Fiber 101

Best Practices in Fiber Design
and Deployment for MDUs

iBwave

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Introduction

The purpose of this eBook is to give you a general overview of the current fiber deployment landscape. It begins with a quick history of the technology and an introduction to the state of the market. Naturally, the industry is constantly evolving, so to avoid the information in this text becoming outdated, we'll adopt a relatively broad approach to the subject.

After finishing the book, you should understand the main challenges and best practices of in-building fiber design, with a focus on several use cases of fiber deployment to multi-dwelling units.

You'll also be introduced to iBwave's FiberPass, a software tailored specifically for fiber design that was developed to address and solve the challenges identified by key players in the industry.

But before we get into all of that: If we're going to talk fiber, we need to go back.

Way, way back.

A Brief History of Fiber

1798

The optical semaphore telegraph has just been developed by French inventor Claude Chappe. Almost a century later, in 1880, Alexander Graham Bell patents an optical telephone system, the photophone. But it's his previous invention, the telephone, which proves to be far more practical.

1920

Fast forward to the 1920s. John Logie Baird in England and Clarence W. Hansell in the United States patent the idea of using arrays of transparent rods to transmit images for television and facsimile systems. It takes more than 120 years for these innovations to come to fruition, but without them, the fiber industry doesn't exist today.

1953

Bram Van Heel makes the crucial innovation of cladding fiber-optic cables. Van Heel covers bare fiber with a transparent cladding of lower refractive index. This greatly reduces cross talk between fibers, providing a foundation for fiber optic deployment in the 20th century.

1960

But there were still many challenges to overcome. By 1960, glass-clad fibers attenuated at about 1 decibel (dB) per meter. That was fine for medical imaging, but communication devices needed to operate over much longer distances and required a light loss of no more than 10 or 20 dB per kilometer.

1964

A crucial specification is identified by Dr. Charles K. Kao for long-range communication devices: the 10 or 20 dB of light loss per kilometer standard. Dr. Kao also illustrates the need for a purer form of glass to help reduce light loss.

1970

A team of researchers experiment with fused silica, a material capable of extreme purity with a high melting point and low refractive index. Corning Glass researchers Robert Maurer, Donald Keck, and Peter Schultz invent fiber-optic wire, which can carry 65,000 times more information than copper, through which information can be decoded hundreds of kilometers away.

1972

The team had solved the decibel-loss problem presented by Dr. Kao. By June of 1972, Robert Maurer, Donald Keck, and Peter Schultz invent multimode germanium-doped fiber with a loss of 4 dB per kilometer and much greater strength than titanium-doped fiber. This would prove to be a massive leap forward in fiber deployment.

1973

John MacChesney develops a modified chemical vapor-deposition process for fiber manufacture at Bell Labs, spearheading the widespread commercial manufacture of fiber-optic cabling.

1977

General Telephone and Electronics test and deploy the world's first live telephone traffic through a fiber-optic system running at 6 Mbps, in Long Beach, California. They're followed by Bell in May 1977, with an optical telephone communication system installed in the downtown Chicago area, covering 2.4 kilometers. Each optical-fiber pair carries the equivalent of 672 voice channels.

And here we are, forty-one years later: more than 80 percent of the world's long-distance voice and data traffic is carried over optical-fiber cables.

We've come a long way.

The State of the Market

Today, fiber connectivity is quickly becoming the global standard for telecommunication.

According to the Global Broadband Statistics, full-fiber, fiber-fed copper, or cable connects over 50% of people in more than 40 countries. This includes 97% in Singapore, 89% in China, 87% in the U.S., and 55% in the UK. The statistics consider subscriptions through the end of 2017.

With over 530 million connections, FTTX, and other fiber-fed subscriptions made up 57% of broadband subscriptions.

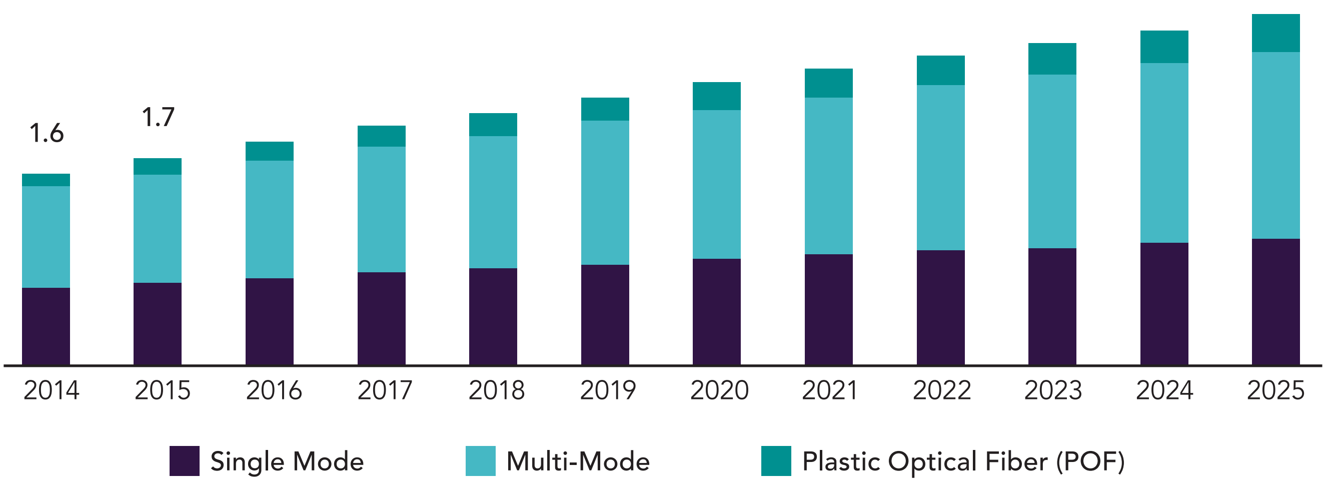
"We're finding that customers across most global regions increasingly prefer faster broadband services delivered over fiber platforms, as opposed to ADSL," says Jolanta Stanke, research director at Point Topic. "This trend will continue as more bandwidth-hungry young consumers become paying decision makers."

