Solving the Fiber to the Premises Challenge with Pushable Fiber

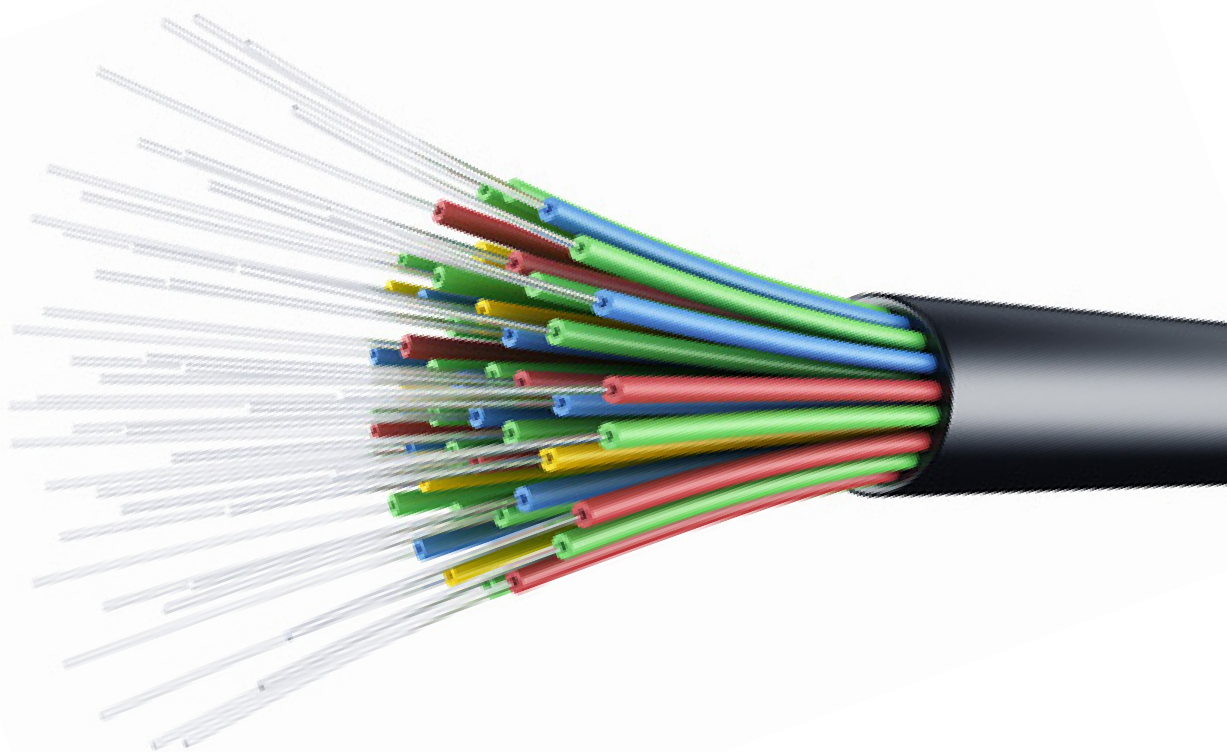
A Guide for Network Operators and Installers

How Pushable Fiber Solves the Fiber to the Premises Challenge

Fiber optic cable has come a long way. In 1910, Hondros and Debye developed a theory of dielectric wavelengths. However, it was not until 1966 that the technology became commercially available. The first optical fiber was invented that year by Charles K Kao and George Hockham at Standard Telecommunication Laboratories (STL) in the United Kingdom.

Over the past four decades, the fiber optic waveguide has become one of the leading transmission mediums for communication systems. From the medical through to the defense and data storage industries, fiber optic cable is being used in an ever-widening range of products. Undersea cables containing fiber now connect even the remotest parts of the world to the Internet. And increasingly, home owners and businesses are enjoying the benefits that superfast broadband provides. By 2020, over half the world will have access to FTTx or cable broadband, which will make up 80% of broadband connections.

