Montgomery County
Office of Broadband Programs

Broadband Infrastructure for Developers: A Fiber Optic Connectivity Guidebook

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for Montgomery County, Maryland

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1 Executive Summary

Today's businesses need robust and reliable, "always on" Internet access. Businesses rely on Internet service for basic operations, from providing telephone service to accessing client contacts and business records. But increasingly, businesses are relying on robust broadband service to provide enterprise services, enable remote access for teleworkers, run complex software applications, and reach data on off-site servers in hardened data centers. Because of the importance of broadband Internet access, it is becoming common place for businesses to purchase Internet service from at least two broadband service providers.

Fifteen commercial providers and four government/educational networks offer wireline broadband service providers in Montgomery County. But more often than not, a business's specific address will determine whether the company can get the level of broadband service it needs, and which broadband service providers it can purchase service from. And in addition to address, a building's infrastructure design, broadband wiring infrastructure, and building access policies for competitive broadband services can be critical factors to determine the availability of broadband Internet access for businesses.

Commercial property owners, brokers, and building managers are realizing the benefits of next-generation broadband infrastructure and its ability to differentiate a building from competitor developments in either the County or in neighboring jurisdictions. Similarly, economic development professionals increasingly place broadband among the top priorities for promoting future job growth, both among established organizations and emerging businesses.

Montgomery County's Office of Broadband Services presents *Broadband Infrastructure for Developers: A Fiber Optic Connectivity Guidebook* to offer practical advice that developers can use to make more broadband service options available to their tenants.

Developers can lower the barriers for communications carriers to offer tenants high-speed and highly reliable broadband services by installing additional conduit when constructing a new site and installing robust in-building wiring. Building owners and property managers can also leverage these best practices during renovations to cost-effectively add value to their properties. Installing additional outside conduit and robust in-building wiring during the construction of the building has several benefits:

1. The cost of constructing conduit and installing redundant wiring is cheapest when it is an incremental addition to the construction of the building;

2. The conduit and wiring can be used by any provider that wishes to provide services to the building's tenants and is not owned or controlled by a particular telecommunications provider;

3. The conduit and wiring reduce the time and cost required to provide services to the building, which decreases the cost of broadband services for the tenants;
4. Multiple providers can share the same conduit and wiring, which allows tenants to competitively shop for broadband services;
5. Redundant building entrances and riser paths allow tenants to purchase premium high-availability broadband services; and
6. The availability of multiple communications providers is a critical marketing point for tenants.

By leveraging these best practices, developers, building owners, and property managers can ensure that their commercial tenants have access to as much robust, reliable, “always on” broadband service to the business needs of today and tomorrow.

2 Fiber Optic Technology

Fiber optic technology is the highest capacity transportation medium in widespread use. One fiber cable can have thousands to millions of times the capacity of other wired media, such as copper telephone lines or coaxial cable. Moreover, fiber is sturdier, less likely to suffer interference, and is safer, due to its lack of metal components. Fiber has a long lifetime, and the electronics that connect to it can continuously be upgraded, so that the capacity can expand without the fiber operator needing to replace or upgrade the fiber itself.

Compared to wireless, fiber optic technology has greater capacity and longer range. Therefore, wireless service providers use fiber optic cable to connect their towers and central offices.

Fiber optics have been in wide use since the 1980s—and in places where entirely new communications infrastructure is being built, the infrastructure is started with fiber. Cable companies like Comcast continue to use coaxial cable in many parts of their networks, simply because they have millions of miles of existing coaxial cable in their old networks and need to maximize the infrastructure they have (although this may change in the coming years). Phone companies like Verizon are pursuing a strategy of steadily replacing copper wires with a combination of fiber optics and wireless technologies.

3 Benefits of Fiber Service

Because of its capacity, having fiber at your business or home enables you or your tenants to buy Internet and communications services at faster speeds than if you only had coaxial cable or copper telephone lines. Businesses in recently built developments in Montgomery County typically have fiber, but those from the 1990s or earlier might not, especially if they are located further away from other recent commercial development, or if the tenants have in the past not been focused on fiber services.

Moreover, having fiber from multiple service providers at your office building increases the competition among potential providers of services to your tenants. Fiber operators compete based on price, speed, contract length, reliability (for example, having two routes to your building), service, and special offerings such as symmetrical speeds (which enable customers to “host” servers or video), or direct connections between campus buildings.

Increasingly, the County has found that businesses (potential tenants) of all types are demanding access to a wide range of quality fiber optic services—and that potential tenants consider such access a key factor in choosing a building, on par with price, location, traffic, parking, and other considerations. Therefore, a building owner or developer that takes steps to attract multiple high-quality fiber providers has a better chance of attracting and retaining those tenants. Tenants who find that a potential location has fewer fiber options than their current building may demand better services or look elsewhere.

Fiber companies have different business models. Some are “facilities-based,” meaning they build, maintain, and own the fiber. Others are resellers, which obtain fiber on a wholesale basis from facilities-based companies and then market and sell services to end users. Having multiple reseller companies offering service in a building can still create a level of competition, even though only one cable may enter the building.