Even with the proliferation of FTTX in the last few years, the demand is expected to continue to grow well into the 2020s. In the U.S. alone, the fiber optic market size is projected to grow to USD 3.56 billion by 2025.

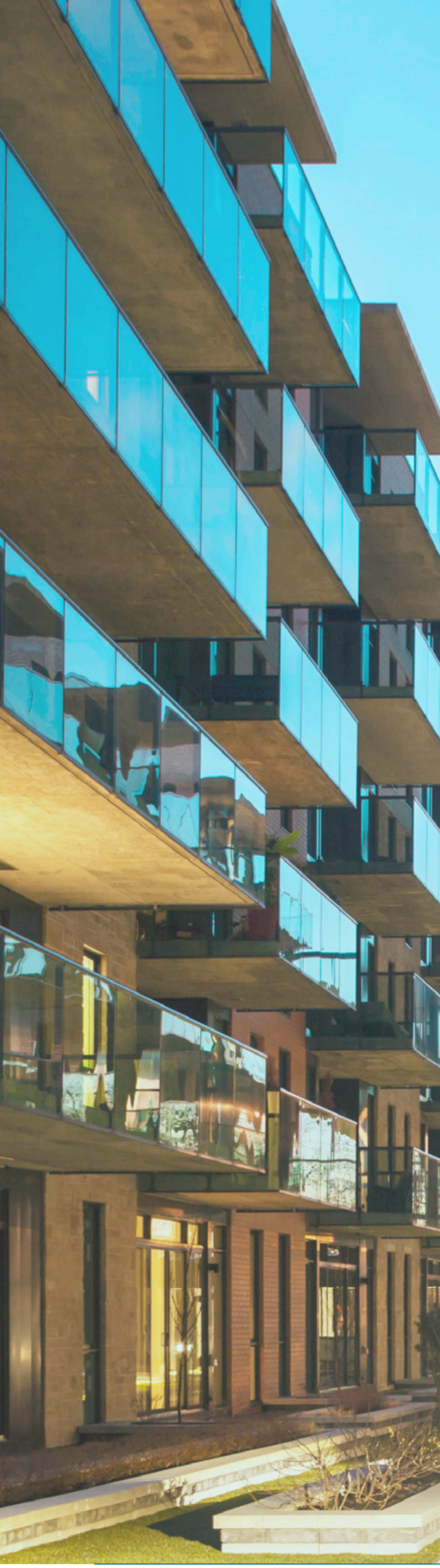
Furthermore, a rise in the popularity of cloud-based applications, audio-video services, and Video-on-Demand (VoD) services stimulate an increased demand for high-speed wireless access provided by fiber.

Medical and military and aerospace application segments are also poised to witness significant growth, increasing adoption of optic technology devices.

North America fiber optics market size, by type, 2014 - 2025 (USD Billion)



Source: www.grandviewresearch.com



Concurrent with the increase in demand, innovations in fiber optic technology continue to evolve the market.

In January 2018, Corning, Inc. opened a manufacturing facility for fiber optic cable in Newton, North Carolina. The facility helps meet demand for optical fiber and cable across the globe. In March that year, the company launched a new product, Corning TXF Optical Fiber, that enables high data-rate transmission over longer spans and extended reach for improved network flexibility, all while lowering network cost.

Fiber network expansion began at central offices, first by feeding hubs and then extending to nodes. Now, they reach all the way to the living unit. FTTx is quickly becoming the standard for greenfield construction in single-family home developments. However, MDU builders have been slower to adopt the same practices - older MDU buildings with outdated wiring are often overlooked altogether.

Clearly, the demand and opportunity for unprecedented growth in the in-building fiber market is only in its infancy.

Comparing Greenfield and Brownfield Fiber Design Projects

Before we get into the challenges and best practices of FTTH design, let's compare two different contexts for in-building design: greenfield versus brownfield buildings.

'Greenfield' describes a fiber deployment project in which a new building is being constructed without existing infrastructure. These builds tend to be relatively inexpensive, so approval is quick. When following accepted in-building telecom practices, approval from the building owner is usually not a problem. The big challenge is the communication and coordination to work around other construction activities and utilities.

'Brownfield' describes a fiber deployment project in which there is already existing infrastructure (legacy network connections) in a building that is currently occupied by tenants. For Brownfield projects, coordination is usually easier as you often only have a single point of contact to work with. Since the infrastructure is complete, no configuration changes will be introduced by other parties.

The big challenges for brownfield projects are pathway limitations and the associated costs to create new ones; directional boring under concrete, core drilling between floors to create risers, and installing fiber drops inconspicuously down hallways. When pathways are not already available, the least expensive placement methods tend be the most visible, which poses a challenge in gaining approval from building owners who demand a certain aesthetic.