As you start to deploy FTTH for greater capacity per subscriber, you may discover that the fiber drop from the pedestal or pole to the home will be the greatest challenge. Whether it is landscape and environment, regulatory issues, customer inconvenience, or deployment cost, the challenges of the last drop mean you can be faced with countless challenges on any FTTH rollout. We focus on a solution that easily installs quickly and efficiently using your installer's existing skills.



Solving the FTTP Challenge

As operators around the world ramp up FTTP deployment, they are discovering that it is the last leg of the connection, from the cabinet to the individual home or building – often termed “the last drop” - that is proving to be the greatest challenge. Whether it is landscape and environment, regulatory issues, customer inconvenience, or deployment cost, the challenges of the last drop mean an operator can be faced with countless individual civil engineering projects on any FTTP rollout.

While there exist a number of products and methods that can be employed for the last drop (see our eBook The Complete Guide to Fiber to the Premises Deployment), it is our contention that using pushable fiber is the best approach you can take for most FTTP installation scenarios. The purpose of this eBook is, therefore, to take a deep dive into pushable fiber. Over the next few pages, we will highlight the key attributes, list the termination options available to operators, and explain how the technology is applied in the field. Our intention is to give you clear, impartial information so you can decide whether pushable fiber is right for your business.

Exploring the need for a pushable fiber solution

The first pushable fiber cables with optimized stiffness and friction co-efficient properties were introduced to the market by m2fx (now PPC) in 2008 for Cincinnati Bell in the United States. Put simply, pushable fiber was invented to solve the challenge of the last drop. Prior to its introduction, there were no products on the market as suitable or efficient for multiple short distance drops.

Directly buried cable, while on the surface simple and cost-effective, is poorly suited for the last drop. It is susceptible to damage, difficult to repair or upgrade, requires splicing, and is unwieldy to use. Even small last drop direct cables, such as Corning ROC drop range are flexible in one orientation only, making installation problematic in confined spaces.

Network operators did have the option of blowing fiber into a premise. However, blown fiber is fragile and designed for longer distance fiber deployments. It can only be used in a duct and cannot be pre-terminated. On top of this, blown fiber technology is not suited to multiple short runs. Equipment set-up and tear down times often exceed the amount of time allocated to blowing. This is particularly the case when large blowing machines are involved and installations are spread over an entire city.

Besides being costly and labor-intensive, blowing can cause inconvenience to customers. Despite the best intentions, engineers sometimes blow soil and water into a customer’s premise during the installation process. >>

Insight

It is the last leg of the connection, from the cabinet to the individual home or building, that is proving to be the greatest FTTP challenge.

▼ While there exist a number of products and methods that can be employed for the last drop, pushable fiber is the best approach you can take for most FTTP installation scenarios.

Prior to the emergence of pushable cable, network operators had the option of using pullable fiber. Pullable cable has the advantage of being suitable for short drops of upwards of 400 meters. It is also a cost-effective option because it requires no extra equipment. However, it is less flexible because it requires a duct with a pull cord in place or, if no pull cord exists (or it's been damaged), one has to be blown in with all of the cost and inconvenience associated with that method.

If done incorrectly, pulling can cause damage to the duct or the cable or both. Around tight bends, cord can saw through duct during installation. And as route length increases, the force required to pull a cable increases. Pullable cable, which is able to withstand only a limited pull force, can be damaged if this force is exceeded.

A quick and cost-effective solution

Pushable cable was designed to address the limitations presented by blown, pullable and direct buried cable. Unlike other solutions on the market, pushable fiber can be implemented quickly and cost-effectively, particularly when pre-terminated pushable connectors are used. Pushing can either be done by hand or machine. The machines used in pushing are small enough for a single person to carry into a premise. Instead of spending tens of thousands of dollars on purchasing a large blowing machine and high pressure compressor, for example, operators can use these devices together with an inexpensive low-pressure compressor (if needed) to push fiber into or out of a premise. In the process, they can make savings and improve the efficiency of their capital spending.