Some fiber service providers only build to a building or area where they have an agreement with an “anchor” customer, typically a large company or institution that pays the construction cost of the fiber. That fiber service provider then markets to other companies in the neighborhood of the anchor. Other companies have a more speculative approach, building to areas where they have identified many smaller customers, or where they believe they may have fertile ground to sell services.

Several facilities-based and reseller fiber service providers provide service in Montgomery County. However, many parts of the County have little or no fiber service or competition—like other development, fiber deployment depends on the cost of building and the service provider’s ability and interest in serving an area. Construction can cost from $30,000 to $500,000 per mile and depends on factors such as availability of utility pole space, coordination with existing utilities, availability of underground conduit, and cost of restoring the surface. Simply building from the street into a building typically costs thousands of dollars—more if streets or parking lots need to be crossed.

Service providers also need to coordinate with building owners and receive their approval to enter a building, place equipment, and connect to tenants. Service providers who face excessive cost or delay in entering a building may determine it too risky to serve a building and invest elsewhere.

4 Technical Overview

In the sections that follow, we describe the technical aspects of fiber and fiber construction.

4.1 What is fiber?

A fiber optic cable contains strands of glass surrounded in concentric cylinders by protective material and, depending on the cable, a strength member or armor. Typical outside-rated fiber cable ranges from ¼ inch to 1.5 inches in diameter and looks like an ordinary communications cable.

Figure 1: A fiber cable[1]

Electronic equipment at one end of a fiber route sends data over the fiber as pulses of light; equipment at the other end of the fiber receives the signals. Single-mode fiber can carry optical signals over long distances due to the large difference in the refractive indices of its core and cladding. The fiber cladding reflects almost all the optical power and contains it within the core, thereby minimizing loss.

There is no set capacity for a fiber optic strand. Capacity in a fiber strand can be increased simply by upgrading the transmitting and receiving electronics at each end. As a result, the capacity of a fiber strand increases with the speed of the network equipment used—a factor of 10 increase every few years is typical as network operators upgrade to new generations of equipment.

A sample speed for a large business fiber connection is a symmetrical one gigabit per second (1 Gbps) connection, or more than one billion "1s" or "0s" per second. This corresponds to 100

[1] Image source: http://commons.wikimedia.org/wiki/File:Optical_fiber_cable.jpg (Creative Commons-licensed image)

simultaneous high-definition video streams in both directions, and is suitable for cloud computing, data backup, remote hosting, and Internet needs of a very large business or institution. It is about 10 times faster than the types of services used for the highest speed residential services in the County. Relatively standard off-the-shelf technologies can provide this service over just one or two fibers.

Companies and institutions that are using very advanced technologies, such as imaging, simulations, or 3D printing/manufacturing, may use more capacity. So may large institutions such as universities or school systems. These sites may require 10 Gbps, or potentially even 100 Gbps. Again, this can be accommodated over a single fiber or fiber pair, but with somewhat more expensive equipment.

Optical fiber is usually laid in counts of 24, 48, 72, 144, 288, or 324 fiber “strands”. The cost of construction remains about the same regardless of the fiber count in a given route; the cost of the fiber itself increases only marginally as the count increases, and more fiber splicing is required. A single cable can easily provide all the capacity needed for a large building or development area, once it is constructed and brought into a building.

