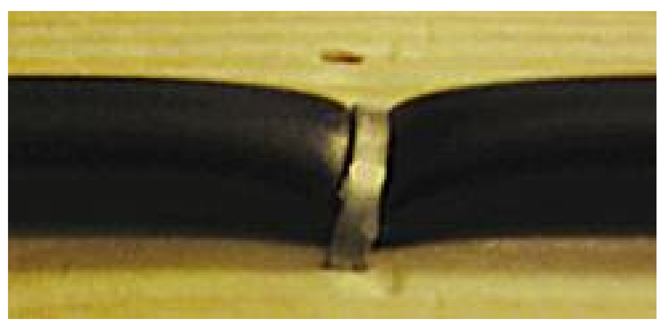

Figure 4.4b – ClearCurve Rugged Drop Cable Stapled to Joist | Photo NS162

Bends and stapling are routine practices for ClearCurve Rugged Drop Cable as seen in Figures 4.4a-c. Figure 4.4c demonstrates how the bend limiting sheath controls bending, even when stapled.

ClearCurve Rugged Drop Cables are available in an indoor riser-rated version in an appealing neutral off-white color or standard "single-mode yellow." An indoor/outdoor riser-rated version is also available in black. Tensile rating is 100 lbf., twice that of conventional interconnect cable used for drop and similar to that of coaxial cable. The indoor/outdoor version is both water-blocked and UV-protected for exposure to the elements.

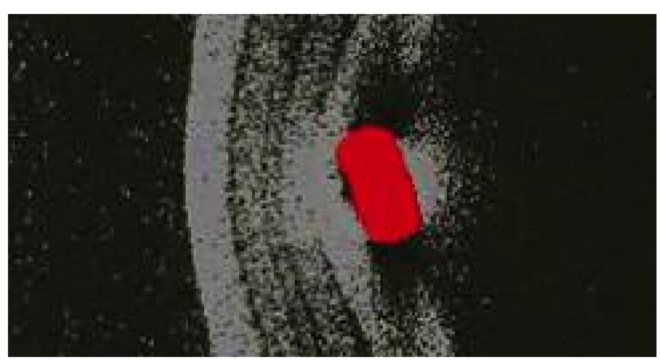

Figure 4.4c – X-Ray of Stapled ClearCurve Rugged Drop Cable | Photo NS156

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Passive Optical System Components for MDUs

Compact Drop Cables
ClearCurve® Compact Drop Cables utilize the same bend-insensitive fiber as rugged drop cable, but in a smaller 2.9 mm sheath. Compact drop cables are best where a smaller, more aesthetic appearance is desired, or where cables are run in raceway or microduct, and where the self-bend-limiting feature of the rugged drop cable is not needed. Compact drop cable is ideal for installers preferring the use of microduct, as it has the same diameter as the interconnect cables currently in use. However, it has the same tight bend capabilities as the ClearCurve Rugged Drop Cable, down to a 5 mm minimum bend radius.

Drop Cable Packaging – Bulk and Preconnectorized
ClearCurve Rugged and Compact Drop Cables are both available in bulk reels in various lengths. Standard reels can be placed on normal pay-off stands. Reel-in-a-box packaging, which requires no pay-off stand, is also available, making set up and tear down fast and easy when placing drop cables. Rugged drop and compact drop cables are available in 1500 and 4500 feet bulk reels, respectively. Bulk cables can be pulled in and conveniently cut to length, minimizing waste. Preconnectorized drops, with connectors on one or both ends, are also available to speed field deployments. The most popular preconnectorized option is a length of cable with a connector on one end that can be pulled from the living unit to the distribution terminal for field termination, leaving the preconnectorized end at the living unit for ONT connection. Preconnectorized drops are typically ordered and stocked in a variety of popularly used lengths and deployed as needed. Figure 4.5 shows a reel-in-a-box with ClearCurve Rugged Indoor Drop Cable.

Cable Protection and Aesthetics
As noted earlier, ClearCurve Rugged Drop Cable precludes the need for microduct to protect MDU drop cables, resulting in greatly accelerated drop installation and elimination of microduct material costs. However, for purely aesthetic reasons, surface raceway is often used to hide network cabling. Conduit may also be used for vertical runs of riser and drop cable in riser pathways and outside wall of buildings. ClearCurve Indoor/Outdoor Rugged Drop Cable can be secured directly to exterior building surfaces or placed in outdoor raceway/conduit for added protection and visual appeal. Compared to traditional practices in which microducts are run in large exterior raceway/conduit to protect them from UV exposure, indoor/outdoor rugged drop cable is UV protected. Where raceway/conduit is deployed, a smaller size raceway/conduit can be used compared to that which is required for microduct.

Figure 4.5 – Reel-in-a-Box Rugged Indoor Drop Cable | Photo NS245

Information for Traditional Deployment Technology

Cables and Fiber Types

SMF-28e® and SMF-28e®XB Fibers
Standard single-mode fiber (SMF-28e Fiber) performs well in MDU applications. The MDU environment can be challenging for fiber optic cables due to the tight bends encountered when routing drop cables to each living unit. SMF-28eXB Fiber offers superior bending performance and is quickly becoming the fiber of choice where tight bends must be negotiated while maintaining acceptable optical performance. SMF-28eXB Fiber is compatible with SMF-28e Fiber, showing only a very minor attenuation increase when fusion splicing or connecting it to standard single-mode fiber. Using these fiber types in the same network will be virtually transparent to both the installer and the network electronics.

Drop Cabling – Indoor
A 2.9 mm single-fiber cable provides a good balance of routing flexibility and cable robustness. The cable is reinforced with dielectric strength elements and jacketed with a riser-rated flame-retardant PVC. Plenum-rated drop cables are available as well. Cables are available with factory-installed connectors or in bulk spools.

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Preconnectorized Drop Cables

For RF video applications involving angled-polish connectors, a factory-installed connector is an excellent choice, as it helps reduce installation times and provides the required reflectance performance. The connectorized end is placed at the ONT in the living unit and the bare cable end is routed to a telecommunications closet where a pigtail is spliced to it in the MDU terminal. Preconnectorized assemblies (Figure 4.6) are available in a wide variety of lengths.

Bulk Drop Cable

The 2.9 mm cable just described is available on bulk spools of 500 and 1,000 feet. Purchased in this form, drops can be pulled in and cut to length, minimizing the need to keep an inventory of various length assemblies on hand. Factory-made pigtails can be spliced OR field-installable no-epoxy/no-polish connectors can be installed onto the ends of the cable. Both angled polish (APC) and ultra polish (UPC) field-installable connectors are available.

Cable Protection

Cable protection, especially for drop cabling, can be accomplished by placing microduct inside of walls or by using a variety of surface raceways and moldings into which the drop is pulled or placed.

Figure 4.6 – Preconnectorized Assemblies | Photo NS150

Microducts in Greenfield Deployments

Microduct can be installed easily by electrical contractors during the rough-in phase of new construction. In this scenario, the placement of the pigtail cable assembly can be done after drywall installation and painting. This delayed installation prevents damage during the drywall and painting process. Note – When pulling 2.9 mm single-fiber drops in microducts, a special pulling attachment is used to crimp all of the cable elements to the pull string. This will prevent damage to the optical cable (Figure 4.7). Microduct can be installed in existing structures; however, it is less common due to the cost, time and potential interruption to residents which are involved.

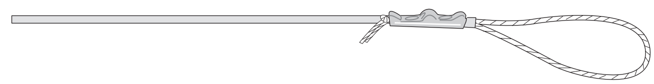

Figure 4.7 – A string loop is crimped to the end of the indoor drop. The pull line is then tied to this loop for pulling in microduct. | Drawing ZA-3094

Microducts run indoors (Figures 4.8a-4.8c) will generally be brought to a common point near the MDU terminal or LCP. At this point, drop cables in the microduct must be consolidated to then enter the terminal or LCP. This function may be built into the terminal/LCP or be accomplished separately. A simple pull box can also be used, provided it is sized to allow for proper bend radius management and easy pulling access to individual microducts. This transition must be kept as close to the terminal/hub as possible to allow for easy drop repair/placement in the future – thus avoiding the need to pull one drop through the existing group.

Figure 4.8a – Microduct | Photo NS119

Figure 4.8b – Microduct | Photo NS120

Figure 4.8c – Microduct | Photo NS121

Figure 4.9 – Transition Pull Box | Photo NS122

Figure 4.9 – Microducts are placed into a simple pull box to transition the drop cables into an MDU Terminal. The MDU Terminal will be mounted next to the pull box. Drops will be pulled later, as required.

Figure 4.10 – Stacked Closet | Photo NS123

Figure 4.10 – Microducts enter a stacked closet from the outside of a three-story MDU. One microduct terminates at a plywood backboard for the unit on this floor. Two more microducts go through the ceiling to serve the two units above this one.

Additional Deployment Information for Both Technologies

Aesthetic Raceway and Moldings in Brownfield Deployments

Where walls and ceilings are already completely sealed and finished, cables can be run on the surface and covered with raceway.

Indoors, surface mounted raceways, such as decorative crown moldings or basic channels, are ideal for routing drop cables from the MDU terminal (at the riser) to the living unit. Multiple drops can be routed in one raceway and dropped at each living unit along the hallway. Raceway products include bend-management components to help prevent bend-induced attenuation in drop cabling, although these devices are not needed with ClearCurve® Drop Cables. Decorative raceway hides and protects drop cables and can be re-entered to add or replace drops.

In Figure 4.11, raceway in the form of decorative crown molding hides and protects drop cables. The raceway can be re-entered to add or replace drops.

Figure 4.11 – Raceway in the Form of Decorative Crown Molding | Photo NS124

Outdoors, drop cables that originate outside and are routed to an indoor destination, or which must be routed entirely outdoors because there is no other available path, can be routed within outdoor surface raceway to provide aesthetically pleasing physical protection for cables. Cables which are not UV-protected must be run in raceway.

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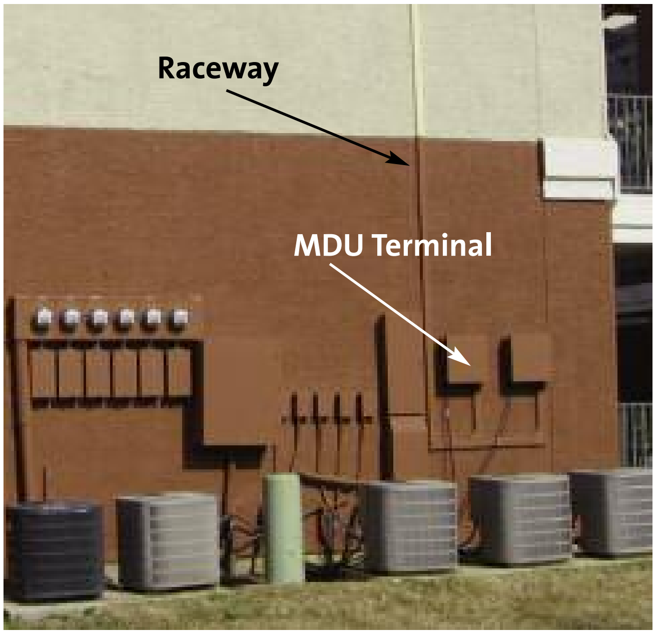

Figure 4.12 – Outdoor Raceway | Photo NS125

In Figure 4.12, raceway can be run on the exterior surface of the MDU to the point of entry for the building – in this case extending up to an attic area. The raceway provides physical and UV protection for the drop cables. As seen here, it has been painted to blend into the color scheme of the building for an aesthetically pleasing installation.