Challenges of Fiber Design and Deployment for MDUs

Like any burgeoning industry, fiber deployment to MDUs has a host of unique challenges that operators are struggling to overcome. Let's look at the three biggest obstacles that can complicate and slow down a fiber design and deployment.

Lack of Standardization

Given the relatively new adoption of fiber in the home market, it makes sense that we have yet to see a standardized process for FTTH design. There are many different tools and approaches used by operators to complete a fiber design. Documentation can be recorded and shared in a multitude of formats, from pen and paper, to excel spreadsheets, to AutoCAD drawings. Most often, you see the use of multiple systems with disparate output formats. Carriers then rely on complex processes to ensure that the fragmented data is accounted for and maintained.

Within an organization spanning multiple regions, local practices prevail. Certain methods and procedures that are common in those areas will be followed by habit, regardless of cost or time. Without tools in place that encourage best practices, achieving business objectives becomes difficult.

So, fragmentation of software and documentation is a major problem in the FTTH industry. For example, two engineers from the same company at different locations may end up using vastly different data collection tools to perform site surveys. Changes and tweaks to a network design quickly become cumbersome when you have to make them for several different tools. And not only does this complicate the sharing and circulation of survey results, it also prevents a standardized precedent for future designs.

When creating a new fiber network, how can we learn from past mistakes if we're unable to iterate on and learn from past designs?

Lengthy Design Times

Another primary challenge of fiber deployment is the time it takes to design an FTTH network. For multi-dwelling units - one of the primary venues for FTTH - initial design can take upwards of three weeks to complete.

There are many factors which extend the time until design completion. From operators, building administrators, engineers, and tenants, there are many groups which have a vested interest in adding fiber connectivity to a multi-dwelling unit. With that in mind, site surveys must be coordinated to ensure minimal disruption for property managers and tenants already living in the building. Or, if the building is still in the process of being built, survey and installation must be organized with construction workers and other utility engineers.

Fiber deployment also often stalls due to delays in property manager approval sign off, which can take months after an initial design is presented.

Property Manager Expectations

Fiber design for multi-dwelling units are typically more invasive than traditional DAS systems, and they must also adhere to the standards and expectations of the building's property manager.

Of course, property owners and managers have their own priorities and concerns, and these can often conflict with the typical process for FTTH design. In buildings where fiber is an upgrade over existing wireless technologies, property managers need to concern themselves with minimizing tenant disruption, as there will already be occupants in the building who most likely don't appreciate the noise of installing a new wireless infrastructure.

Vacant, in construction, and newly built buildings also pose their own challenges when it comes to property manager expectations. The aesthetic impact of an FTTH network will often be a major concern for building owners - optical cables are not exactly pleasing to the eye. Having to factor in aesthetics presents a major challenge in properly optimizing a fiber network.

Proper deployment is also essential to maintaining a positive relationship with the property owner. If damaged drops behind walls must be replaced, it often requires the removal of hundreds of feet of drywall. Time management is also crucial; not completing in-unit work in-time and being locked out after a final-clean can cause delays in the completion of the project. If this window is missed, you have to coordinate with the property manager to get the keys and then be very careful not to dirty up or damage anything in the unit.

Regardless of a building's occupancy status, coordination and collaboration between project stakeholders is paramount. That means that network engineers need to work with both construction workers and a building's property managers to ensure each party is achieving their project goals. When there are so many participants on a project of this scale, each with their own objectives and needs, keeping everyone satisfied and organized is easier said than done - especially when there's no design standardization in place.

Best Practices in Fiber Design and Deployment for MDUs

Now that we've identified some of the challenges associated with fiber deployment for MDUs, let's look at some of the best practices when designing and deploying for these types of venues.

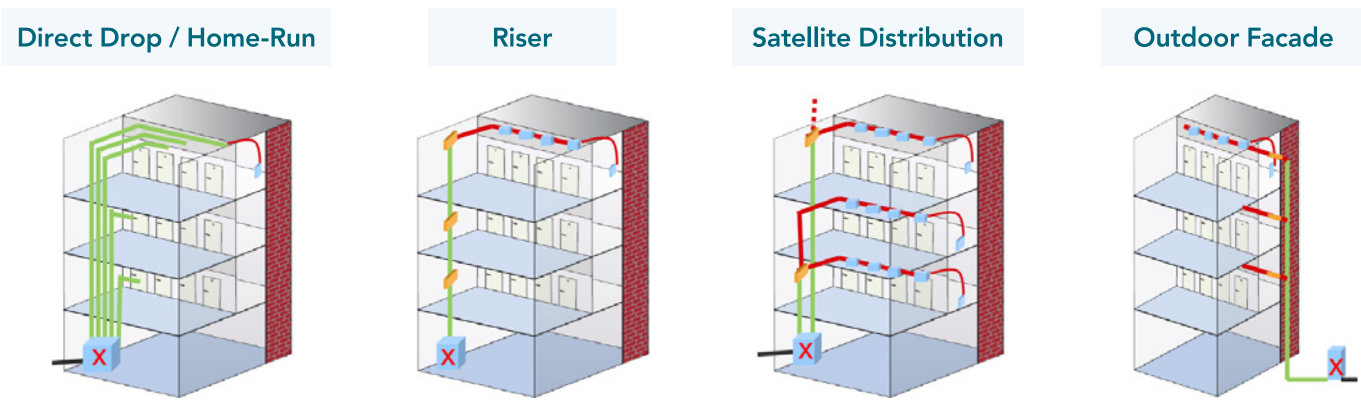
Use the Correct Splitter Topology

Perhaps the most important consideration when planning a fiber network for a multi dwelling unit is to understand the type of technology you're designing for. Depending on the layout of the building, different design topologies can yield a wide range of results.