Utilizing pushable fiber, it is perfectly possible to push cable into a property in the space of a few minutes. Given that labor accounts for 80% of the cost of a typical FTTP deployment, this is a major advantage. And the technology can be deployed by non-fiber specialist engineers that have a limited knowledge of fiber optic installation.

Pushable fiber can also be replaced relatively easily. Should a fiber be cut or damaged, the pushable fiber can be located and pulled from the duct. Once the duct has been repaired, the replacement assembly can then be pushed back in.

Lastly, pushable fiber can be deployed with minimal inconvenience to the customer. Unlike blowing, for example, pushing doesn't bring water or dirt into the premise. If done in conjunction with pre-termination, the process is also quick and easy.

Insight

Pushable cable was designed to address the limitations presented by blown, pullable and direct buried cable.

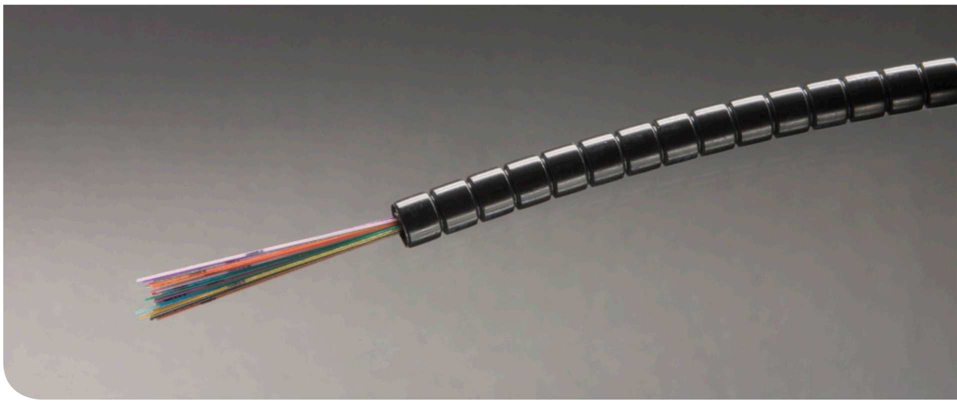
▼ It can be implemented quickly and cost-effectively with minimal inconvenience to the end customer.

What Exactly is Pushable Fiber?

Pushable fiber cable comprises one to 24 fibers in a protective plastic sheath. It is the materials and properties of the sheathing that provide pushable fiber with much of its advantage over other cable types for use in the last drop.

Pushable fiber has to be hard and stiff to be pushed over long distances. It is recommended that network operators use cable that has a Shore Durometer D scale hardness of at least 60. Shore Durometer D is an internationally recognized measure of hardness in rubber and plastics with a range from one (softest) to 100 (hardest). Cable products that have a Shore D in excess of 60 are hard and have a low surface friction. They can be pushed over distance inside duct. Furthermore, the tougher and more robust the cable is, the easier it is to reduce risk and simplify installation.

Paradoxically, pushable cable products must also marry that stiffness with flexibility. A very rigid, strong cable will push along a straight installation route quite easily. If the cable is not sufficiently stiff it will fold in on itself, even along a straight route, kinking the fiber, resulting in signal loss and reduced installation distances. However, once bends and corners are introduced, too much stiffness actually inhibits installation length, so the balance between stiffness and flexibility needs to be precisely gauged.



Another factor linked to a cable's stiffness is its coil set. A considerable amount of force may be required to straighten out a cable when it comes off a drum. This is a good indication that the cable is not suitable for last drop installations.

The best pushable cable products on the market have the right balance between stiffness and flexibility. PPC, for example, have achieved this balance by developing a grooved protective sheath for their cable. The grooves eliminate kinks and allow cables to be bent around sharp radii while keeping the product hard enough to have low friction and stiff enough to allow pushing.