Riser Cables

Riser cables within buildings should be protected by conduit. Because existing MDUs require placement of cable in spaces employed for other uses, such as stacked storage closets or disposal shafts, conduit should be used to protect the cables from physical harm. Cables run on exterior walls should also be protected, using a surface-mounted raceway designed for outdoor applications.

Standard riser cables, such as Corning Cable Systems MIC® and FREEDM® Cable products with Corning® SMF-28e® Optical Fiber, can be used for riser placement. In this case, splicing may be utilized every few floors to tie in MDU terminals. As an alternative, MDU terminals are often deployed with stub cables factory installed and ready for splicing on another floor, in a basement or exterior to the building. New reduced-footprint MDU terminals leverage riser-rated cables with Corning® ClearCurve® optical fiber to achieve significantly smaller physical size.

Outside Plant

Just as with indoor riser and drop, outside plant distribution cables should be physically protected. Cables placed on the outside of buildings or placed underground should be run in conduit for optimal protection.

Terminal Distribution Systems for Outdoor and Riser Applications

Corning Cable Systems FlexNAP™ Terminal Distribution Systems are cable assemblies that offer consistent factory-built quality that increase network construction velocity and cost-effectiveness. Instead of building the cable and terminals onsite in the field, terminal access points (TAPs) are installed on the cable in the factory. The cable is installed like bulk cable but the terminals are now in place. Applications include both outside plant, such as connecting multiple buildings in a garden-style complex, as well as inside plant, connecting terminals to a building riser cable. As a system, these assemblies reduce deployment time and cost by capturing the midspan cable access and splicing that would otherwise be done in the field and performing it in a high-quality manufacturing setting. In the outside plant, distances between consecutive poles and/or handholes along the cable pathway are measured, slack locations and amounts are determined and the fiber count to be accessed at each location is specified. Once all measurements have been made and the exact fibers to be accessed at each terminal location have been determined, the specific requirements for the assembly are entered by the customer into a “configurator.” The configurator accepts the customer order and converts the requirements to a build order that can be executed by the factory to manufacture the assembly. When the custom assembly is built, the cable is accessed and terminal access points (TAPs) are placed on the cable. Each TAP has one or two short tethers with a multifiber connector for attaching a terminal stub cable. TAPs are sealed, low-profile moldings that can be pulled through duct and riser spaces just like any standard cable. The assembly is placed, just like a standard optical cable, and then the CO/HE end is spliced to either an LCP stub cable or a main distribution cable. Terminals are then connected in a plug-and-play fashion, making the network ready for subscriber drop cable connection. In riser applications, TAPs for terminals may be placed every floor, every other floor or every third floor, depending on available space and the number of units to be served on each floor.

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The key components of the FlexNAP™ Terminal Distribution System (Figure 4.13) include:

- A cable assembly, having multiple TAPs at customer-defined locations, which can be placed in the same way as a standard cable.
- The terminal, which can be either an outdoor multiport terminal, OR an MDU terminal (indoor/outdoor use); in some cases, it is desirable to place the assembly, but defer the terminal until the first subscriber is to be connected, thus delaying the cost of the terminal until a future date.
- A hardened OptiTip® Multifiber Connector to join the terminal to the assembly in a matter of seconds.
- Optional loop back caps placed on each OptiTip Connector to facilitate complete system testing from the LCP when terminals have not yet been connected.

To illustrate the advantages of the terminal distribution system compared to a system built with a conventional approach, Figure 4.14 breaks down the time required to build each system. The higher the labor rates where the system is being installed, the greater the dollar savings that can be realized.

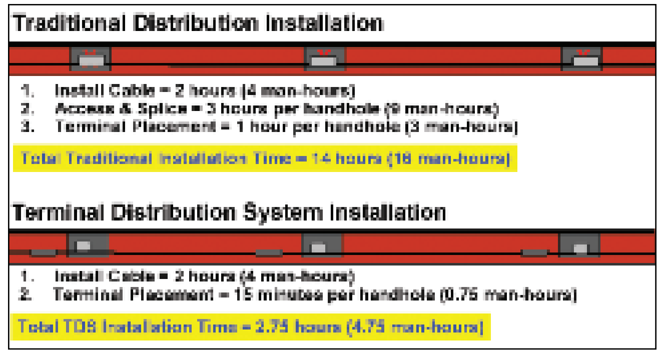

Figure 4.14 – Traditional vs. Terminal Distribution System Installation | Drawing ZA-3086

Features and benefits important when selecting an outdoor terminal distribution system include:

- Wide range of fiber counts (12 to 288)
- Range of fiber counts available at each tap (4-12 per tether with one or two tethers possible)
- Up to 25 TAPs per cable assembly
- Assembly lengths up to 5,000 ft to minimize splicing and/or allow consolidation of several assemblies back to a common point
- Fits into conduit as small as 1.25 in to maximize use of available conduits and minimize cost for new conduits

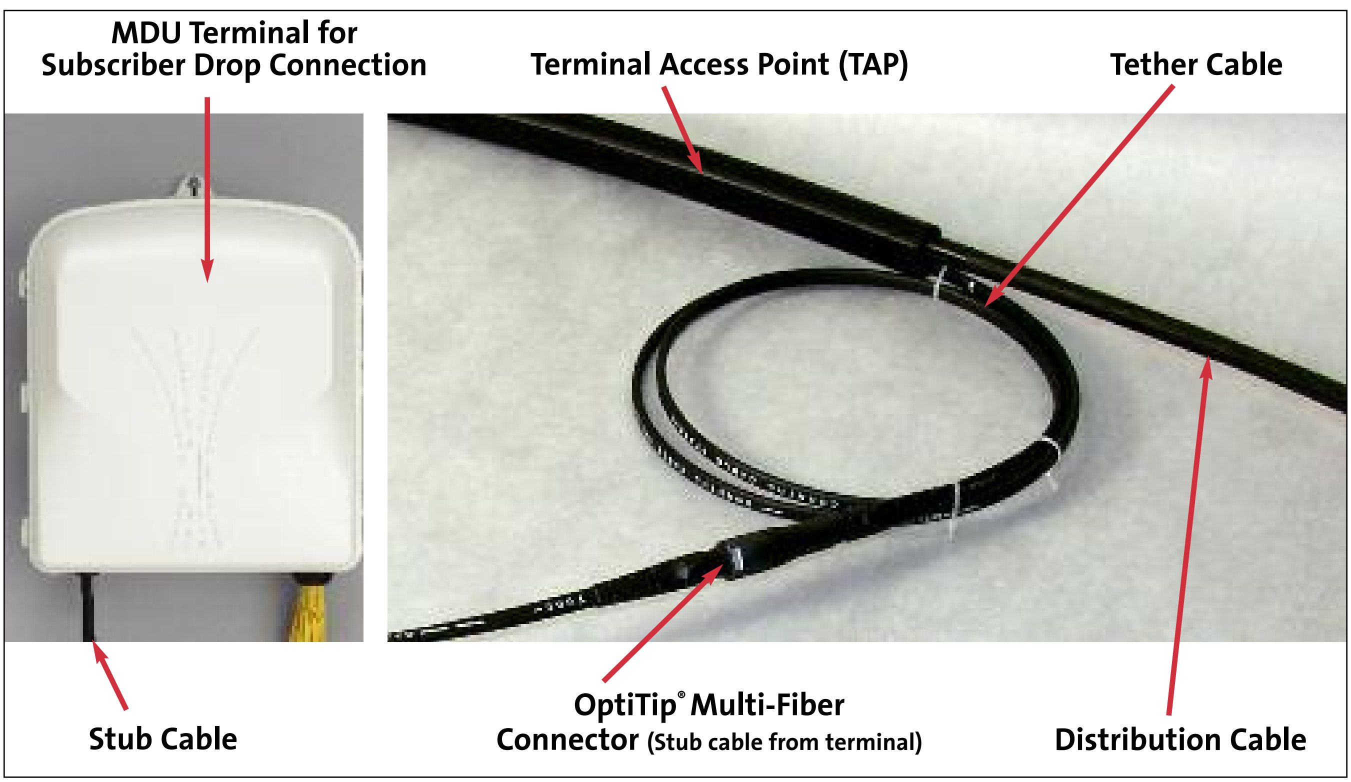

Figure 4.13 – FlexNAP™ Terminal Distribution System Key Components | Photo SHD196, CCO124

- Simple installation techniques – must pull like standard optical cable and provide easy position alignment markings on the assembly to match up to handholes and/or poles.

FlexNAP™ Terminal Distribution System – Riser Applications

Terminal distribution systems for riser applications (Figure 4.15) perform the same function as outside plant systems, except that they are placed vertically in the building riser. The assembly is made using an indoor/outdoor riser-rated cable. TAPs are located at each floor, every other floor or every third floor. This approach is especially useful in medium and high-rise MDU applications. The cable is taken to the top floor and dropped down through the riser so that the taps are lined up with an opening or pull box in the riser conduit where the tether can be accessed. A terminal with a stub cable having a rugged multifiber connector is wall-mounted and connected to the multifiber connector on the tether. Because the TAP connector is ready for connection at any time, terminals can be deferred until the first subscriber is connected. Two tethers can be collocated, one for connection now and one for future use. Multiple assemblies can be used to serve very tall buildings or those with more than one riser. In brownfield installations, conduit as small as 1.25 in can accommodate a terminal distribution system installation.

Since the FlexNAP™ Terminal Distribution System originated in outside plant applications, it is also possible to deploy it vertically and/or horizontally on the outside of an MDU and bring the tether inside to mate to the terminal when a riser pathway is not available.

FlexNAP Terminal Distribution Systems support the ready-to-connect philosophy in riser applications and offer extremely fast deployment of fiber to the home in MDUs. This makes it one of the quickest ways to pass and connect subscribers and rapidly capture market share. FlexNAP Terminal Distribution Systems can also be used in commercial buildings to provide services to business tenants.