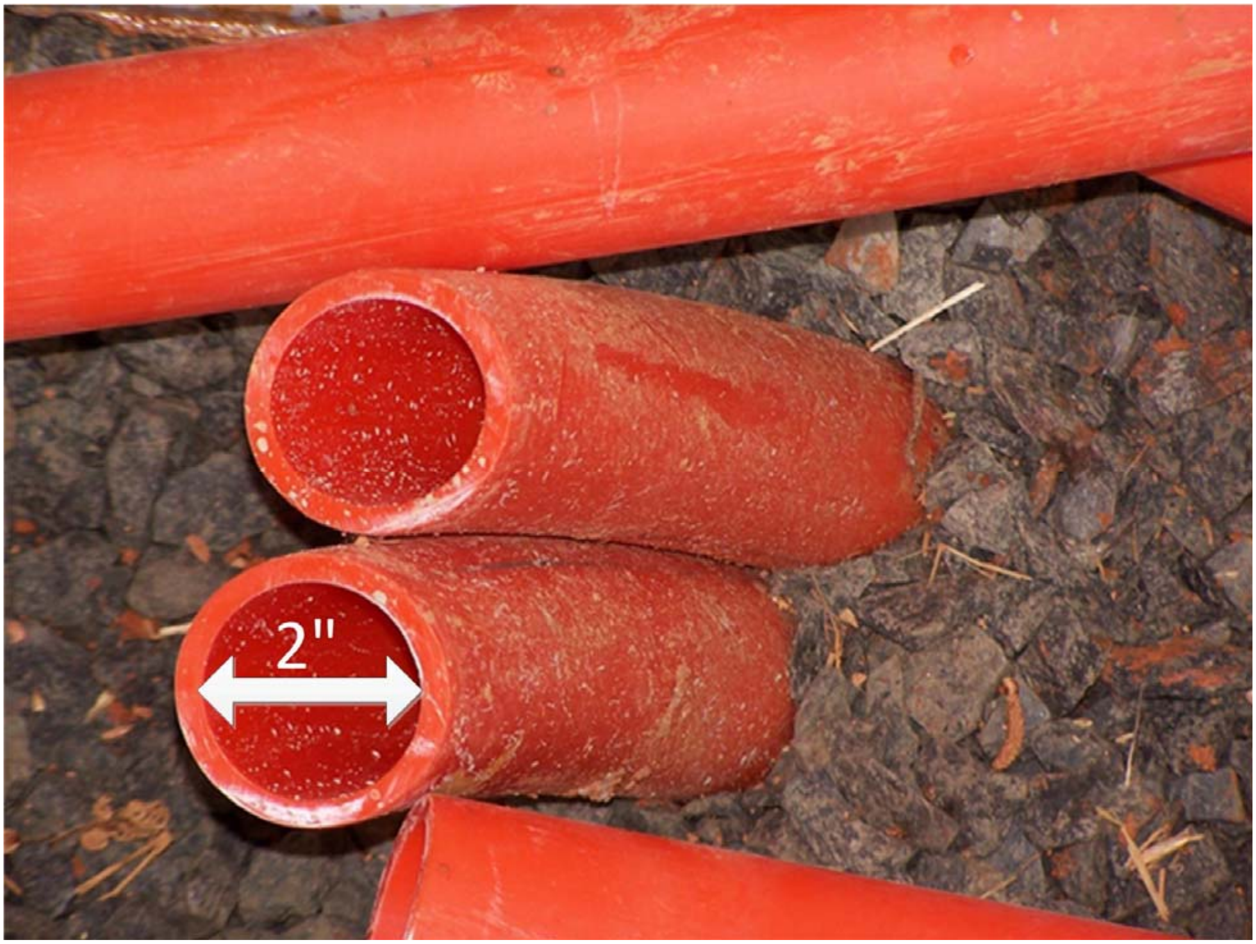
4.2 What is conduit?

Conduit is essentially a pipe, generally composed of high-grade plastic, that is placed underground to house fiber optic cable and protect it from environmental factors (such as water seepage and mud), as well as from stress and pressure created by traffic above ground. Most importantly, conduit provides a path for easily replacing, repairing, or installing additional cables. While it is possible to directly bury many types of communications cables, conduit effectively “future-proofs” the infrastructure by allowing for cables to be replaced or upgraded without most of the costs associated with physical construction.

Conduit can be placed along roads and to individual buildings. Fiber providers (and others) place conduit at the time of underground fiber construction and place the fiber in the conduit. Forward-looking property developers and local governments place conduit at the time of road construction or property development to meet either known needs or, in the case of placing excess conduit, to meet anticipated future needs.

Conduit is typically manufactured with rigid polyvinyl chlorate (PVC) or flexible High-Density Polyethylene (HDPE). Depending on the application of the conduit and the areas in which it is placed, different grades of conduit may be utilized. For instance, a lower grade of conduit can be used in non-traffic areas or areas in which only light pedestrian traffic typically occurs, whereas steel conduit might be used under a train track.

Figure 2: Rolled duct HDPE conduit



Rigid PVC conduit, manufactured in sections and joined with a coupler, is generally only installed in open trenches. Flexible HDPE corrugated conduit, available on reels in lengths of several thousand feet, can be installed in trenches, directly “plowed” into the ground, or placed with directional boring.

Figure 3: Conduit being installed in an open trench

Pullboxes (also called handholes or vaults) are installed along a fiber route to provide access to conduit for fiber placement or to house splice enclosures in underground construction. Pullboxes are spaced at regular intervals (500 to 1,500 feet) between runs of conduit for a variety of purposes, such as:

- Housing excess fiber that provides slack for repairs or future splicing work;
- Relieving the friction that occurs in long runs of fiber pulled through conduit;
- Providing access to conduit for placing new cable; and
- Providing access to fiber for splicing.

Figure 4: A typical pullbox installed in the right-of-way

Pullboxes are often strategically placed in locations where future sites may branch off from a high-count backbone cable, allowing a new conduit/cable to join the backbone without disturbing the backbone conduit.

4.3 Fiber optic construction in the right-of-way

Communications providers install fiber optic infrastructure in existing public rights-of-way. The right-of-way is land owned by the local or state government that has been designated for the installation of utilities such as roads, electric, water, gas, and communications. In the case of fiber, that construction occurs either aerially (strung along utility poles) or underground (in conduit). The right-of-way is typically under or on the side of public streets.

Underground fiber optic construction usually occurs in conduit located outside of the roadways where rights-of-way allow. The pullboxes are generally located in the greenways or shoulders of roadways. During the right-of-way design, pullboxes are often located or added at locations where connections to potential customers can be made. If developers have already constructed lateral conduit from buildings to the right-of-way, the conduit can be intercepted and a pullbox installed so that fiber can be installed into the building.