Although pushable cable is mainly used for short runs, it is sometimes deployed over longer distances. Low pressure air is then applied to provide additional lubrication allowing the cable to be pushed further. Grooved pushable cable is perfect for these types of implementation because the grooves provide extra traction for the air.

Insight

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Considering Your Termination Options

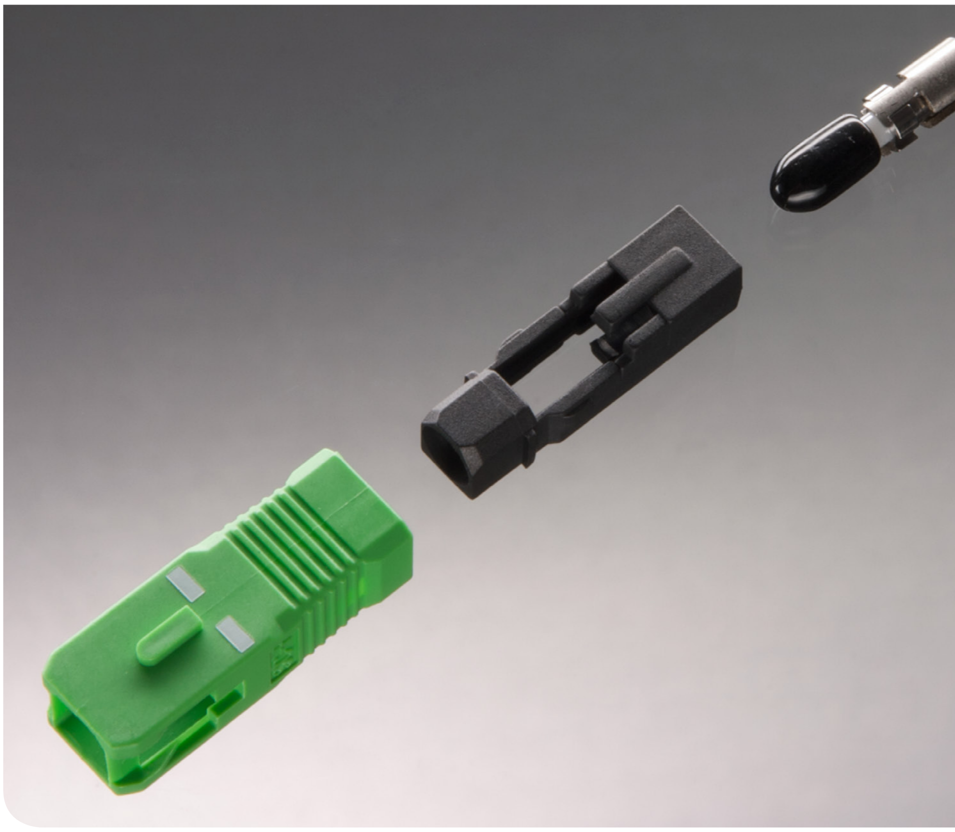
Pushable cable can be terminated in a number of ways. Network operators can use pre-terminated pushable connectors or mechanical and field fit connectors. They can also fusion splice their cable. Each technique has its advantages and disadvantages. Let's explore each of them in turn.

Pre-terminated pushable connectors

Pros

Many network operators choose to use pre-terminated pushable cable because it eliminates the need for time-consuming and expensive fusion splicing. Pre-terminated connectors also cost less than low performance mechanical connectors. As they are factory fitted and tested, the performance of pre-terminated connectors is good and no specialist staff or equipment are needed to install the product. Pre-terminated pushable cable is perfect for multiple last drop installations where the operator has a good idea about the length of each run involved. Installers will typically order a range of lengths of pre-terminated cable – typically in five to ten meter units.

The major advantage of pre-terminated connectors is that they meet the highest quality levels of polish and geometry as well as the best optical performance levels. The international standard applicable to these products is IEC 61753 and all reputable termination houses can supply fully compliant products. The applicable measurements are insertion and return loss respectively.