Features and benefits important when selecting a terminal distribution system for riser applications include:

- Riser-rated cabling
- Wide range of fiber counts (12 to 144)
- Range of fiber counts available at each tap (4-12 per tether with one or two tethers possible)
- Plenty of access points per cable (25)
- Lengths suitable for any building height, including cable to route horizontally or to adjacent buildings to reach the LCP
- Fits into conduit as small as 2.0 in to maximize use of available riser space/conduits and minimize cost for new conduits

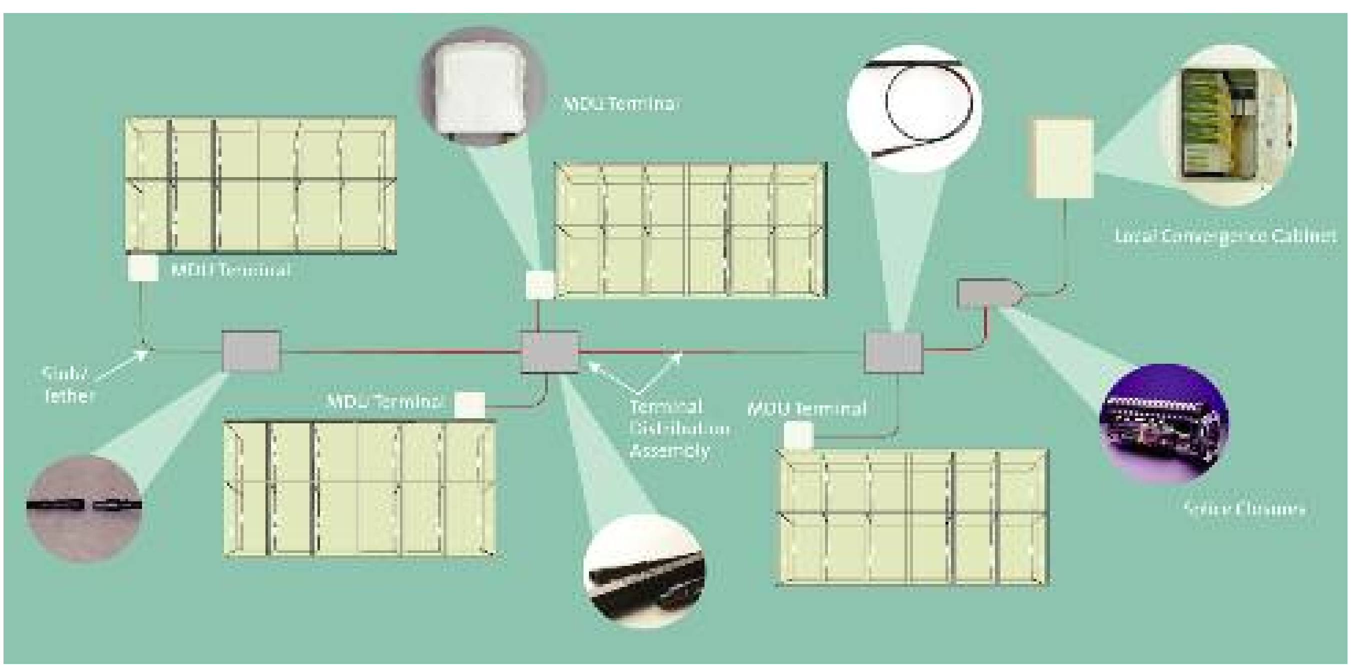

Figure 4.15 – FlexNAP Terminal Distribution System for MDU Complex | Drawing ZA-3208

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Optical Hardware for MDUs

While cabling joins the various points in the network, optical hardware provides the connectivity, splitting and splicing needed to configure and manage the network. Many hardware products are available prestubbed, with a connectorized cable already in place and ready for splicing. This speeds deployment, cutting labor costs and enabling faster revenue generation. Cabinets, sometimes called "hubs," house splitters at the local convergence point and are available in indoor and outdoor versions. MDU terminals can be located on the outside or inside of buildings to connect smaller groups of subscribers. At the living unit, optical outlets can be used to connect to network electronics.

This section outlines the various hardware types used in MDU deployments as well as their respective applications. A reference table at the end of the section provides easy access to Corning Cable Systems product specifications for each type of hardware.

Local Convergence Points

Local convergence points (LCPs) serve as the splitter and connection point described earlier in the section on architectures. They provide individual subscriber connectivity to splitter outputs and serve as the demarcation between the feeder and distribution portions of the network. For the local convergence model, the most com-

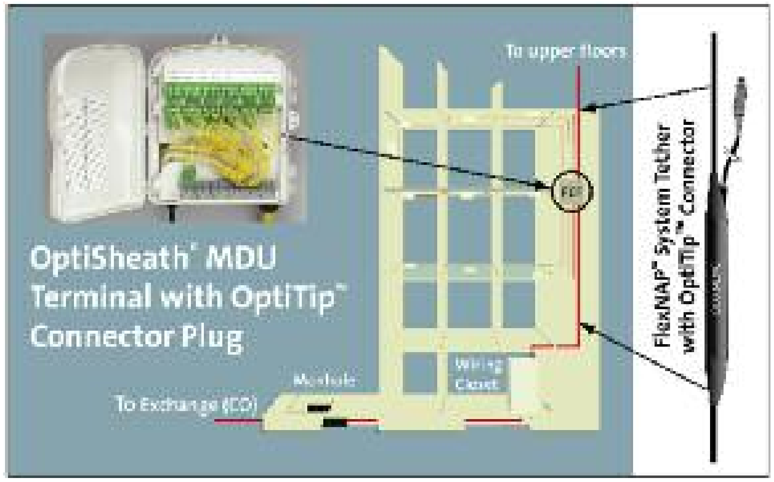

Figure 4.17 – FlexNAP Terminal Distribution System and Terminal | Drawing ZA-3083

mon architecture in use today, they contain all optical splitters. There are three common formats – outdoor cabinets, sealed outdoor closures (see Figure 4.20) and cabinets for indoor use (see Figure 4.18).

Outdoor LCPs – Cabinets

Outdoor LCPs are used to serve single-family homes, groups of small to medium MDUs or a combination of both. They may also serve small- or medium-sized business accounts. Features and benefits important when choosing outdoor LCP cabinets (Figure 4.19) include:

- Wide range of capacities for design flexibility; 144 to 864 fibers
- Small footprint and compact design to minimize real estate used and optimize aesthetics

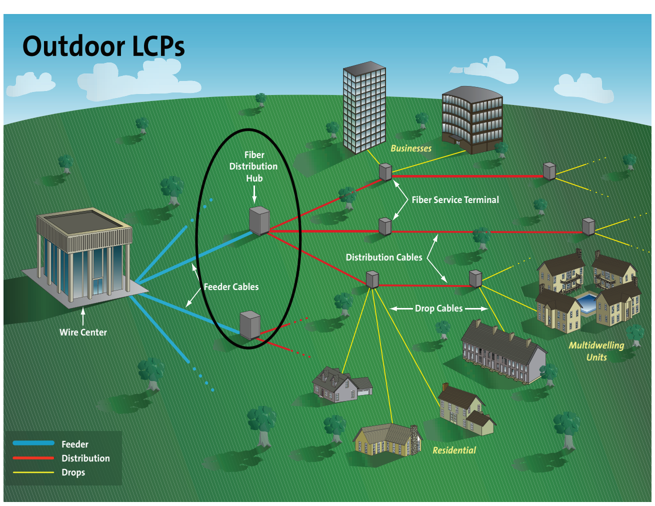

Figure 4.16 – Outdoor Fiber Distribution Hub | Drawing ZA-3085

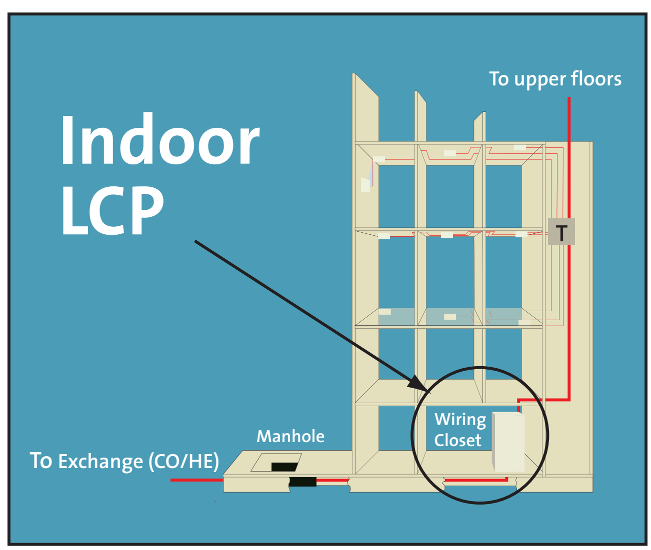

Figure 4.18 – Indoor Fiber Distribution Hub | Drawing ZA-3084

Chapter Four:

Passive Optical System Components for MDUs

- Universal "one-size-fits-all" splitter modules across all cabinet sizes
- Factory preconnectorized stub cables to permit easy installation
- Pole-, pad- and wall-mount capability
- Ample parking for unassigned splitter output legs
- Simple, intuitive fiber management
- Clear dust caps for easy VFL location in the distribution field
- Protective see-through cover for feeder inputs and modules
- ITL tested to applicable sections of GR-2898, GR-487, GR-63, GR-449-CORE, UL listed

Outdoor LCPs – Sealed Closures

Sealed LCPs (Figure 4.20) serve the same purpose as cabinet-based LCPs (to contain splitters and provide assignment of splitter outputs to subscribers), but are intended for underground use in handholes and vaults. Their primary use is where an "out of sight" network is desired. By placing the LCP below grade, there is usually no concern for additional permitting or real estate (right of way) needs. Sealed LCPs provide splitter connectivity management as well as parking for unused outputs. They are prestubbed for feeder and distribution sides, just like cabinets. Because they are sealed and more compact than cabinets, their subscriber capacity is smaller, too. Features and benefits important when choosing a sealed LCP include:

- Range of capacities for design flexibility; 72 to 144 fibers
- Simple, intuitive fiber management
- Buried (handhole, vault), aerial, pole and pedestal mounting capability
- Prestubbed and preconnectorized
- Ample parking for unassigned splitter output legs

Figure 4.19 – OptiTect® Local Convergence Cabinet, LS Series | Photo HWPSS1794

Indoor LCPs

Indoor LCPs (Figure 4.21) provide the same functionality as the outdoor units but are intended for indoor use. They come with and without stub cables. They can contain space for splicing within the cabinet and offer the appropriate hardware for indoor mounting. Features and benefits important when choosing an indoor LCP include:

- Wide range of capacities for design flexibility that includes medium to very large MDUs; 72 to 432 fibers
- Splicing options for feeder and distribution cables
- Small footprint and compact design to facilitate deployment in tight spaces
- Universal "one-size-fits-all" splitter modules for all cabinet sizes

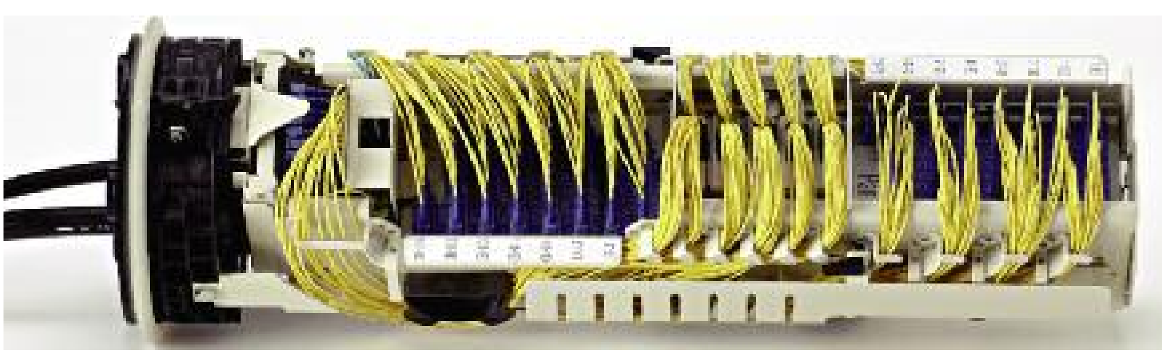

Figure 4.20 – OptiTect® Sealed LCP Enclosure | Photo SHD186

Chapter Four:
Passive Optical System Components for MDUs

- Factory preconnectorized stub cables to permit easy installation
- Wall- and rack-mountable capability
- Ample parking for unassigned splitter output legs
- Simple, intuitive fiber management
- Clear dust caps for easy VFL location in the distribution field
- Protective see-through cover for feeder inputs and modules

OptiSheath® MDU Splitter Terminals

The OptiSheath® MDU Splitter Terminal is a rugged, low-cost, low-profile interconnect between the central office feed and the indoor/outdoor drop cables for multi-dwelling unit applications. It simplifies the MDU installation by reducing the installation materials, complexity and the space required to turn up service. A single housing combines the functionality of a local convergence cabinet with an MDU terminal.