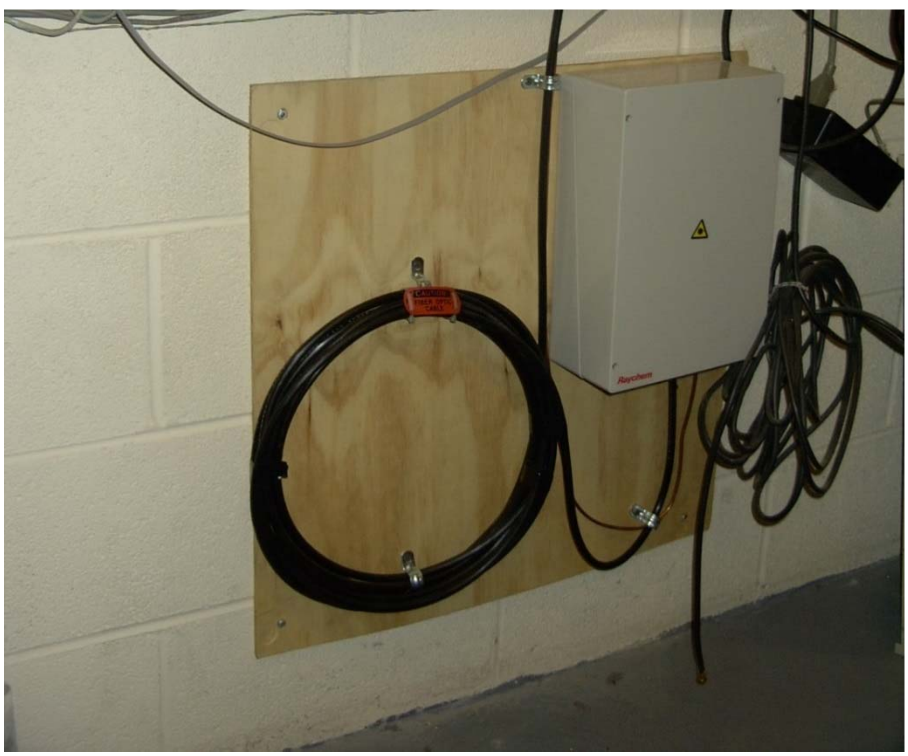
Road construction or building development provide opportunities for less expensive fiber construction. This is because construction can be coordinated with open trenches and placement of other utilities, and conduit can be installed before driveways and sidewalks are placed and surfaces are landscaped.

4.4 Outdoor wiring fiber termination points

Indoor wiring can be a complicated and expensive endeavor if the building entrance location is distant from the location where the outdoor fiber will be terminated. Generally, innerduct or conduit must be installed inside the building to provide a path for the cable installation. If the distance is greater than 50 feet, the outdoor cable must be spliced to a cable with proper indoor ratings (primarily relating to the toxicity of the fumes generated if the cable burns), or the cable must be placed within electrical metallic tubing (EMT).

The outdoor fiber may be terminated in a wide range of available fiber termination cabinets, whether wall-mounted or within an equipment rack, containing connectors manufactured with small fiber pigtails, splice trays to house splices between pigtails and the fiber cable, and cable management equipment.