Cons

The main drawback to using pre-terminated pushable cable is that there is almost always excess cable left over from installations. The excess cable has to be coiled in a storage box on the premise or housed in a facility beside the curb. This issue can be mitigated by using a small pushable cable that is flexible enough to be coiled into a small diameter for storage. Aside from the aesthetic considerations, some companies don't want to spend money on fiber that is just permanently stored in a box. >>

Insight

Many network operators choose to use pre-terminated pushable cable.

▼ The major advantage of pre-terminated connectors is that they offer the best optical performance levels. The drawback is the inevitable excess cable left over for each installation.

Mechanical / field fit connectors

Pros

Network operators have the option of using mechanical and field fit connectors to terminate pushable fiber. The cable is first stripped backed to expose the fiber inside. The fiber is then threaded through the components of the boot and body of the connector and fixed to a front end ceramic ferrule containing a pre-polished fiber stub. Little fiber is wasted when mechanical connectors are used. The equipment that is employed to carry out the work in the field is also relatively inexpensive.

Cons

Semi-skilled personnel are still needed to do the job. The connectors used in the field also tend to be twice as expensive as standard pushable connectors. Lastly, the losses from mechanical and field fit connectors are relatively high. Network operators are better off exploring other options – such as fusion splicing and pre-termination – if they want to avoid any significant signal loss.

Fusion splicing

Pros

Fusion splicing offers the best quality connection of all three options and no excess cable is left over when the process is complete. This involves using localised heat to melt or fuse the ends of two optical fibers together. Typically, an engineer will strip off the cable's protective coating to get at the fiber itself. Once the fiber has been exposed it is cleaned with isopropyl alcohol or another suitable cleaning agent, before being inserted into a device called a fusion splicer. The device lines the fiber ends up and welds them together.

Cons

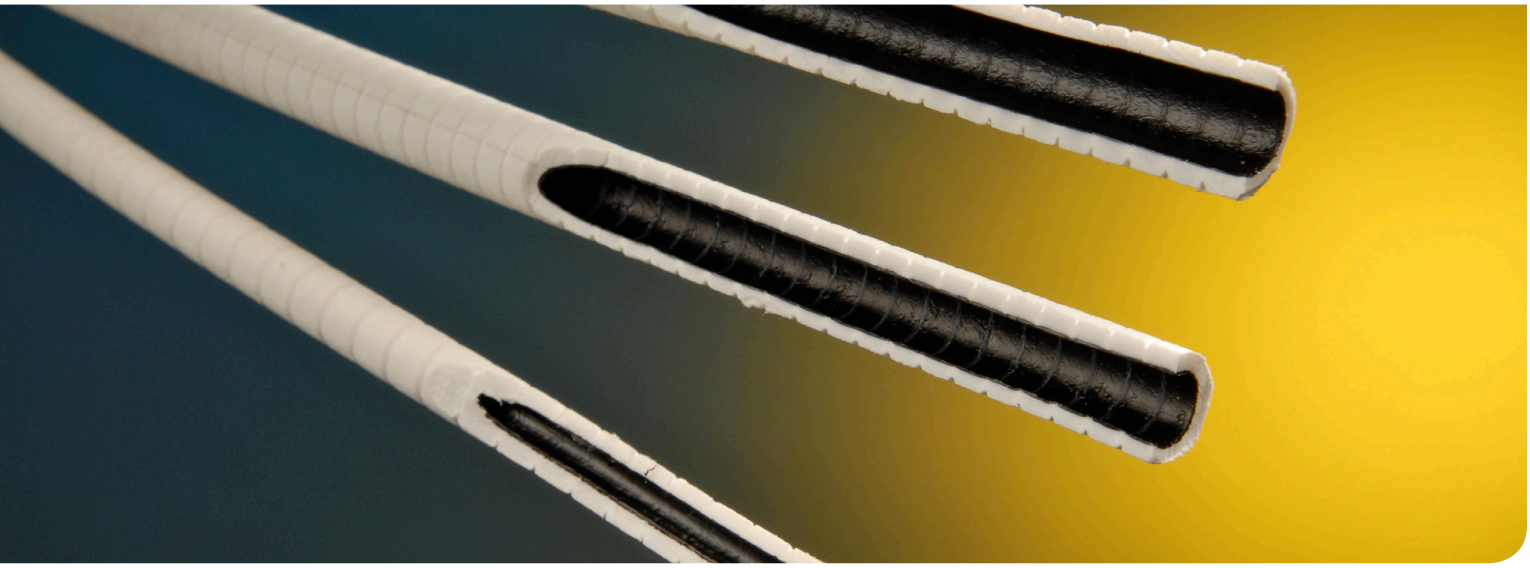
It is time-consuming and requires specialist equipment and experienced engineers to carry out the practice. In developed countries these professionals generally work for large operators and are not freely available. Those that can be obtained on the open market often charge high rates. In many developing countries, trained splicers and jointers are in such short supply that it is unfeasible to use them for a project of any size.