Figure 4.21 – OptiTect® Indoor MDU Local Convergence Cabinet | Photo CCO119

Features and benefits important when selecting an MDU terminal (Figure 4.22 and 4.23) include:

- Indoor and outdoor rated
- Four to 32 ports in a single, low-profile footprint
- Available with 1x4, 1x8, and 1x32 splitters as well as dual 1x4, dual 1x8 and dual 1x16 splitters
- Factory-installed feeder (input) with the option to be direct spliced or connectorized to the splitter input
- 4-fiber input provides extra fibers to use as needed
- Preterminated pigtails simplify splicing of drop cables
- Fast, easy, reliable SC APC connector technology
- Integrated parking with splitter legs pre-routed and parked in place by the factory

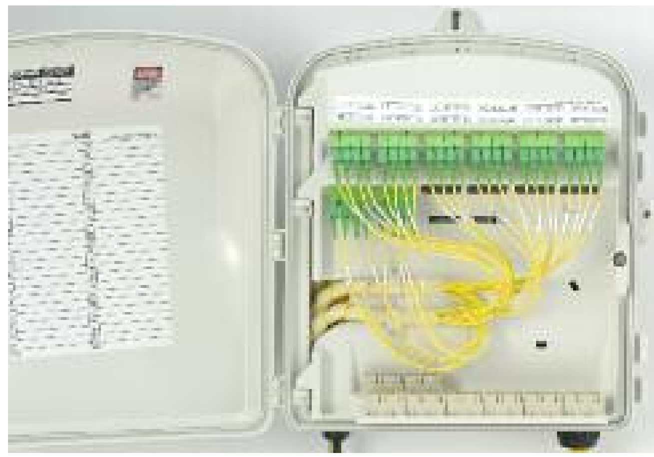

Figure 4.22 – OptiSheath MDU Splitter Terminal | Photo SHD213

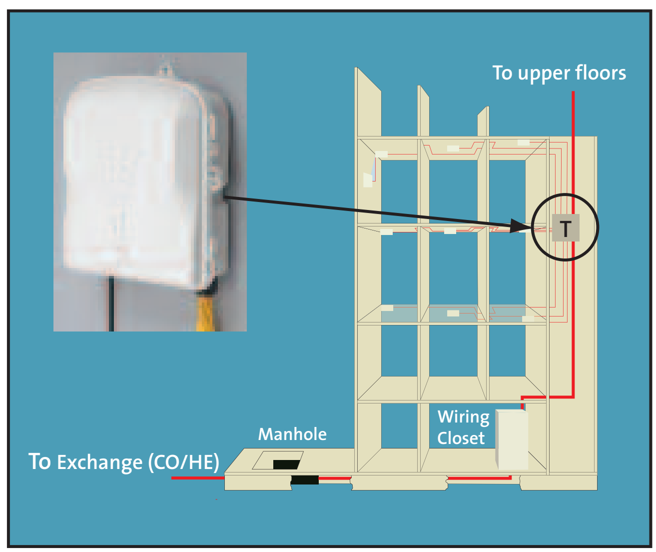

Figure 4.23 – OptiSheath MDU Splitter Terminal | Drawing ZA-3095

ClearCurve® Fiber Distribution Terminals

The ClearCurve® Fiber Distribution Terminal (Figure 4.24) is a small, simple, rugged interconnect between the fiber optic distribution network and drop cables, ideally suited for MDU and FTTB applications.

Figure 4.24 – ClearCurve Fiber Distribution Terminals | Photos CCV004, 005

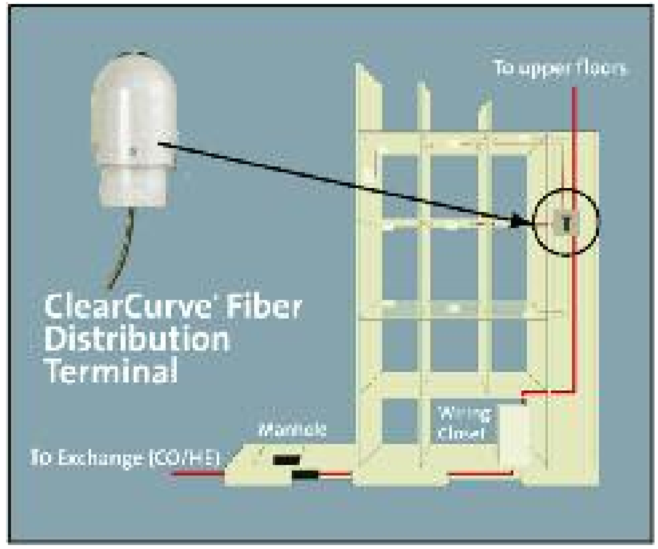

Figure 4.25 – ClearCurve Fiber Distribution Terminal | Drawing ZA-3204

The terminal can be mounted directly to any wall surface or pole in either indoor or outdoor applications, making it ideal for both high rise and garden-style apartment applications. The ClearCurve® FDT is preterminated on the distribution side with outside plant or indoor/riser rated cable stubs enabling simple and quick connection to the fiber plant and maximum flexibility with a single product.

The ClearCurve FDT features a separate mounting plate which allows quick and easy mounting by one person without the risk of damaging factory-terminated cables. The terminal engages onto this plate and is locked into place when the cover is on. This unique feature also hides the mounting hardware, making the unit more attractive and preventing unauthorized removal of the terminal.

Features and benefits important when selecting a ClearCurve FDT terminal (Figure 4.25) include:

- 12- and 24-fiber capacity
- Minimal footprint/depth, making it easy to find a mounting location in space-constrained deployments
- Separate mounting plate and preterminated distribution stub allow easy, fast, risk-free installation
- Aesthetically superior and tamper proof design with hidden mounting hardware
- Indoor and outdoor mounting capability
- Optional skirt provides up to 12 in of coiled slack and eliminates extra hardware, conduit and fittings for microduct transition or wall exits
- Individual drop entries allow the deferment of drops until subscriber turn-up
- Drop installation is quick and easy using entry grommets which double as the strain-relief
- Engineering-grade thermoplastic housing is corrosion-resistant, impact-resistant and flame-retardant
- Terminals are designed and tested to applicable sections of Telcordia GR-771

Optical Wall Plates

Drop cables may be routed directly to the ONT or to a wall plate to terminate it in the living unit. OptiWay® Wall Outlets isolate the drop cable with a jumper used to connect to the ONT. Because the drop connector remains in the wall behind the wall plate, the chance for damage is minimized. If the jumper to the ONT is damaged, it can be easily replaced. Wall outlets can be

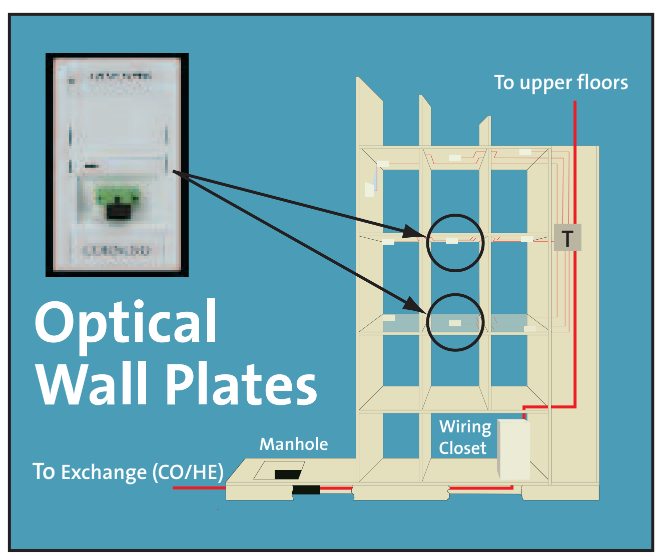

Figure 4.26 – OptiWay Wall Outlets | Drawing ZA-3096

Figure 4.27 – OptiWay Network Interface Device | Photo NID011

attached to standard, deep single-gang electrical boxes or to low-voltage outlet brackets.

Features and benefits important in selecting an optical wall outlet (Figure 4.26) include:

- Mounts to standard single-gang electrical box
- Utilizes modular panels
- Angled adapter increases connector and jumper protection and enhances eye safety
- Optional spring-loaded dust cap
- Includes unit identification labels
- Optional copper connectors available upon request

Optical Network Interface Devices

OptiWay® Network Interface Devices (NIDs) provide a convenient optical interface for one or several distribution and/or drop connections. They can be used on the outside of small MDUs such as duplexes and quadplexes or on an interior surface, such as in a garage, basement or closet. In addition to a connector interface, they usually offer splicing capability, as well. ONT vendors use similar housings to contain their electronics boards and cable interfaces.

Features and benefits important in choosing an optical NID (Figure 4.27) include:

- Tamper proof housing that can be padlocked
- Indoor and outdoor mounting capability
- Accepts fiber optic, coax, Ethernet and telephone cabling
- Accepts conduits and raceway
- Slack storage devices available to store up to 40 feet of drop cable
- Capability to perform and protect pigtail splicing
- UL certification

Figure 4.28 – OptiSnap® Optical Fiber Cleaver | Photo CCA206

Figure 4.29 – OptiSnap Connector Installation Tool | Photo LAN771

Optical Connectors and Termination Methods

Optical Fiber Termination Methods

Optical fibers are terminated wherever they must make connections to electronic devices (CO/HE and subscriber ONTs) as well as anywhere it is necessary to mate, un-mate and re-mate to other fibers and photonic devices. Terminating a fiber requires that a connector be installed on it. Connectors provide a means for making easy connections and the ability to connect test equipment for performance verification and troubleshooting purposes, without the need to break and remake splices.

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Termination in the outside plant (OSP) is generally done by fusion splicing a pigtail (fiber with a factory-installed connector) to the end of the fiber being terminated or by field installing a no-epoxy/no-polish connector directly on the fiber/cable. Both single-fiber and multifiber pigtails are available for terminating cables. Pigtails offer factory-polished and tested end-faces for top performance. For inside plant, such as in MDU terminals and indoor LCPs, pigtail splicing is also used.