A Typical Cable Layout for MDU Fiber Deployment (F1/F2/F3 represent fiber cables)

Let's look at five MDU splitter topologies and the pros and cons associated with each:

- **Local Convergence:** Typically found in North American markets where a cabinet of 1x32 splitters is housed between the F1 and F2 network feeds. The cross-connect functionality of the cabinet allows for a pay-as-you-grow model, starting with one splitter (and associated PON) to serve the first 32 customers before needing to add a second.
- **Distributed Split:** Typically found in European markets or areas with only one provider, unlike the local convergence topology, the distributed split layout is made up of several 1x4 and 1x8s in series to reach the total 1x32 split. This method reduces the amount of cabling in the F2 network but requires the splitters to be placed from project outset. In a competitive environment, distributed split methods may have a higher cost impact.
- **Central Switch Home-Run:** The most flexible and future proof variation, each fiber to the unit tracks back to the central office where the 1x32 splitter is located. This fiber-rich topology is the costliest, requiring high-fiber count cables and vast amount of splicing.
- **Segmented Split:** This method pushes the 1x32 splitter as far into the network as possible. It is effectively the opposite of the central switch home-run method. A less robust but significantly more cost-effective approach.
- **Point-to-Point:** Comparable to Central Switch Home Run. Characterized by dedicated fiber run from a localized switch all the way to the unit. In a larger campus network, active switches may replace the passive optical splitter of a GPON network with various switch locations connected on a separate fiber ring.

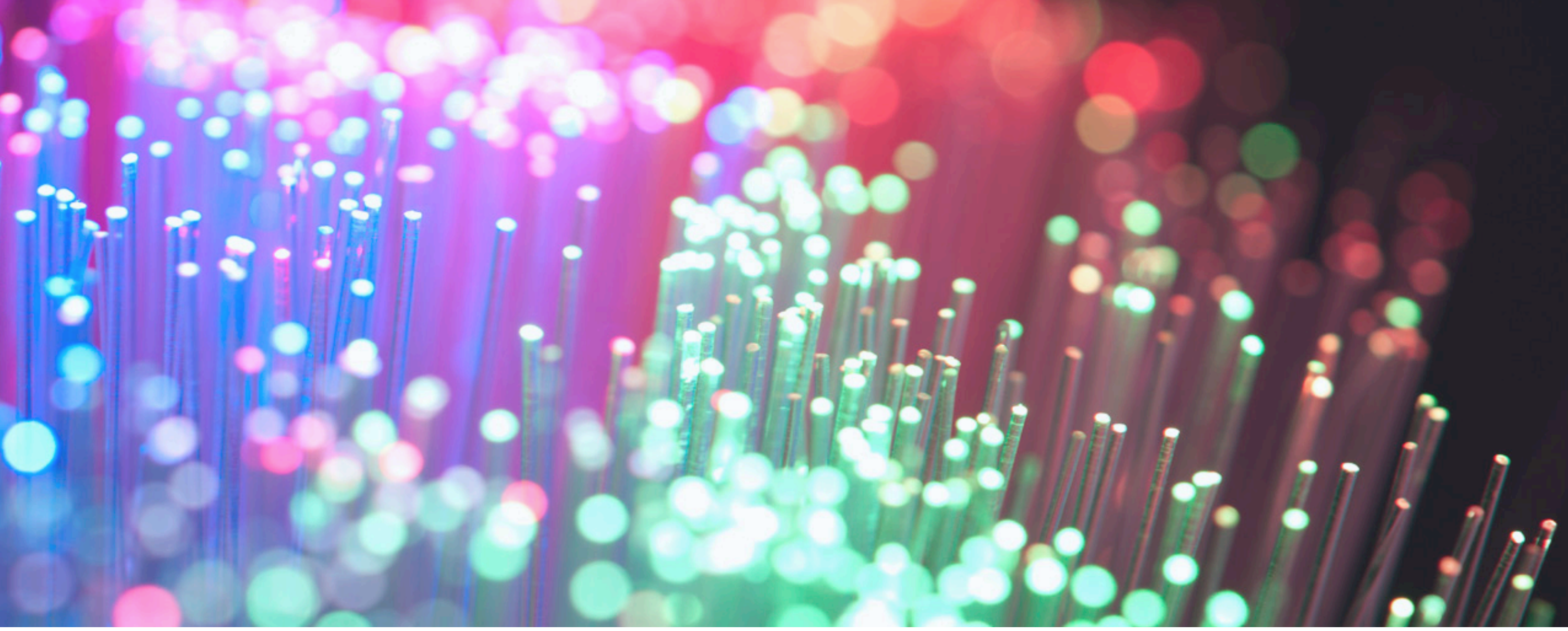


Regularly Communicate and Engage with The Property Manager

As discussed earlier, property managers have a vested interest in the seamless deployment of a fiber network to their building. They also often lack the technical understanding associated with designing and installing network architecture.