Insight

Little fiber is wasted when installers splice or mechanically fit connectors in the field.

▼ But costs are high because skilled personal and specialist equipment and materials are required.

What You Need to Know About Your Duct Options



Operators should consider a number of factors around what duct to use in conjunction with pushable cable. The diameter of the duct, the duct's liner, and the level of lubrication within the duct will have a direct impact on the performance of the cable during installation.

One key factor restricting the speed and distance of fiber cable installation into duct is the friction between the duct's inner surface and that of the cable being deployed. Therefore, it is vital to have a liner surface within the duct that minimises the co-efficient of friction.

Low friction liner material is key

Ideally, a dry, low-friction duct liner surface should be used for pushable fiber implementations. There are liner products on the market that are made from a variety of materials, including silicone, to boost performance. However, some ducts need, or are supplied with, liquid lubricant. Use of ducts with liquid lubricant should be avoided with pushable fiber. This is because it is difficult to control the amount of lubricant throughout the duct and, once lubricant builds up, the resulting shear force can become too great to allow the cable to be pushed.

Most commercial ducts on the market are made from polyethylene. However, polyethylene generates static, which impacts on installation distances as charge builds up – especially in dry air conditions. This issue can be dealt with by adding anti-static materials to the liner, which are effective over a wide humidity range.

Operators also need to consider the relationship between a cable's outside diameter and the duct's internal diameter. The internal diameter should not be too wide - otherwise the cable will buckle if the push force is too high. Fortunately, cable buckling can be mitigated by a cable design with sufficient stiffness to push. In most cases for pushable fiber the cable diameter should be at least 50% of the inside duct diameter. >>

Insight

One key factor restricting the speed and distance of fiber cable installation into duct is the friction between the duct's inner surface and the cable.

▼ A dry, low-friction duct liner surface with added anti-static materials should be used for pushable fiber implementations.

On the other hand, the cable should not fit too tightly into the duct. For small ducts, the diameter of the duct should be at least a millimeter wider than the cable. When a duct is bent due to the nature of the route, the "equator" of the duct gets larger but the north-south axis gets smaller. In essence, the shape of the duct becomes elliptical. There should be sufficient space between the duct and the cable to compensate for this - otherwise the cable will get jammed in the duct. In the real world this means limiting the cable diameter to between 50% and 70% of the duct inside diameter. >>

Push forces

Most optical fiber cables can be pushed to a limited extent. However, compressive forces quickly build up the further the cable is pushed. After a modest distance (depending on cable and duct properties) the force required to push increases rapidly so that further pushing is effectively impossible and the cable becomes "locked" in the duct.

Bends in an installation route are almost unavoidable and will affect the distance a cable is able to be pushed. This is because a bend magnifies the resistance of the cable in the duct. Since the installation force is higher at the end of the route, the result of the magnification is worse at the route end.