Advances in no-epoxy/no-polish connectors are now making it possible to field install connectors directly on MDU drop cables without the use of a fusion splicing machine. Initial use of these connectors will be at the ONTs located inside living units and at MDU terminals. These connectors are available in both angled (APC) and non-angled (UPC) versions. Installation of these connectors takes the operator just a couple of minutes. The installation tool is easy to use and provides immediate "go/no-go" feedback on connection quality. It is now possible to deploy indoor drops using bulk cable reels, where the cable can be pulled and cut to length. Because set up time is minimal, the impact on tenants is minimized and overall deployment is accelerated. The OptiSnap® Field-Installable Connector uses simple cleaving and installation tools (Figures 4.28 and 4.29).

The following features and benefits are important when selecting field-installable connectors and tools:

- Ergonomic craft-friendly designs for cleaver and installation tool
- Integrated, battery powered continuity test system
- Go/no-go analysis and instant feedback to know connector is good
- Cleaver with integrated fiber capture
- Correct cleave length every time
- Compatible with wide range of fiber coating and sheath sizes
- UPC and APC connectors available (Figure 4.30 and 4.31)

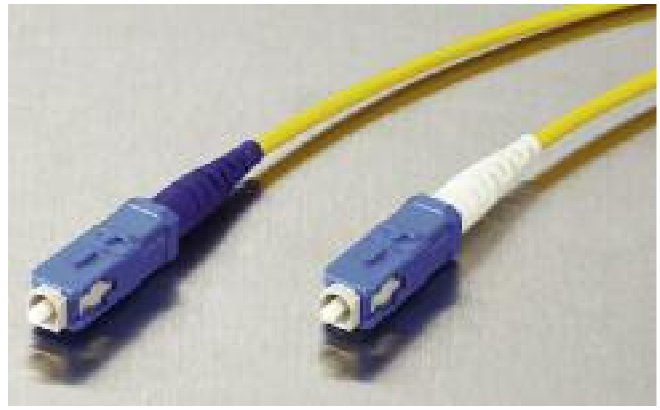

Figure 4.30 – UPC Connectors | Photo LAN620

Optical Fiber Connection Performance

Optical connectors are characterized by two main properties: reflectance and insertion loss.

Reflectance

Reflectance is defined as the ratio of power reflected from an individual component, such as a connector, compared to the power being transmitted through (or incident upon) it. It is expressed as a negative value, and the lower (more negative) the value, the better the performance. For example, a value of -65 dB indicates that the reflection from the component is 65 dB below the incident signal being transmitted through the connector. Reflected optical power can decrease the received signal-to-noise ratio (SNR) and carrier-to-noise ratio (CNR) in video applications. For RF video overlays, this can mean degraded picture quality for television services. For data, it can increase the bit error rate (BER) leading to reduced transmission rates and poor network utilization. The higher the reflectance, the better the transmitted signal quality will be. The electronic system's connector reflectance specification is the parameter that should dictate component performance.

Figure 4.31 – APC Connector | Photo LAN807

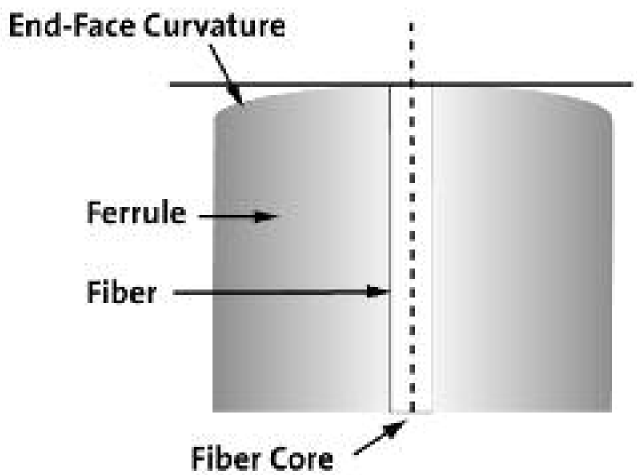

Figure 4.32 – UPC Connector End-Face | Drawing ZA-3128

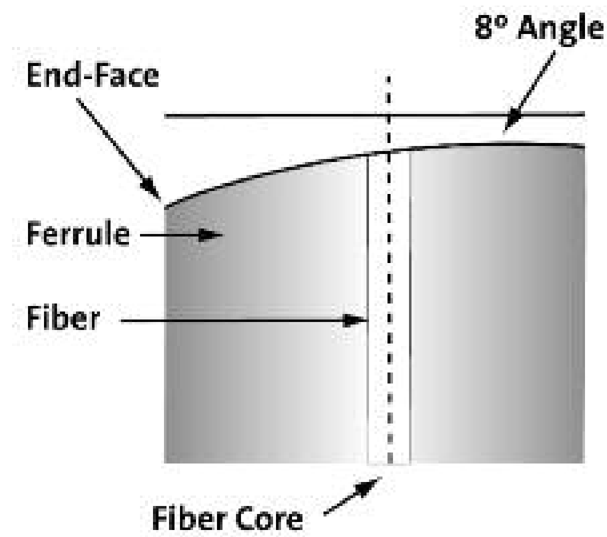

Figure 4.33 – APC Connector End-Face | Drawing ZA-3127

Insertion Loss

Insertion loss represents the amount of signal loss (attenuation) caused by inserting (or introducing) a component into a system. The smaller the insertion loss, the better the performance. This relative loss (dB), specifies optical performance. Lower insertion loss values are better, thus a maximum attenuation level is often specified at 0.5 dB. Connectors that lower insertion loss enable more connections in the channel, all else being equal. Premium-performance connectors are available to help minimize system attenuation, potentially increasing network distance range.

Optical connectors are classified into two groups based on how the mating surface of the connector ferrule is polished:

Ultra physical contact (UPC) connectors

Ultra physical contact (UPC) connectors (Figure 4.32) have a basically “square” end-face, which is actually polished to have a slight radius (curvature) to it. These connectors offer reflectance of ≤ -55 dB. This performance is generally accepted for Ethernet, BPON and GPON connections and is often used on the output ports of OLTs in the CO/HE. These connectors and their interconnect adapters are easily identified by their industry-recognized blue color.

Angled physical contact (APC) connectors

Angled physical contact (APC) connectors (Figure 4.33) also have a radiused polish, but the mating surface of the connector ferrule is angled at 8 degrees to the passing light beam. This angled end-face minimizes reflections. This is required for systems using RF video overlay techniques, to avoid poor carrier-to-noise performance which can degrade picture quality. APCs are commonly used on CATV RF equipment such as EDFAs (erbium-doped fiber amplifiers). These connectors provide a reflectance performance of ≤ -65 dB. APCs and their interconnect adapters are easily identified by their industry-recognized green color. Even if a system will not be using RF video, it is recommended that APCs be used throughout the system for future-proofing purposes to ensure compatibility with present and future technologies.

A Note on Connector Cleanliness

Proper connector cleaning is critical for maximum system performance. Cleaning kits are available for all types of connectors and connector adapters. Both dry cleaning methods (used mainly in outside plant) and wet cleaning methods (used mainly indoors or when a stronger process is required) are available. Cleaning maximizes connector reflectance, minimizes attenuation and ensures the longest possible life for connectors. As a rule, connectors should be cleaned before each mating. Where high power is present (> 15 dBm), as in RF overlay systems, proper cleaning minimizes the chance of connector damage due to high system power. When cleaning connectors, the power should be reduced, or ideally, turned off during cleaning. Proper eye safety procedures must always be used.

Fiber Splicing

There are three methods used for splicing in fiber optic systems. Single-fiber and mass fusion splicing methods provide the lowest possible attenuation with zero reflectance. In fusion splicing, the glass fibers are fused (welded) using a high-temperature electric arc and computer-controlled mechanism to optimize the joint. The third form of splicing, mechanical splicing, holds the fibers in permanent contact and alignment using a physical device. Because the glass is not actually fused, there may be some non-zero reflectance observed.

Single-fiber fusion splicing involves stripping, cleaning, cleaving (for a clean cut) and splicing two fibers to each other. Several different types of alignment mechanisms are available, from low-cost "V-groove" technology to more sophisticated methods that identify the fiber claddings and/or the fiber cores and use these images for computer-guided alignment.

Mass splicing is used to join fiber ribbons of four to 12 fibers together all at once. The ribbon is stripped, cleaned, cleaved and spliced much the same as for single-fiber splicing, but can achieve much higher productivity where ribbon cables and/or high-fiber-counts are involved. The attenuation for mass spliced fibers may be slightly higher than for single-fiber splicing but the productivity gains far outweigh the differences.

Mechanical splicing involves much the same preparation as for fusion splicing: stripping, cleaning and cleaving the fiber. Because mechanical splicing may contribute some reflectance to the system, it is not commonly used for permanent splicing applications. However, for temporary use, such as a fiber cable restoration, a mechanical splice can be used to get the system up and running quickly, followed by a permanent fusion-spliced solution.

Standard Performance Splitter Specifications	Typical IL	Maximum IL
1x2 Coupler/Splitter	3.1	3.90
1x4 Coupler/Splitter	6.3	7.70
1x8 Coupler/Splitter	9.7	10.75
1x16 Coupler/Splitter	12.7	14.00
1x32 Coupler/Splitter	15.8	17.10
1x64 Coupler/Splitter	18.9	20.50
2x2 Coupler/Splitter	3.1	3.90
2x4 Coupler/Splitter	6.3	7.80
2x8 Coupler/Splitter	10.0	11.20
2x16 Coupler/Splitter	13.0	14.80
2x32 Coupler/Splitter	16.0	18.00

Figure 4.34 – Standard Performance Splitter Specifications | Drawing ZA-3124

Splitters

Splitters (also called couplers) are photonic devices that split a single optical signal into two or more outputs. PON systems use splitters to divide the downstream signal power from the CO/HE into multiple outputs, typically 16 or 32 outputs, for delivery to subscriber ONTs. The ONTs in turn send signals upstream, which are combined onto one single-fiber back toward the CO/HE. The OLT/ONT electronics manages communications between the CO/HE and the 16 or 32 subscribers connected over the fiber and splitter.

Because the splitter divides the optical power of the signal, it has an important impact on the system loss budget. Each time the signal is divided in two, it represents a 3 dB attenuation, plus a small allowance for inherent losses in the device itself. Therefore 1x16 and 1x32 splitters used in typical PON systems have considerable alteration. Figure 4.34 relates various split ratios and their typical insertion loss performance. Splitters with two inputs and 16 or 32 outputs are also available and can be used in applications where signals from two sources must be combined and then shared among the outputs.

Corning Cable Systems Master Product Reference Chart

For more information on the wide range of MDU solution sets, simply click on the product area of interest in the following chart to see a full specification sheet. Use the "Back" button to return to this page.