Figure 5: Wall-mounted fiber termination cabinet



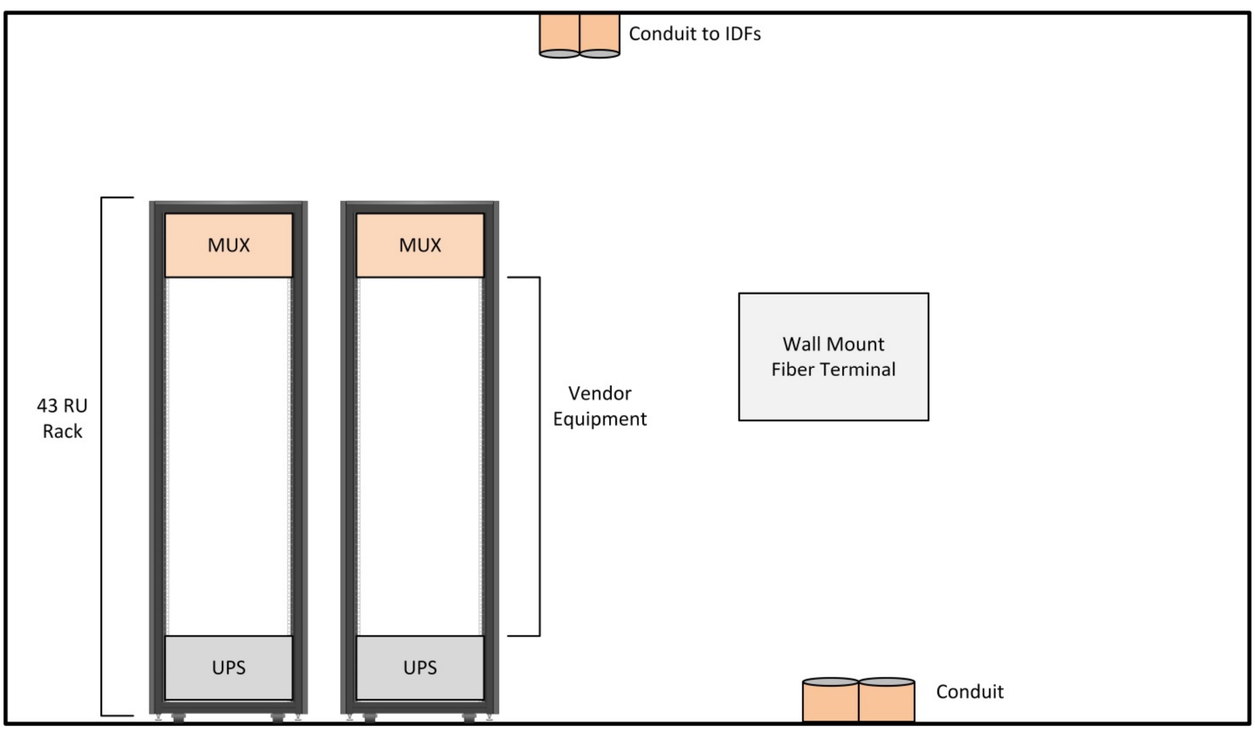
4.5 In-building wiring

This section provides recommendations for in-building wiring that can work effectively with the outdoor cabling and is scalable for future needs. In an approach consistent with industry standards (in particular, ANSI/TIA-568-C), a Main Distribution Frame ("MDF")—a central telecommunications distribution point for in-building cabling and termination of outdoor cabling—is placed in the building in a secure centralized wiring room (Figure 6) near the building entry. The room is connected to the building entrance, outdoor conduit, and fiber infrastructure over the lateral conduit. The room includes equipment racks for electronics and fiber termination, and uninterruptible power supplies (UPS). Racks should also have separate lockable partitions for multiple service providers.

Each building should also house Intermediate Distribution Frame ("IDF") locations—these are intermediate wiring and equipment closets are typically on each floor or in each major portion of the building, no more than 270 feet from the farthest wiring endpoint. This approach works with a wide range of network architectures and electronics, is compatible with open access, provides logical points of demarcation between building owner and service provider, and is scalable.

The pathways between MDFs, IDFs, and tenants also need to meet industry standards (TIA/ANSI) so that bend radius, distances, clearances, and locations of termination points are correct for the potential range of technologies that might be installed.

Figure 6: Main distribution frame layout

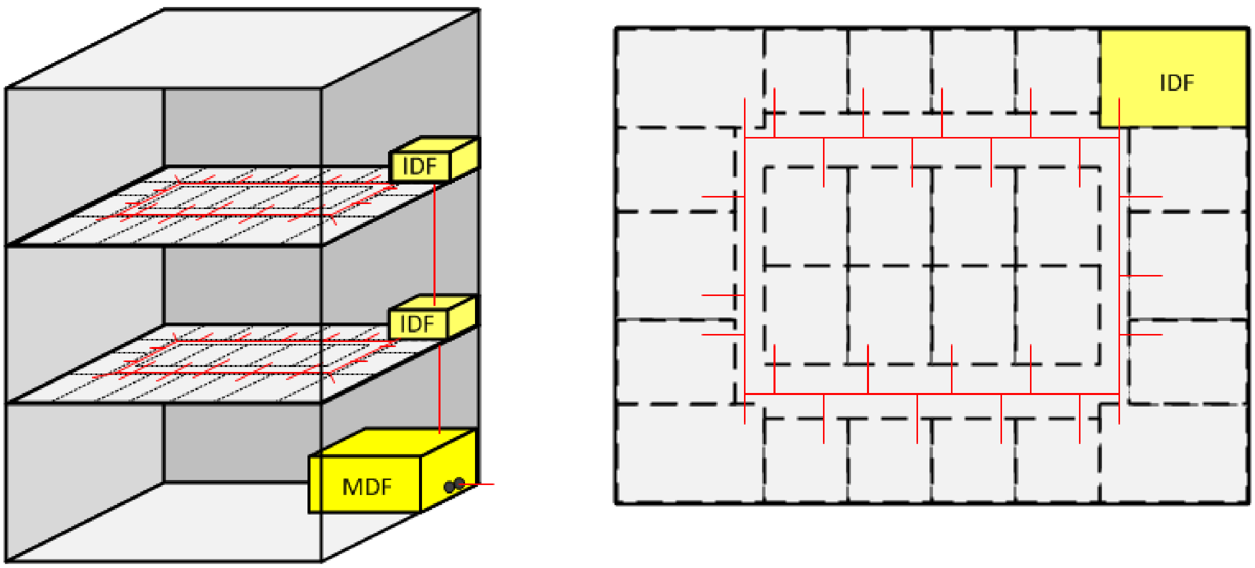


4.5.1 Residential buildings

In residential buildings, we recommend a cabling approach that can provide two internal single-mode fibers from the MDF to each unit (see figure below). Fiber can enter the building via the developer's lateral conduit to the right-of-way and either be patched through the MDF and IDFs or pass through electronics or splitters at those locations.

Each building should have sufficient conduit from the MDF to the right-of-way to enable multiple service providers to enter, using a range of network architectures. In a large building, with 100 or more apartments, at least four 2-inch conduit or the equivalent capacity in other sizes should be installed, in addition to conduit already allocated to phone cable and other service providers at the time of construction. In smaller residential buildings, two 2-inch spare conduit may suffice.