You can forgive them if they're less concerned with splitter topologies and more concerned with the big picture: how much is this going to cost, how long is this going to take, and how will it affect my tenants?

Luckily, there are tools in place to help facilitate engagement between network designers and building owners. In a later section we'll discuss how software tools like iBwave's 3D visualization and report generation can help immerse property managers in the design process, but the key here is that regular communication and expectation setting goes a long way toward getting your design approved.



Bend Insensitive Fiber Cables Make A Big Difference

When installing fiber cables indoors and routing patch cords around patch panels, fiber optic cables may be subjected to tight bends. This stress can cause signal loss and even long-term failure.

Cable manufacturers now offer bend-insensitive fibers, both singlemode and multimode, that are more tolerant of tight bending. Bend insensitive fibers are a big advantage for patch cords or whenever fibers are subjected to stress, but manufacturers should be consulted to see if these fibers require special techniques for splicing, termination or testing.

Invisible Cabling Solutions

When a building's existing wiring is outdated and can no longer support bandwidth speeds that meet customer demand, fiber cabling often has to be built down the hallway. Disguising or hiding these cables can a big challenge. While vendors continue to innovate, the most common methods for solving this issue include:

- Installing behind drywall
- Installing molding with built-in cable pathways
- Connecting to existing infrastructure/cabling, if available

Ultimately, careful planning and visualization are important to gain building approval for any hallway solution.

Overprovision to Anticipate Demand

Given the steady increase in demand for FTTH, it's obvious that operators and system integrators need to ensure they have enough fiber to anticipate the growth of the industry.

Though the adoption of fiber continues to grow exponentially, new fiber deployment projects should be overprovisioned to anticipate a radical increase in demand in the near future. The cost associated with redesigning an existing fiber network because infrastructure was not already in place to meet this demand is significantly higher than buying extra bandwidth for customers that may not yet need it.

As the adage goes: it is better to be prepared for an opportunity and not have one than to have an opportunity and not be prepared.

TRUE STORIES

Case Studies on Fiber for MDUs

In this section we'll look at some case studies of fiber deployment for MDUs in a variety of contexts.

Given the scope of this eBook, we'll keep these simple; they're intended to highlight some of the challenges and nuances you should consider when preparing to design a fiber network for MDUs. In a later section we will address these challenges and how they can be solved using software designed specifically for these types of use cases.

Modern Brownfield High-rise - Portland, Oregon

Our first case study looks at a 23-floor high-rise building in Portland, Oregon. The building was built over ten years ago, and already had pre-existing network connectivity before a new fiber connection was commissioned.

Designing a fiber network for this unit proved challenging. With an underground parking garage, retail locations, commercial offices, and residential units, there were multiple parties, each with different needs and use cases that could potentially be affected by service interruptions and installation.

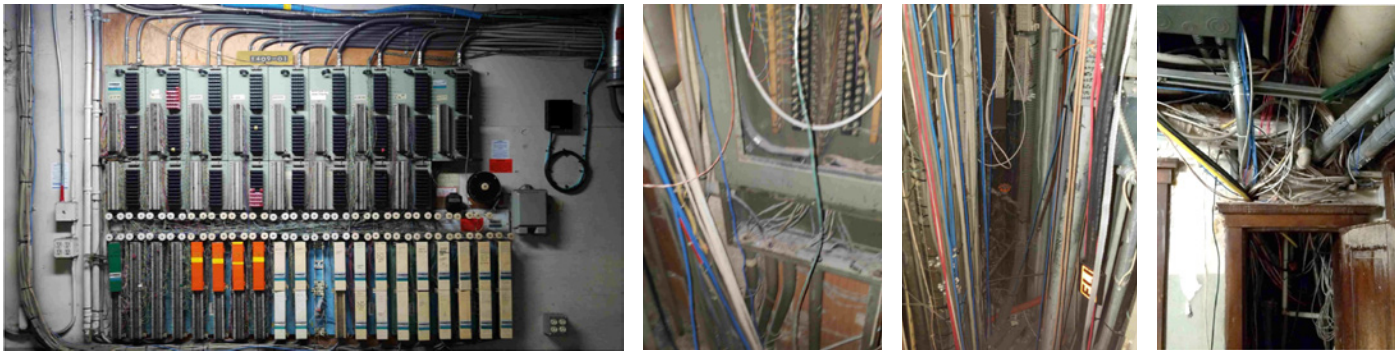
Luckily, as a relatively newly constructed building, each residential unit had CAT 5e cables running to existing multi-port capable ONTs in the IDF closet. This reduced the amount of fiber cabling required by 25%. Additionally, with a newer building, the riser conduits had enough space to pull-in a compact cabling solution, eliminating pathway creation costs.

This is a good example of how a multi-technology design can cut costs and save time in future wireless deployments. While fiber was not common when the building was first constructed, the infrastructure in place insured that when new technologies emerged, the building would be ready to handle the upgrade.

Outdated Brownfield High-rise - Spokane, Washington

Unlike our modern building in Portland, this next case study focuses on a significantly older brownfield high-rise. Nearly one hundred years old, this building has seen multiple configuration changes over the ages. Walls have been torn down, renovations have taken place, and even an entire wing was added two decades after initial construction.