However, these factors can be addressed fairly easily. Operators don't need to worry about cable "lock-in" so long as they are pushing a cable down a route that doesn't exceed 100 meters and are using a suitable cable that marries stiffness and flexibility.

Insight

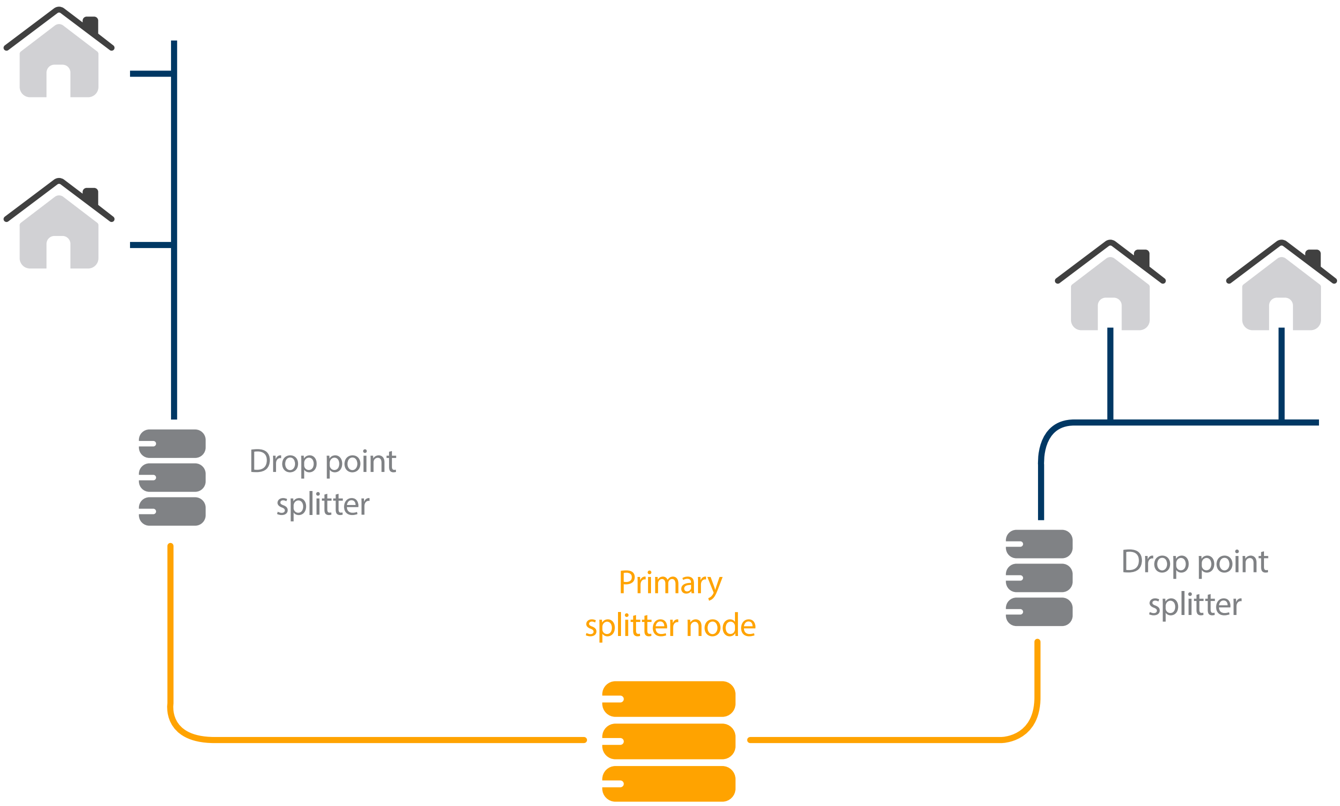
The build-up of compression forces limit the distance a cable can be pushed.

▼ Operators can maximise the route distance by using a cable that marries stiffness and flexibility and the ideal-sized duct that has a low friction, static-resistant liner.