Figure 7: Indoor cabling overview for residential buildings

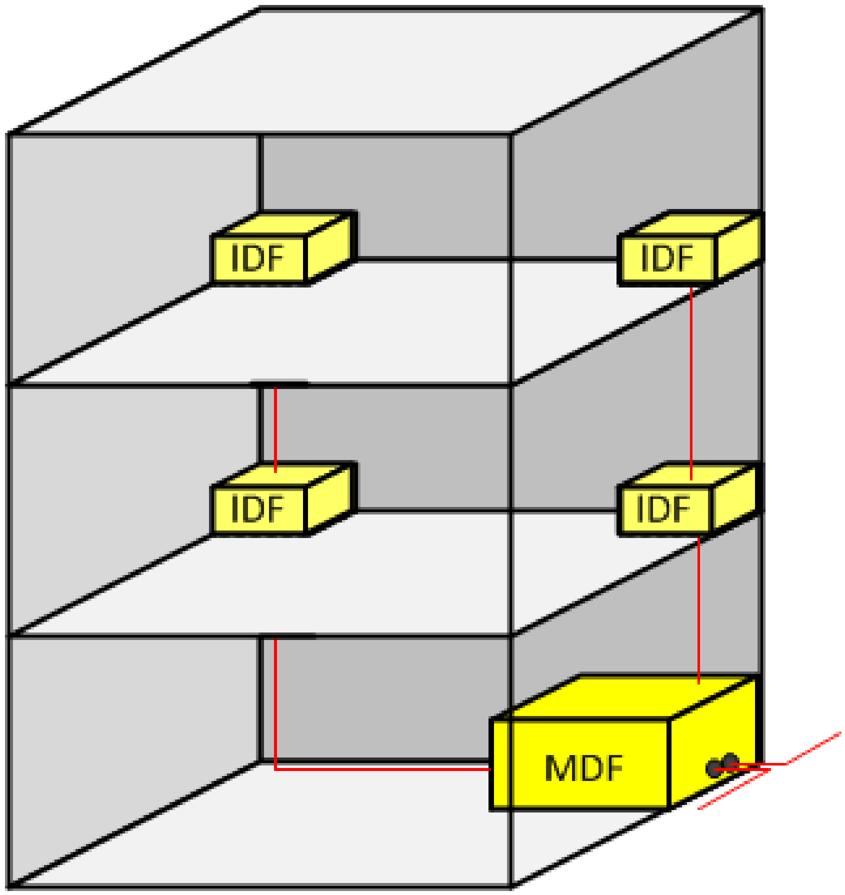


4.5.2 Office buildings

As with residential buildings, we recommend two internal single-mode fibers from the MDF to each unit in office buildings (see figure below**Error! Reference source not found.**). Fiber will enter the building via the developer's conduit to the right-of-way. The horizontal fiber (from the IDF to an individual unit) may need to be moved, removed, or replaced if offices are moved or divided. In many buildings, this fiber travels above false ceilings or through cable raceways, and fiber should be installed with the idea that moves or additions may be necessary.

Each commercial building should have sufficient conduit from the MDF to the right-of-way to enable multiple service providers to enter, using a range of network architectures. In medium to large multi-tenant buildings, at least four 2-inch conduit or the equivalent capacity in other sizes should be installed, in addition to conduit already allocated to phone cable and other service providers at the time of construction. In smaller buildings, two 2-inch spare conduit may suffice.