Naturally, this presented its own set of challenges when it came time to upgrade the building with fiber connectivity. For one, there were already seven active networks operating in the building before the mandate to add fiber was made. There were also several abandoned networks of outdated cabling dispersed through the structure. This reduced the backboard space available to add fiber cabling and made wire management a significantly more tedious process than would normally be found in a greenfield or modern brownfield project.



Cabling confusion in the Spokane Brownfield High-rise

Pathway creation and planning became an essential component to adding fiber to this MDU. Given the lack of available space and existing wireless infrastructure, creative management of cabling proved necessary to successfully complete this project.

Related to this, the building owner's priorities must be considered as well. While the owner obviously wants their building to have fiber connectivity, they also want to minimize costs, tenant disruption, and understand the aesthetic impacts that a new network will have on their property. With so little space to hold fiber in the IDF closet, cabling may need to be installed elsewhere in the building, which could potentially negatively affect the look of the building.

With that in mind, visualization of potential network designs proved to be crucial to the successful completion of this project. Providing the building owner with a visual preview of the design enabled a significantly faster approval sign-off, as they were able to easily see the impact a new network would have on the building.

The Spokane high-rise is a good example of how strong communication with building owners and visual data collection tools can go a long way to ensuring an FTTX project gets completed with a satisfied property manager. It also highlights the challenges associated with layering new technologies onto existing properties when a building is not properly future proofed.

Greenfield Mid-rise - Minneapolis, Minnesota

In this case study, we'll look at a greenfield mid-rise apartment complex. As a newly built building, there were no legacy technologies to work around when designing the fiber network.

With that said, the amount of space for cabling in the IDF closet was limited due to other building utilities. There were also only a few riser closets to use as mid-rise buildings tend to have reduced space allocation for these types of services.

Another common challenge associated with mid-rise buildings (as was the case for this project) is the level of experience technicians will have with fiber when it comes time to install. Typically, building owners will outsource the job to low-voltage technicians as a means of cutting costs, but these specialists tend to have limited experience with fiber and might not necessarily understand the nuances and limitations of the technology.

For this design, the project managers engaged early on with industry officials and building owners in order to both set expectations and fully communicate any challenges that might occur during the deployment process.

This level of collaboration proved key, as the building owners communicated to the project managers that there would be limited power and electrical access in the riser closets for network implementation since the structure was still being built. With access to that knowledge, the designers bypassed the splicing and plugged their terminals in with a pre-connectorized cabling solution.

Ultimately, the project proved to be a resounding success thanks to the close collaboration of project stakeholders through each stage of the design process.

Greenfield Cottage - Longmont, Colorado

In this case study, we have the unique scenario where every building is identically sized at 32 units each. Naturally, that fits well with the GPON segmented split approach to splitter topology.

Each 1x32 splitter was pushed as far into the network as possible, being placed into an MDU terminal that was mounted on each building. From the terminals, a single fiber drop was routed into each individual unit.

One of the main challenges in this project involved the level of competition amongst operators, each vying for bulk agreements to be the primary provider in this particular market. Ultimately, the contract was given to the operator who could provide design solution visualization and who fostered communication between project planners and the building manager.

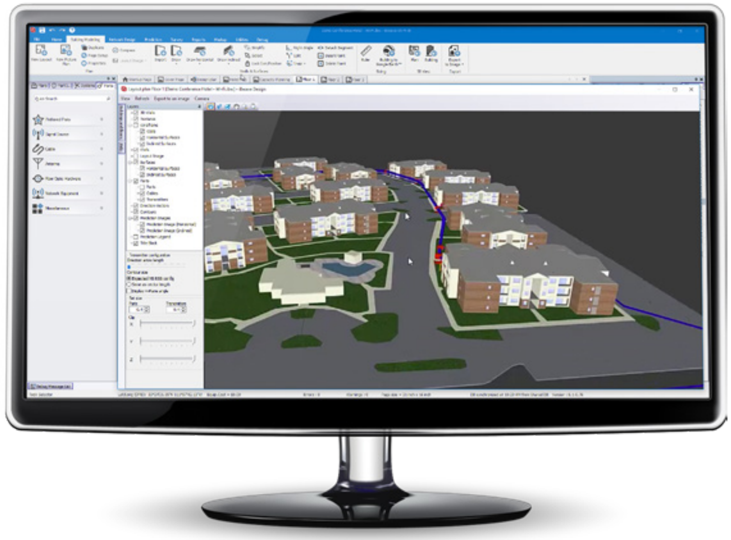
Another challenge related to this case study was the length of time it took to fully deploy the network. Since each unit was still in the process of being completed, the average pace for building completion was around one per month spread out over a year's time. As such, the conduit plan had to be established very early on in the development lifecycle to ensure no productivity or time was lost.

A New Solution: iBwave FiberPass

We've seen how the lack of standardization in FTTH deployment has created something of a wild west in the industry. Without guidelines, precedents, or rules, the successful deployment of fiber networks is unpredictable and uncertain.

Enter iBwave's FiberPass. Developed with FTTX design principles in mind, and with input from major telecommunications operators, FiberPass was created with the goal of taming this wild west. And since its adoption by tier 1 operators, FiberPass has simplified the entire fiber deployment lifecycle - from initial design to follow-up maintenance.

FiberPass changes the landscape of FTTX design in several ways, and the benefits start right from project conception by providing a massive time improvements to the survey and design process.