Product Family	Corning Cable Systems Product Name	Small MDU	Medium MDU	Large MDU	Literature Code
Local Convergence Point - Outdoor	OptiTect® Local Convergence Cabinet, Gen III Series OptiTect® Local Convergence Cabinet, LS Series	X X	X X		EVO-613-EN EVO-771-EN
Local Convergence Point - Sealed	OptiTect Sealed LCP Enclosure	X	X		EVO-596-EN
Local Convergence Point - Indoor	OptiTect Indoor MDU Local Convergence Cabinet		X	X	EVO-707-EN
Riser Cable	FREEDM® Loose Tube Ribbon Cable		X	X	EVO-158-EN
Riser Cable	MIC® Cables Ribbon Riser		X	X X	EVO-149-EN EVO-839-EN EVO-837-EN EVO-838-EN EVO-114-EN
MDU Terminals	OptiSheath® MDU Terminal ClearCurve® Fiber Distribution Terminal	X X	X X	X X	EVO-578-EN EVO-765-EN
Drop Cable Assembly	ClearCurve® Drop Cable Assembly	X	X	X	EVO-786-EN
Drop Cable - Outdoor	OptiTip® Multi-Fiber Drop Cable Assembly ClearCurve Rugged Drop Cable	X X	 X	 X	EVO-463-EN EVO-762-EN
Drop Cable - Indoor	Cable Assemblies Single-Fiber Riser Cable Single-Fiber Plenum Cable ClearCurve Compact Drop Cable ClearCurve Rugged Drop Cable	X X X X X	X X X X X	X X X X X	EVO-29-EN EVO-855-EN EVO-854-EN EVO-761-EN EVO-762-EN

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Literature codes listed above are up-to-date as of June 2009. Corning Cable Systems shall not be responsible for the performance of third party products or for any incorrect installation or installation in violation of Corning Cable Systems specifications and procedures. For the latest Evolant® Solutions updates, visit our Web site at www.corning.com/cablesystems/evolant.

Chapter Four:

Passive Optical System Components for MDUs

Corning Cable Systems Master Product Reference Chart

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Product Family	Corning Cable Systems Product Name	Small MDU	Medium MDU	Large MDU	Literature Code
Optical Network Interface Device	OptiWay® Network Interface Device (NID)	X	X	X	EVO-486-EN
Wall Outlet	OptiWay Wall Outlet	X	X	X	EVO-584-EN
Field-Installable Connectors	OptiSnap™ Connector	X	X	X	EVO-734-EN
Fusion Splicers - Single-Fiber	OptiSplice® One Handheld Fusion Splicer	X	X	X	EVO-702-EN
Fusion Splicers - Ribbon	OptiSplice Ribbon Fusion Splicer	X	X	X	EVO-703-EN
Test Equipment - Attenuation Test Set	OTS-400 Series, Optical Meters, Sources & Testers	X	X	X	LAN-726-EN
Test Equipment - OTDR	OV-1000 Optical Time Domain Reflectometer (OTDR)	X	X	X	EVO-697-EN
OTDR Accessories	Portable Test Fibers *(OptiTap® Connector Test Fiber Bag)*	X	X	X	LAN-599-EN *Call for information*
Tools	Fiber Optic Tool Kits	X	X	X	EVO-230-EN
Tools	Indoor Drop Pulling Kit	X	X	X	SRP-004-108
Connector Cleaning	Universal Connector Cleaning Cassette	X	X	X	LAN-130-EN

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Chapter Five:
Cabling Practices (Physical Install)

Building Code Considerations

Building codes vary from location to location. The building codes discussed herein are primarily geared to the U.S. market and are intended as guidelines. Codes vary on both local and national levels; therefore, the reader should always check with the local authority having jurisdiction to verify specific code requirements before installing network elements. The reader is also referred to resources such as the National Electric Code® (NEC®) in the United States and similar guidelines in other countries. Important code considerations include:

Raceways and indoor cables must be rated for the space in which they are placed. Spaces such as hallways and living space on the same floor are considered general cabling areas. Vertical runs, including riser pathways, require riser-rated products. And any area that is used as an air handling space requires plenum-rated products. Optical cable jackets are labeled as OFNG, OFNR or OFNP, for "optical fiber non-conductive general, riser or plenum." Optical cables in MDUs are generally non-conductive, but cables with metallic armor would be rated OFCx. When used together, non-metallic raceways and cables are effectively rated at the lowest rating of the combination. In other words, a riser cable in a plenum raceway is considered suitable for riser use only. Optical cables for indoor use are generally sold as OFNR and OFNP products; OFNR is used to cover OFNG applications. In addition, plenum can be used in plenum, riser and general applications.

Non-rated cables are used for outside plant applications, such as the aerial and below-ground cables that come to the MDU or run through the MDU complex. Under the NEC, these cables can be run up to 50 feet inside the building to reach a terminal. If the cable must be run longer than 50 feet, it must be placed in metallic conduit to within 50 feet of the terminal location. A cost-effective alternative is to use an indoor/outdoor cable, such as Corning Cable Systems FREEDM® Cable, which is suitable for outdoor applications but is made with materials allowing it to be OFNR rated, as well.

Distribution and Drop Cabling Considerations

Distribution cables can be defined as those cables in the building that carry traffic for more than one subscriber AND which do not offer individual subscriber connections directly.

Drop cables can be defined as an individual cable that serves a single subscriber, or a cable has the means to break out individual subscriber connections.

Duct and Raceway

Duct and microduct can be defined as any pathway through which the cable is pulled. For drop cables, microduct with a pre-installed pull string has been used extensively; however, rugged drop cables now available can be placed without microduct at a much lower installed cost.

Raceway can be defined, in this context, as any pathway into which cables can be placed, rather than pulled. This includes surface-mount and crown moldings into which cable is laid and then a covering is snapped into place.

Path Creation

Path creation refers to the process of determining cable pathways and placing the raceway, conduit, duct and innerduct, as well as any required cutting or drilling, so that the cables may be placed. A variety of installation options are available to create paths in both greenfield and brownfield installations. These are described in further detail in the sections that follow. There are three main approaches to path creation. One option is to create a path by placing conduit, duct and cables directly inside walls, ceilings and basements/crawl spaces. A second option is to place cables in raceway, along the outside surface of a building. The third approach is to place raceway along the inside surfaces of the building. In many cases, the project will ultimately be accomplished with a combination of two or all three approaches. For example, a bundle of rugged drop cables may be run up the side of a building, covered in raceway, then spread throughout an attic where they are dropped down through a wall or conduit to reach a floor below.
The main goal is to create the path at the ***lowest cost*** with the ***least interruption*** to residents and in the ***shortest time***. Every MDU is different, therefore each MDU must be evaluated on an individual basis and the path determined accordingly. However, with the introduction of ClearCurve® Rugged and Compact Drop Cables, as well as the wide range of raceway and conduits, cables and hardware in the "tool box," virtually any MDU can be treated to the benefits of a high-speed fiber optic access network.

Chapter Five:
Cabling Practices (Physical Install)

In-Wall Installation

In-wall installation involves placing microduct for traditional deployment technology or using ClearCurve® Rugged Drop Cable directly through and between studs in the cavities between studs and joists, and in attics, crawl spaces and basements. Greenfield applications use this method almost exclusively, since it can be easily roughed in before drywall is installed. It can be quickly installed, and the result is an invisible network. It is the most aesthetically pleasing method. In-wall installation is used in all sizes of MDUs, from low-rise to high-rise.

ClearCurve Rugged Drop Cable and traditional methods are used in brownfield applications as well. Cables are often pulled through attics, then down through stacked closets or other structures. In high-rise applications, cables are pulled through ceilings to reach living units, if that space is available, or placed in raceways that provide an aesthetically pleasing outward appearance.

For in-wall installations, the rugged drop cables are run from each living unit back to an MDU terminal common to one to three floors. In smaller MDUs, the rugged drop cables may be run to a terminal in a telecom room in the basement of the building, which serves the entire building.

Interior Surface Installation

This method is used in a broad spectrum of brownfield applications, including low, medium and high-rise MDUs that have interior hallways for tenant access. Raceway, consisting of a mounting track and cover, is attached to the walls in hallways for aesthetic purposes. Drop cables are placed in the track and the cover snaps in place to hide and protect the cables. Various types and shapes of raceway are available, including basic rectangular cross section products as well as decorative crown molding types. Inside and outside corner guides are available, as are radius guides where cables must penetrate a wall, such as to enter a living unit. Radius guides are generally not required for rugged drop cables and to only a minimal extent with compact drop cables. Radius guides are required with non-ClearCurve fibers. Raceway may also be used in the living unit to protect the drop cable when it must run some distance to reach the ONT.

In the interior surface installation method, an MDU terminal is located in the building, often in a closet, and serves living units for the floor where it is installed. In some cases, it also serves living units on other floors, usually one floor up and one floor down. Individual drops converge on the MDU terminal where they are connected to a common distribution (backbone) cable that runs vertically through the building.

Exterior Surface Installation

This method is used primarily in low- and some medium-rise MDUs, where access is available to work on the exterior walls. Surface raceway designed for outdoor use is run from a fiber distribution terminal mounted low on the building, up walls (vertically) where it protects the drop cables until they either penetrate living units, enter attic space or turn and run horizontally to nearby units. Once in the living unit, the rugged drop cable may immediately enter an outlet or ONT housing, or it may run some distance on indoor surface raceway to reach the ONT.

Also known as "wrapping the building," the exterior surface installation method provides less disruption to tenants, in their common areas, than the interior surface installation method. Entry to living units is still required to complete the installation. Holes are drilled in exterior walls so cables can pass through to the interior of the living unit. On the outside, raceways can be painted to blend into the color scheme of the building.

Network Testing and Documentation

Testing within the MDU environment involves three segments: drop cables, riser distribution and outside plant (OSP) distribution. Where splitters are present, they can also be tested.

An **attenuation test set** (power meter and light source) should be used to test between the LCP and MDU terminal and again between the MDU terminal and the living unit. At a minimum, both 1310 and 1550 nm wavelengths should be tested. Test sets are available that test at all three FTTH wavelengths: 1310, 1490 and 1550 nm.

Chapter Five:
Cabling Practices (Physical Install)

An **optical time domain reflectometer** (OTDR) can be used to verify length and identify high reflectance connectors when needed. At a minimum, OTDR traces should be completed on each fiber link in the riser distribution and any OSP portions of the network, at 1550 nm. Testing at 1310 nm may also be completed, but 1550 nm is best to identify any bending concerns, should they exist. OTDR testing on drops can be performed on an as-needed basis for troubleshooting purposes.

System **documentation** should include all attenuation test values and all OTDR traces. In addition to test values, documentation should include information on all cable and pathways, terminal and hub locations, splitter and OLT assignments and splice locations.

Troubleshooting and Repair

Troubleshooting MDU fiber networks requires two things: 1) a structured approach to breaking down and analyzing the problem, and 2) the proper equipment to perform needed optical testing. A structured approach to troubleshooting will determine if the trouble is in the MDU cabling or exterior to it. The following series of questions serves as a troubleshooting guide:

Is the outage affecting all subscribers on an LCP? If so, the problem is in the feeder portion of the network, between the CO/HE and the LCP.

- Use an OTDR and/or power meter to inspect the feeder portion of the network, from the CO/HE to the LCP (feeder input fibers).
- Visually inspect suspect areas in the network for damage. Otherwise …

Is the outage affecting all subscribers on ONE splitter in the LCP? If so, the problem is in the CO/HE electronics, the input connection to the splitter, the feeder fiber connecting that splitter or the splitter module itself.