Figure 8: MDF/IDF architecture for office buildings



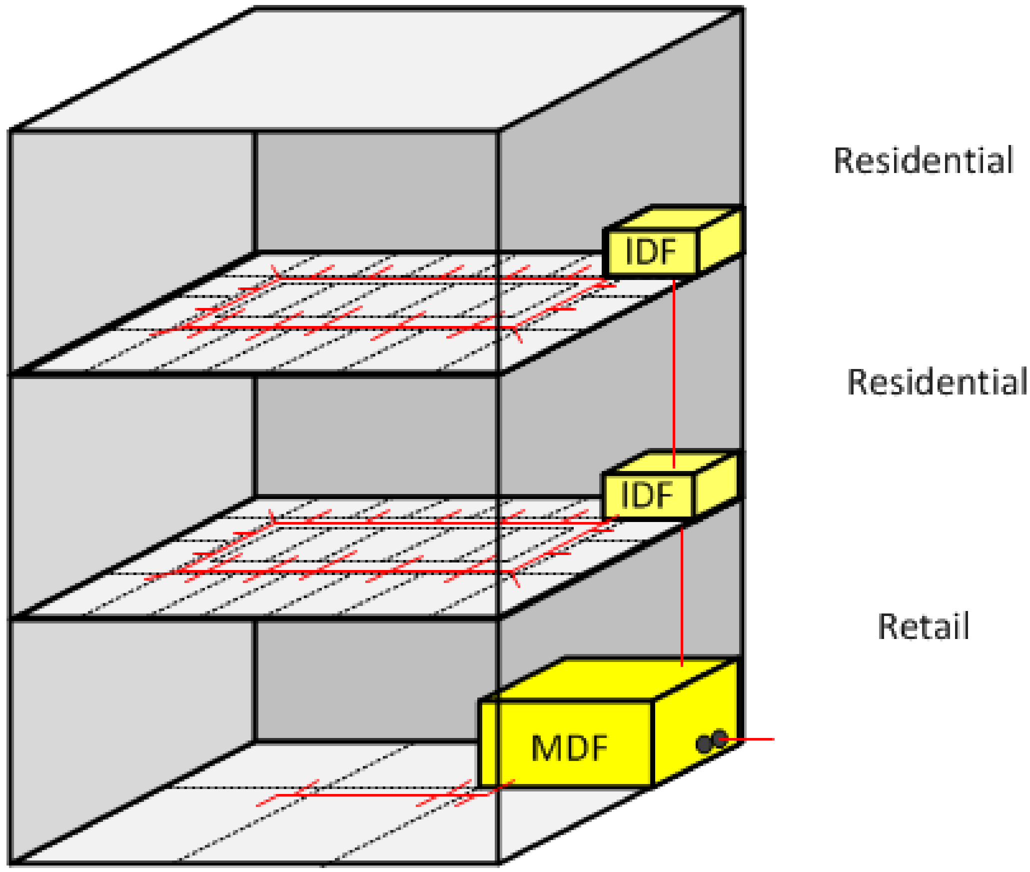
4.5.3 Retail/mixed-use buildings

The recommended architecture and fiber count for retail/mixed-use buildings matches the specifications for residential buildings, because these buildings have a demand profile similar to the residential-only buildings.

A best practice for mixed-use buildings is the installation of two internal single-mode fibers to each unit (see figure below) from the MDF. Fiber will enter the building via the developer's conduit from the right-of-way.

Each building should have sufficient conduit from the MDF to the right-of-way to enable multiple service providers to enter, using a range of network architectures. In a large building, with 100 or more units, at least four 2-inch conduit or the equivalent capacity in other sizes should be installed, in addition to conduit already allocated to phone cable and other service providers at the time of construction. In smaller buildings, two 2-inch spare conduit may suffice.

Figure 9: Architecture for retail/mixed-use buildings



5 Recommendations for Developers

Providing high-speed data services to homes and businesses requires extension of communications infrastructure to and within the premises. In apartment buildings and multi-tenant office buildings, this requires extension of fiber from the right-of-way to a central telecommunications distribution point, and from there to individual units. If cable pathways exist from the right-of-way to each apartment or office unit, the cost of serving potential customers in a large building will be lower. If pathways must be installed, doing so during other construction or renovation will cost less than retrofitting solely for network deployment.

One significant barrier to entry for a new network provider is the physical entry into buildings. Ensuring the availability of spare building entrances and lateral conduit into buildings can reduce installation time, risk, and costs.

A building entrance is the physical entry point for the fiber optic cable. For aerial construction, this may consist of a "drop" cable that is strung from the nearest pole to the building, much like the way in which cable TV or telephone service is provided by the local providers; the drop cable is attached to the building facade using an anchor, and then penetrates the building wall. In underground construction, there is generally a conduit that comes from the right-of-way into the building.

Buildings without spare fiber entrances and lateral conduit will require underground construction and new building penetrations, which can be costly and time-consuming. In addition, if there is land between the right-of-way and the building that is not owned by the developer, an easement or a right of entry agreement to construct into the building may have to be obtained.

When constructing new facilities, building entrances and lateral conduit should be designed and built during construction of the building. In new construction, conduit is installed during the foundation installation and earthwork phases of construction. Developers and builders are already accustomed to providing pathways for telephone, power, and cable TV from the property line to a room designated for utility services within the building, but ideally, they should also construct spare capacity for use by other fiber providers in the future.

The developer installs conduit from the room location to the exterior of the building (typically either encased in the slab or under floors) and through the exterior wall. The developer then trenches conduit to the property line, where it is properly marked so that the utilities can determine which conduit is for their service.

For facilities that cater to tenants with high-availability network bandwidth needs, a developer may install a second physically diverse lateral conduit path and riser paths. A second diverse conduit and riser path ensures that there is not a single point of failure of the physical fiber path from the provider to the tenant. Diverse paths allow providers to provide higher reliability services that are not possible over a single path.

The developer's incremental cost is relatively low to add an additional conduit for fiber optic cable in the same trench as the other utilities' conduit. Adding a 200-foot path from a building's utility room to the property line would cost approximately $2 per foot for labor and $2 per foot for materials—or approximately $1,000 in additional construction costs for the outside plant portion of installing conduit.