5 floors / 401 units

10 days to 4 hours

3 floors / 143 units

10 days to 5 hours

13 floors / 164 units

10 days to 4 hours

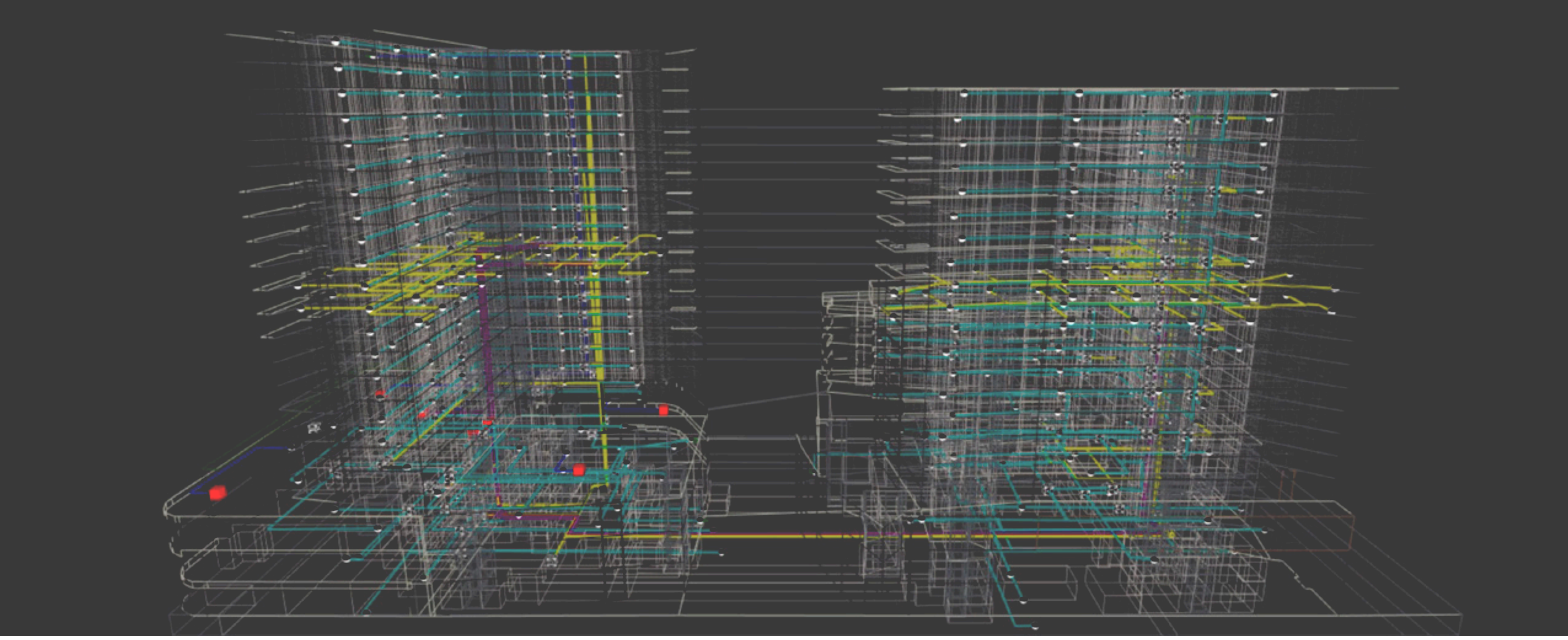
5 floors / 246 units

10 days to 4 hours

Design with Mobility

Engineers using FiberPass on mobile to perform site surveys can complete up to 80% of a design right on an Android tablet.

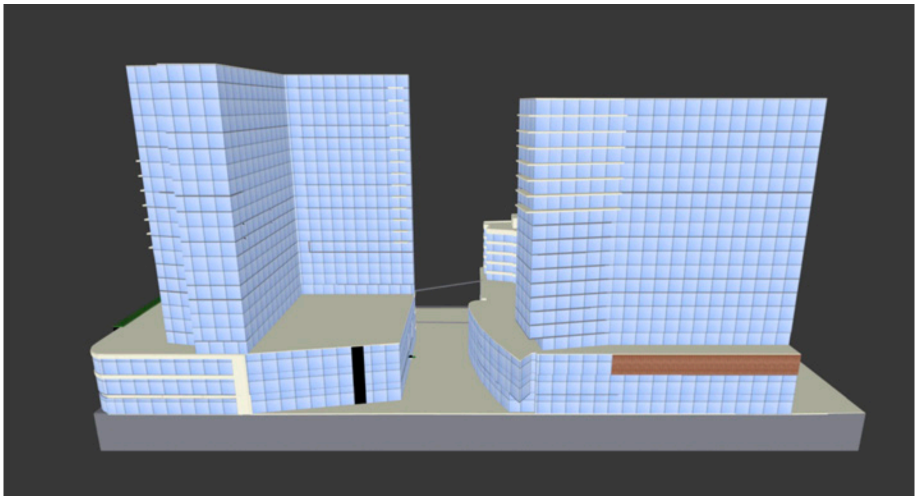
With iBwave Unity, they can then take survey data and send it to the cloud for easy access both on and off premises. A building owner headquartered far away from the design project can still review updates and easily sign off on approval without having to leave their offices.



Visualization Tools as a Means of Engagement and Collaboration

FiberPass can generate 3D building plan virtualization, giving property managers a convenient and detailed look at the network design. With the ability to take photos and annotations while surveying, engineers can also compile information for property managers about aesthetics, tenant impact, and unique challenges in a building's design all in the same application.