- Verify that the CO/HE electronics that feed the affected splitter are functioning properly.
- Ensure that the feeder input connection is properly cleaned.
- Use a power meter to verify the presence of the feeder signal in the LCP.
- Verify the presence of the optical signal on the splitter outputs. Otherwise …

Is the outage affecting all subscribers on one MDU terminal? If so, the problem is most likely in the cabling (riser or outdoor) between the MDU terminal and the LCP.

- Use a power meter to check for light levels at the MDU terminal drop connections.
- If no power is present, inspect the cabling between the terminal and the LCP; use an OTDR, if necessary to troubleshoot the link. Otherwise …

Is the outage affecting just one subscriber or subscribers on one building floor? If so, the problem may be anywhere between the MDU terminal and the subscriber ONT. In some cases, it could be between the MDU terminal and the LCP.

- Locate the MDU terminal that serves the subscriber with the outage. Use a power meter to verify the presence of the optical signal at the terminal for that subscriber.
- If no light is present, verify the presence of the signal at the splitter output for that subscriber at the LCP. If the signal is present at the LCP, troubleshoot the LCP-MDU terminal link with an OTDR and visual inspections. If no light is present, inspect the splitter output leg for damage and ensure the connector is properly cleaned. If this does not resolve the issue, verify the presence of the signal on another output leg from that splitter. Troubleshoot the splitter or feeder link as need.
- If normal light levels are present at the subscriber's connection at the MDU terminal, visually inspect the drop cable path for signs of damage to the cable. A visual fault locator can be used to find breaks in 2.9 mm cables, where accessible.
- If no obvious damage is found, consult the building owner or tenant, according to approved local practices, and gain appropriate access to the living unit. Verify the presence of normal optical signal levels at the ONT. If normal levels are not present, repair or replace the drop cable. Otherwise …

Is there a normal optical signal level at the ONT? If so, the ONT may be the source of the outage.

- Test the ONT for proper operation according to manufacturer's recommendations. Repair or replace accordingly. Otherwise …

Is the inside wiring (IW) connected and in proper working order? If the ONT is functioning properly, the IW may be the source of the outage.

- Verify all ONT connections to the IW.
- Query the tenant regarding any work done in the living unit or changes that may have impacted the IW. Otherwise…

Verify that network appliances are properly connected and functioning.

Chapter Five:

Cabling Practices (Physical Install)

The equipment needed to fully troubleshoot an MDU optical network consists of a VFL, power meter and light source and an OTDR. The VFL provides a blinking red laser light that will shine through the jacket of drop cables and pigtails when there is hidden damage inside. It is a simple, low-cost tool. It will not, however, shine through microduct, duct, raceway or larger cable sheaths. An OTDR can be used to measure the distance to and the signal loss of hidden damage in cables. A power meter and light source are used for both checking power levels and for end-to-end testing of links to compare to the expected link loss. Once the link is repaired, the meter/source can be used to test and document the now good condition of the link.

Troubleshooting and Repair Flowchart – The following flow chart integrates the steps listed on Page 47

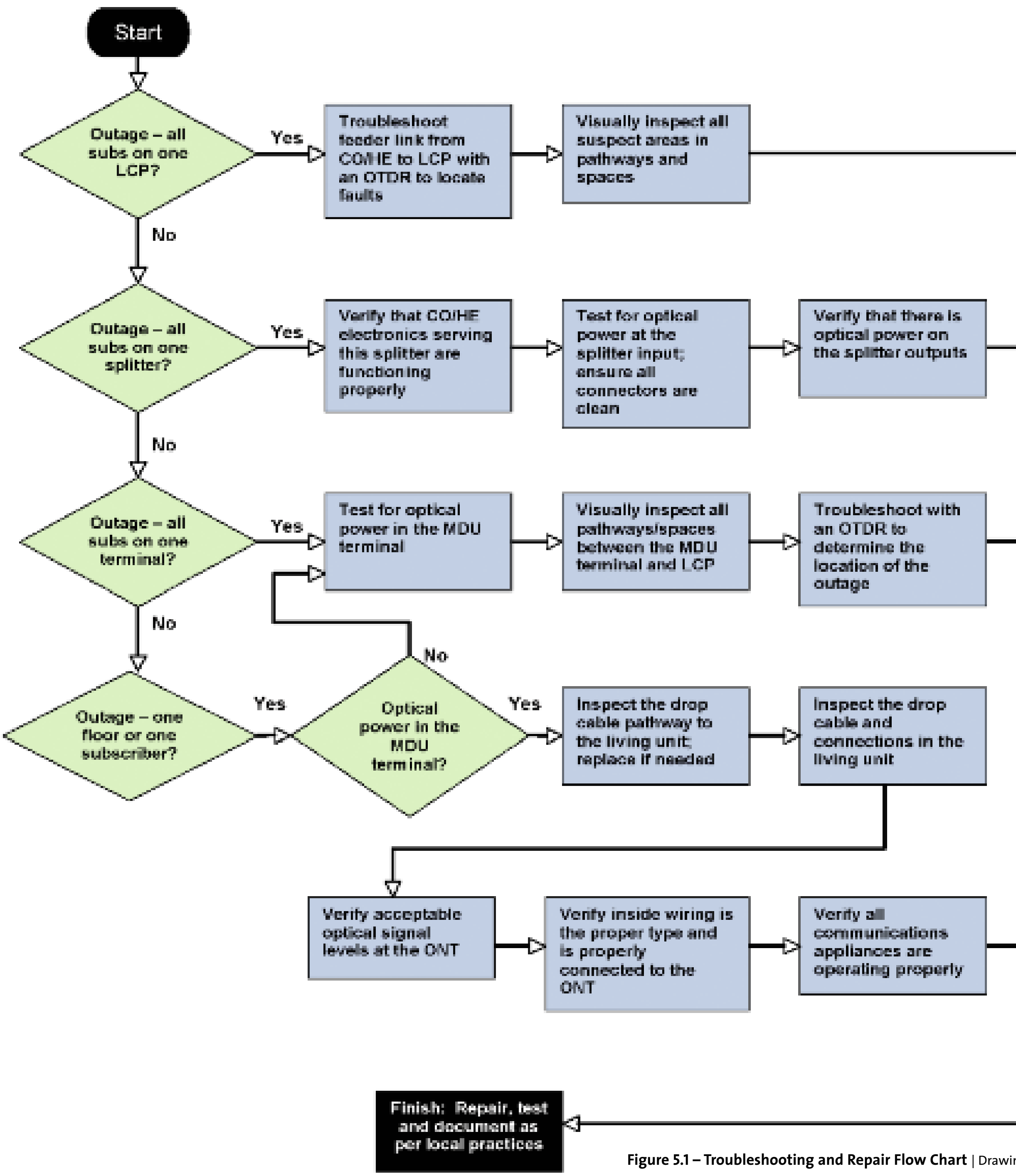

Figure 5.1 – Troubleshooting and Repair Flow Chart | Drawing ZA-3147

Chapter Six:
Tips for Architects, Builders and Developers

This section is a quick summary of the discussion in this guide for use when planning MDU construction to ensure the building will be ready for FTTH.

Spaces and Pathways

ONT
Standardize on a location for the ONT in each dwelling unit. Provide a dedicated 15 amp branch circuit to this location. Between-stud rough-in boxes are ideal and can have power and rugged drop cable pre-routed to them and ready to accept the ONT backplane when the tenant moves in. Standard communications and power outlets are also effective when the ONT will be surface mounted. All inside wiring must also converge to this point, either entering the rough-in box, an oversized outlet or separate demarcation, as desired. The actual location should be in a closet, garage or other protected structure. Avoid the use of GFCI circuits for power whenever codes will allow to avoid nuisance trips.

Drops
Provide appropriate paths for drops to be installed. Rugged drop cables that do not require microduct are quickly being adopted in the industry. These optical cables are installed directly through and secured to building structures, just like copper and coax cables. When raceway and conduit are used, it is primarily for aesthetic purposes.

MDU Terminals
For medium and large buildings, space in a wiring closet on each floor should be provided to accommodate an MDU terminal for drop connection on that floor. Smaller town home and garden-style MDUs may require a location on the outside of the building. New, reduced footprint terminals are now available that minimize the space required and make planning easier.

Riser Cables
Riser cables to connect MDU terminals to the LCP or splice point in the basement of the MDU (or outside) also require proper pathways. A conduit path with minimal bends is the best way to provide a protected path for this cable. Building plans and as-built measurements showing floor thickness, ceiling height and horizontal distances will assist in estimating both riser and drop cable needs.

Building Terminal/Point of Entry
The building entry may be outside or in a basement or telecom room, but sufficient space should be allowed for converging rugged drop or riser cabling, as well as for an MDU terminal or LCP. Size requirements will be proportional to the building size and number of living units present.

Inside Wiring
Proper phone (CAT 3 or CAT 5e), data (CAT 5e or CAT 6) and video (coax) cables must be provided from telecommunications outlets in each room, work or entertainment area to the ONT location. These cables must be **homerun** to the ONT; ***daisy-chained wiring is not acceptable.*** Proper cable types and the use of a star architecture in the living unit will allow the most flexibility and the use of lower cost non-MoCA/HPNA ONTs. At the very minimum, each room and work area should have at least one CAT 3, one CAT 5e and one coax cable. Large areas should have additional outlets based on where internet and entertainment appliances may be located. In kitchens, each individual countertop area should have its own data outlet with the same complement of cabling.

Power Requirements
Power must be present (15 amp **dedicated** branch circuit) at the ONT location. It must be dedicated to the ONT in order to avoid nuisance trips of the breaker by plugging in other appliances in the living unit (such as vacuum cleaners, hair dryers, etc.). This practice will also reduce the occurrence of voltage surges in the ONT, increasing its life. Avoid GFCI circuits, if possible.

Glossary

Term	Acronym	Definition
Angled Polish Connector	APC	Connectors which have their end-face (mating surface) polished at an 8 degree angle to the fiber axis. Minimizes reflections; required in RF video applications.
Architecture		Describes how network elements logically relate to each other.
Attenuation Test Set		Test set having a calibrated light source and meter; used to measure the power loss in an optical link or network.
Bend-Improved Optical Fiber		Class of optical fibers compatible with ITU G.657.A recommendations and having bending performance of 0.75 dB per 360 degree turn at 1550 nm with a 10 mm bend radius. These fibers are required to be backward compatible with standard single-mode.
Bend-Insensitive Optical Fiber		Class of optical fibers with bending performance of 0.1 dB per 360 degree turn at 1550 nm with a 5 mm bend radius.
Bend-Optimized Optical Fiber		Any fiber that has been engineered to provide low loss at 1550 nm under tight bending conditions, when compared to standard single-mode fibers.
Bend-Tolerant Optical Fiber		Class of optical fibers compatible with ITU G.657.B recommendations and having bending performance of 0.5 dB per 360 degree turn at 1550 nm with a 7.5 mm bend radius. These fibers are not required to be backward compatible with standard single-mode fibers.
Broadband Passive Optical Network	BPON	System described in ITU G983 standard. Uses optical splitters to create a one-to-many relation between the CO/HE and the subscribers. Capable of delivering voice and data; usually combined with an RF overlay for video. Usually no active (powered) components between CO/HE and subscriber.
Brownfield		Existing MDUs and/or neighborhoods already served by at least one provider.
Building Homerun		MDU topology in which each subscriber's fiber link runs all the way to a common point for the entire building (usually a terminal in the basement or mounted on an outside wall).
Bulk Cable		Cable, such as drop, purchased in long lengths, on spools or reels and placed/cut to length and terminated onsite.
Category n Cable	CAT 3 CAT 5 CAT 5e CAT 6 CAT 7	Copper twisted-pair data cables. CAT 3 is general telephone and low-data-rate performance level; others are data cable performance levels. The higher the number, the greater the bandwidth and/or distance performance.
Central Office	CO	The telephone company's central location containing active (powered) equipment, from which services are provided. May contain telephone switching equipment and/or optical line terminals and RF video for BPON and GPON systems.