Figure 10: Example of installing conduit from public right-of-way to building

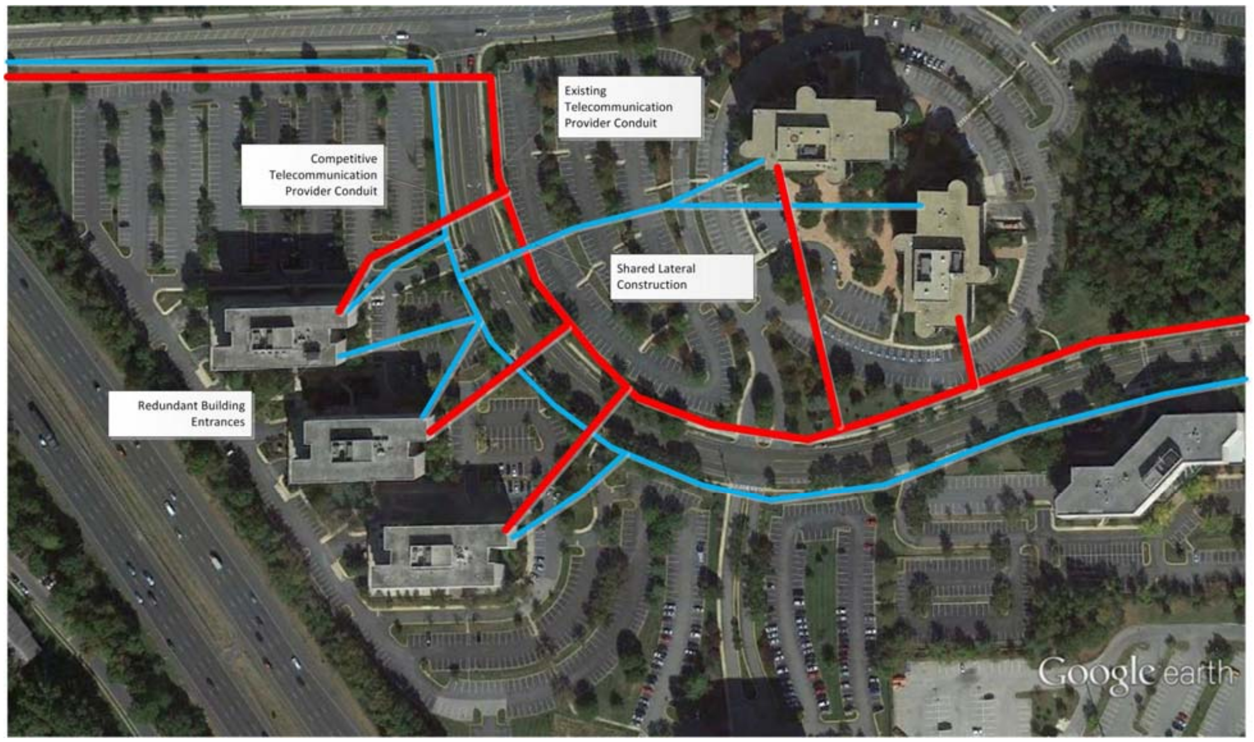
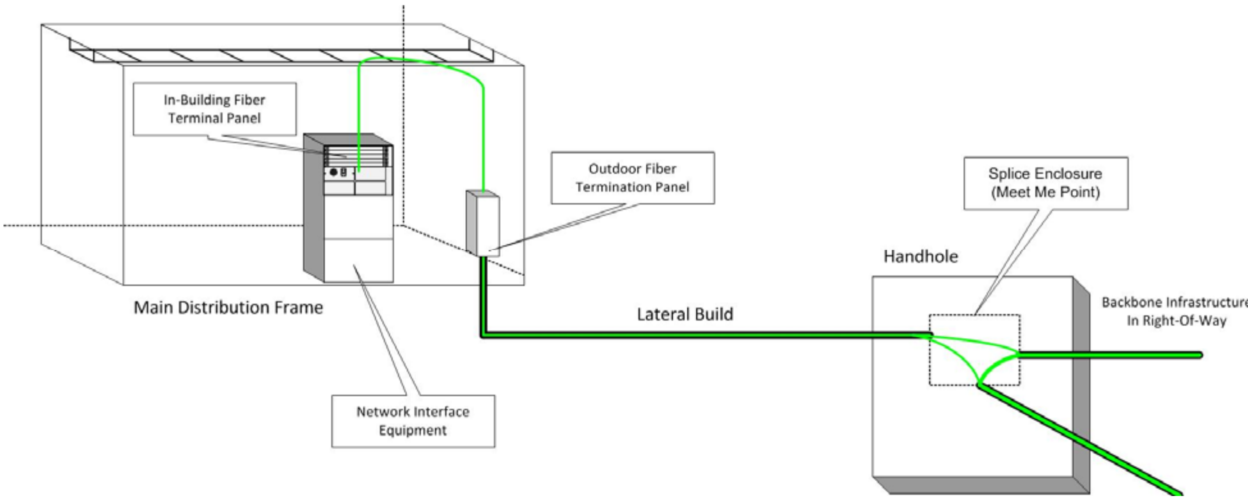


Figure 11: Detailed diagram of lateral construction components



In contrast, the cost for new construction of the same route can be $1,500 to $10,000 if a network provider needs to create a new entry path. The higher cost is realistic if the right-of-way is on the opposite side of a major road, if the provider needs to cross under a parking lot or driveway, and if restoration (both outdoors and in the building) is extensive.

Constructing a new route into a building may also involve weeks or months of delay for permitting, engineering, design, utility location, and coordination with the building owner. These are delays that could be avoided if conduit already exists when a provider is ready to begin connecting customers.

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