As we learned in the case studies section, the ability to visualize a wireless design concept is essential to getting a timely sign off on an FTTX design.



iBwave's 3D Virtualization in Action

Designs as an Asset

FiberPass was built with the philosophy that in-building wireless designs should be an asset. What this means is that there are tools in place to replicate and iterate on past designs made within the software. Not only does this future proof past designs by allowing engineers to layer new technologies onto legacy designs as they emerge, it also creates a precedent for future designs that an operator can refer to as needed. There are also features in place to duplicate building units within FiberPass, which saves a dramatic amount of time when designing projects such as the greenfield cottage case study we looked at earlier.

Find the Right Equipment with The Component Database

A component database with nearly thirty thousand parts is built directly into the iBwave suite. Not only will you be able to find the correct splitter topology for your design, you'll also have access to bend insensitive fiber cabling to ensure connections stay strong well into the future. All equipment in the components DB are modeled down to their own specification and will act as they would in a real-life wireless environment.

Automated Deliverables

Once equipment has been compiled from the components database, it can be automatically copied to an equipment list report. The equipment list report can be shared with a building owner to give them an at-a-glance outline of the bill of materials required to complete the design.

The Approval Sign Off report is another handy document to provide to the property manager. An automated electronic sign off document helps shorten the acceptance process, with some designs being approved hours after a site survey is completed. If an approver is offsite, iBwave Unity's cloud connectivity ensures they'll be still be able to immediately access any documents shared by the engineer performing the site design.

All deliverables can be created in the format most convenient to project stakeholders, including PDF, excel, image files, and more.

Faster Validation and Approval

If there's been one continual pain point for operators designing fiber networks, it's the time it takes to get a design approved.

A Canadian tier 1 operator had two MDUs which had been waiting for approval from the property manager for over nine months. Development was about to be cancelled since the projects were stuck in limbo. iBwave did their own survey and design of the building, and the designs were approved within days. What would have taken nearly a year was completed in under a week.

The Path to Standardization

One of the core philosophies of FiberPass is to lead the way on the path of fiber optic design standardization.

iBwave software's automated processes, design replication, and report generation have all been built around the notion that projects should be repeatable and iterative. That doesn't mean the software doesn't play nice with other design tools. In fact, it integrates with existing GIS and operator tools, so solution is easy to adopt and helps facilitate a standardized procedure to FTTX design.

Legacy Process vs FiberPass Process: A Comparison

Legacy Process 1	**4 DAYS** Multiple site surveys a day. Takes 4 days before one site survey is assessed.	**6 DAYS** Takes 6 days to implement the design.	**30+ DAYS** Property approval can takes months
Legacy Process 2	**14-20 DAYS** 14-20 days before property receives a report from Operator.		
FiberPass	**3 Hrs** FiberPass removes any backlog after site survey. From 4 days to 3 hours	**0 Hrs** FiberPass removes 6-day backlog during Design process. Approval documents are automated.	**0 Hrs** FiberPass consolidates survey and design process. Property sign off document sent and signed electronically immediately after site survey.

Glossary

BROWNFIELD ENVIRONMENT: Describes a fiber deployment project in which there is already existing infrastructure (legacy network connections) in a building that is currently occupied by tenants.

DISTRIBUTION CABLE: The distribution cable is sourced from the local convergence point and splits into several paths with endpoints at MDUs and commercial buildings. Also known as the F2 cable.

DROP CABLE: The drop cable is the smallest range cable and is intended to distribute fiber to apartments from connection points. Also known as the F3 cable.

FDH: Stands for Fiber Distribution Hub, this is the terminal from which drop cables extend to the end user.

FTTX: Stands for "Fiber to the 'X', referring to fiber optic deployment to a variety of venues. A catch all acronym that can be further subdivided into specific categories such as FTTH (Fiber to the Home), FTTB (Fiber to the Building), and FTTC (Fiber to the Cabinet).

FEEDER CABLE: The feeder cable transmits fiber from the Optical Line Terminal to a splitter. It is typically several kilometers in length and typically splits into several distribution cables from the local convergence point. Also known as the F1 cable.

GIS: Stands for Geographical Information Systems, a framework for gathering, managing, and analyzing data. Rooted in the science of geography, GIS integrates many types of data and is the primary method of planning wide scale outdoor fiber deployment.

GREENFIELD ENVIRONMENT: Describes a fiber deployment project in which a new building is being constructed without existing infrastructure.

MDU: Stands for Multi Dwelling Unit, a residential building with more than one family living within.

MTU: Stands for Multi-Tenant Unit, a commercial building with more than one business operating within.

MULTIMODE CABLES: A cable with a larger diameter than single mode, typically 50-100 microns for the light carry component. Considered to be the "domestic" fiber as they are typically used in FTTH design. Multimode can reach up to 100Gbps Ethernet.

OLT: Stands for Optical Line Terminal, this is effectively the "head office" of a fiber distribution network; the starting point from which fiber is delivered.

ONT: Stands for Optical Network Terminal, placed near the end user, usually on customer premises.

SINGLE MODE CABLES: A single strand of glass fiber with a diameter of 8.5-10 microns.
Compared to multimode fiber, the single mode patch cords carry a higher bandwidth, but requires a light source with narrow spectral width. The single mode gives a higher transmission and up to 50 times more distance than the multimode.

Sources and Acknowledgements

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