Glossary

Term	Acronym	Definition
ClearCurve®		Bend-insensitive fiber developed by Corning Incorporated which uses technology in the fiber to trap light, producing performance of 0.1 dB per 360 degree turn at 1550 nm with a 5 mm bend radius, while remaining backward compatible with standard single-mode fibers. This fiber represents the state-of-the art for MDU deployments.
Coax Cable		Video cable in which a central signal conductor is surrounded by a metallic shield. Most common inside wiring types are RG59 and RG6; the latter having better performance.
Compact Drop Cable		These cables leverage Corning® ClearCurve® Optical Fiber to minimize or eliminate loss due to bending, but have a smaller 2.9 mm diameter to make them more aesthetically pleasing, when required, and to enable a bend-insensitive solution. For those who prefer to use microduct, compact drop cable is the ideal ClearCurve solution.
Distribution (Cable)		That part of the fiber-to-the-home network between the optical splitter and the start of the drop cable.
Drop (Cable)		The last link in the fiber-to-the-home network, this cable typically serves just one subscriber.
Erbium Doped Fiber Amplifier	EDFA	Fiber amplifier in which the signal to be boosted travels through a special fiber containing, as an additive, the element erbium. Laser light pumped into this special section of fiber excites the valence electrons in the erbium. When the transmitted signal passes through the fiber, the excited electrons give up their extra energy in sync with the transmitted signal, adding to its strength. The output is identical to the input, but now has a much higher power level. EDFAs amplify the optical signal without the need to convert it to an electrical signal and back to optical.
Fiber to the x	FTTx	Refers to a host of acronyms based on taking fiber to the home (FTTH), node (FTTN), curb (FTTC), etc.
Future-Proofing		Design decision process in which elements that may not be required today, but which are very likely to be needed in the future, are either built into the design up front or are planned as simple upgrades.
Gigabit Passive Optical Network	GPON	Similar to BPON, but based on higher gigabit speeds. Like BPON, these systems may use an RF overlay for video, but because of their increased bandwidth per subscriber, are also being used for IPTV deployment, in which all services (voice, video and data) are placed on the GPON and the RF video overlay is not required.

Glossary

Term	Acronym	Definition
Greenfield		New construction of MDUs and neighborhoods. In this case, no service provider and no network exists. Fiber can be planned and placed efficiently while walls, ceilings, basements and attics are openly accessible to create pathways.
Ground Fault Circuit Interrupter	GFCI	Type of electrical power supply circuit protection that detects faults to ground and immediately shuts off the flow of electricity. Required for most outdoor, basement and garage, kitchen and bathroom outlets.
Headend	HE	Cable TV term analogous to the telephone company's central office.
Home Phone Network Alliance	HPNA	HPNAv3 – technology that can use existing copper phone lines or coax lines to deliver broadband services.
Homerun		Installation in which cables are pulled from each outlet or device back to one common location, such as the ONT in a living unit or from each living unit to a common location for the MDU building.
Inside Wiring	IW	The communications wiring inside a home or living unit. Includes phone, data and CATV (coax) wiring.
Intermediate Terminals		Topology in which multi-fiber cables are run (usually in a riser) to serve terminals (MDU terminals) placed on multiple floors. This approach is used in larger MDUs to consolidate individual drops into larger cables that can be easily connected in a central point in the building.
International Telecommunications Union	ITU	Industry organization that makes recommendations for product specifications. ITU G652 defines standard single-mode fibers and ITU G.657 defines bend-improved and bend-tolerant fibers.
Internet Protocol Television	IPTV	Use of Internet protocol to handle transmission of television signals over a data network (instead of doing so over a radio frequency (RF) network such as cable TV). Allows the television signals to be sent over the same "pipe" as data and voice.
Local Convergence Point	LCP	That point in the network, usually a cabinet or closure, that marks the breakout from the feeder cable (from the CO/HE) to the distribution cables that go through a neighborhood or MDU. The LCP usually contains optical splitters.
MDU Terminal		The MDU terminal serves as an interconnection between a distribution cable (with many fibers) and individual drops going to subscriber living units. This is usually a small cabinet or enclosure; in some cases, it may contain splitters. It can be located inside or on the exterior of an MDU.

Glossary

Term	Acronym	Definition
Microduct		Small (usually less than half an inch (<13 mm) duct installed in MDUs to protect single-fiber drop cables. It also makes it possible to easily remove/replace drops in the event of damage. Microduct typically has a total installed cost greater than placement of rugged drop cables directly into building structures.
Migration		The process of moving from one cabling system or technology to another, such as migrating from a copper to optical network.
Multidwelling Unit	MDU	A building structure that has two or more residential dwelling units occupied by separate entities. The living units may be owned individually or the entire building may be owned as one property with units rented to tenants.
Multimedia over Coax Alliance	MoCA	A technology that can deliver broadband services to subscribers using existing coax within a building or living unit.
National Electrical Code®	NEC®	The NEC defines building electrical codes and is adopted by most U.S. municipalities. Section 770 defines riser (OFNR) and plenum (OFNP) requirements for optical cables. Cables so rated are usually marked as such on their outer sheath. Most countries use similar documents.
Optical Line Terminal	OLT	For BPON and GPON systems, this is the electronics that reside in the CO/HE and which control the ONTs served at each subscriber's location. Typically, OLTs service 16, 32 or 64 ONTs.
Optical Network Terminal	ONT	For BPON and GPON systems, this is the electronics located at the subscriber's premises. The ONT converts the optical signal to copper and coax-based signals for connection to phones, computers and televisions in the residence.
Optical Return Loss	ORL	For an optical network, as a system, ORL is a measure of the total reflected signal relative to the signal being transmitted into the network (the incident signal). ORL includes all components, end to end, such as fiber, connectors, splices, etc. in the link. ORL is expressed as a positive value, and the larger the value, the better the performance. For example, 60 dB means the total signal reflected back is 60 dB below the incident being transmitted into the network.
Optical Time Domain Reflectometer	OTDR	A test set that sends out light and senses light scattered and reflected back to the set. It is capable of showing the distance to faults and other "events" in an optical cable, as well as the attenuation (power loss) associated with each event.
Outside Plant	OSP	Cabling outside of buildings, including aerial and buried installations.
Pathway		The path planned and used for cable placement. It includes ducts, raceway, aerial strand, etc.

Glossary

Term	Acronym	Definition
Point-to-Multipoint	P2MP	Network that utilizes optical splitters to divide (and share) bandwidth on the feeder fiber. The splitters also combine subscriber ONT signals on their journey back to the CO/HE.
Point-to-Point	P2P	Network that has a dedicated fiber path from the subscriber all the way back to the CO/HE electronics.
Preconnectorized		Cables having optical connectors pre-installed and tested at a factory before being shipped to the field for installation as an assembly.
Prestubbed		Hardware (such as an LCP cabinet) that has a factory-connectorized or factory-prepared cable (stub) built into it. In the field, the hardware is placed and the stub cable is spliced into the system. The work of connectorizing each fiber or preparing the cable inside the cabinet is already complete, saving field time and labor.
Raceway – Decorative		Usually a surface-mounted pathway, such as a crown molding, that is used to hide and protect a cable.
Reflectance		For individual components, such as connectors, reflectance is a measure of the reflected signal relative to the signal incident upon component. Reflectance is expressed as a negative value. A value of -55 dB means the reflected signal is 55 dB LESS than the transmitted signal. The smaller (more negative) the reflectance value, the better the performance. For example, a reflectance of -65 dB is better than a value of -55 dB.
RF Video Overlay		Use of an RF video signal, usually at a separate wavelength from the data/voice transmission to provide television/video services. The transmission technique is similar to that used for CATV.
Riser		Pathways in a building that go from floor to floor. Cables and non-metallic duct must be "riser rated" for flame propagation to be installed in this space. The exception, depending on local codes, is for cables placed in sealed metallic duct/conduits.
Rough-in		Phase of construction when walls and ceilings are framed, but not yet covered with finishing materials. At this point, the hidden elements of electrical and communications, plumbing, HVAC and other systems can be installed. Once wall and ceiling finishing materials are installed, these systems also receive their finishing work in the form of outlet plates, fixtures, grates and so on. It is during rough-in that microduct, cabling and wiring boxes can be installed to make service connections easy to complete after the building is finished.
Rugged Drop Cable		MDU drop cables designed to provide inherent bend radius control (self-limiting), ensuring low optical loss and robust mechanical performance when installed, bend and stapled like copper and coax cabling. Rugged drop cables typically use bend-insensitive fibers, such as Corning® ClearCurve® Optical Fiber, to minimize or eliminate loss due to bending.

Glossary

Term	Acronym	Definition
Self-Contained Distribution		An MDU topology element in which splitters are placed in the same building as the subscribers they serve. Therefore the entire distribution portion of the network is contained within the building.
Self-Limiting Cable Sheath		Cable sheath designed to limit bending of the enclosed optical fiber(s) to ensure both low attenuation and mechanical reliability.
Shared Distribution		An MDU topology element in which splitters are external to the building and the subscribers they serve. Usually, two or more buildings share a common splitter location (LCP).
Splitter (Optical)		An optical device which splits the optical power of one signal into multiple outputs, each containing the same signal, but at a lower power level. For BPON and GPON systems, splits of 1x16, 1x32 and 1x64 are used.
Topology		The physical layout of the network that describes how the system components are actually placed and connected to each other. While the architecture is the logical view, the topology is a physical view of the network.
Triple Play Services		The offering, by carriers, of voice, video and data services over one medium (one network). Usually this reduces network complexity and cost for the carrier and offers preferred pricing for subscribers.
Ultra Physical Contact Connector	UPC	An optical connector whose end-face has been radiused and polished to minimize reflections. Unlike the APC connector, the mating surfaces are NOT angled to the axis of the fiber. APCs provide superior reflectance performance compared to UPCs.
Wavelength Division Multiplexer	WDM	A passive device used to combine and/or separate optical signals of different wavelengths. Example: WDMs combine the downstream data/voice signals (1310 nm) with RF video signals (1550 nm) in the CO to be sent out toward subscribers.

  

Corning Cable Systems LLC • PO Box 489 • Hickory, NC 28603-0489 USA
800-743-2675 • FAX: 828-325-5060 • International: +1-828-901-5000 • www.corning.com/cablesystems

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