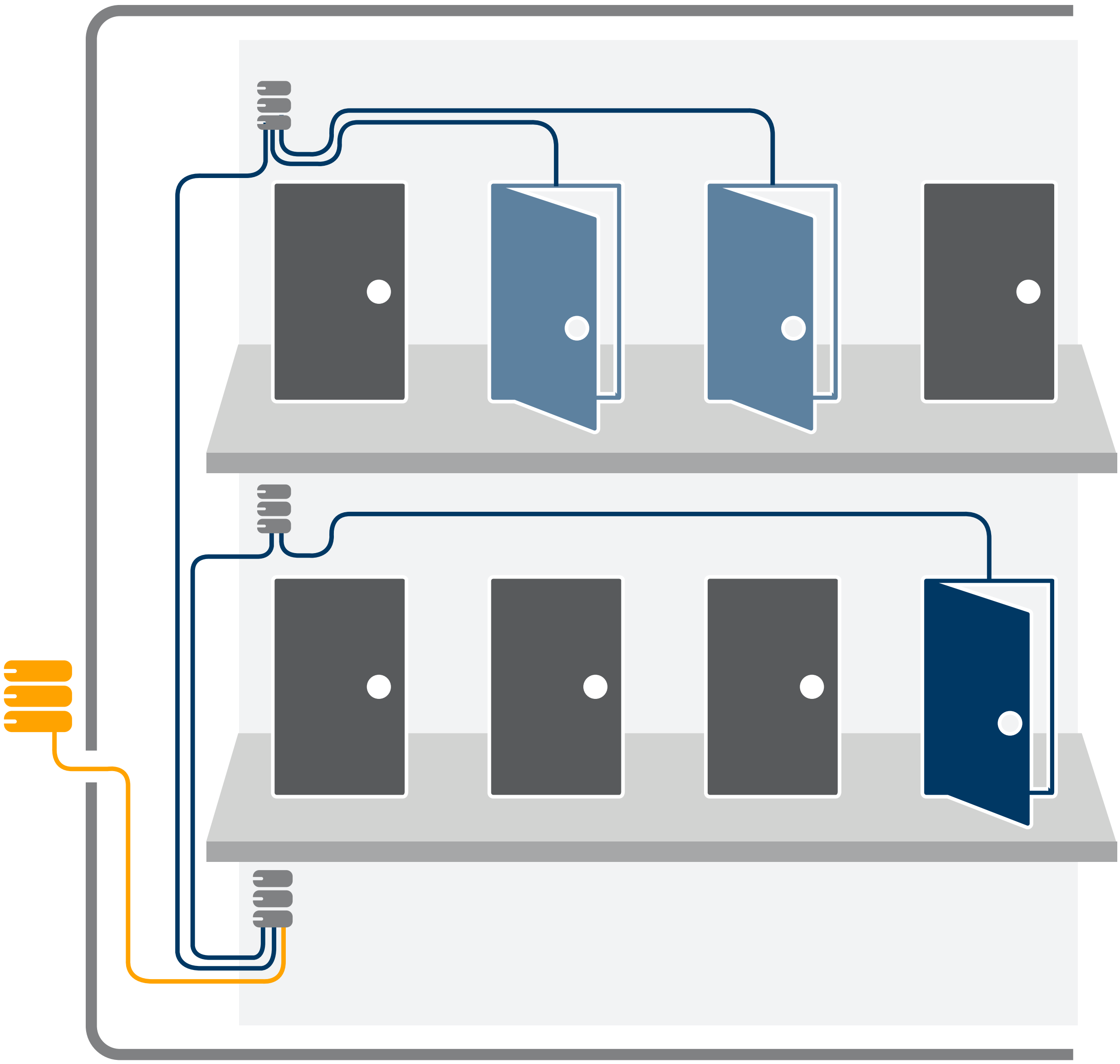
How is Pushable Fiber Used?

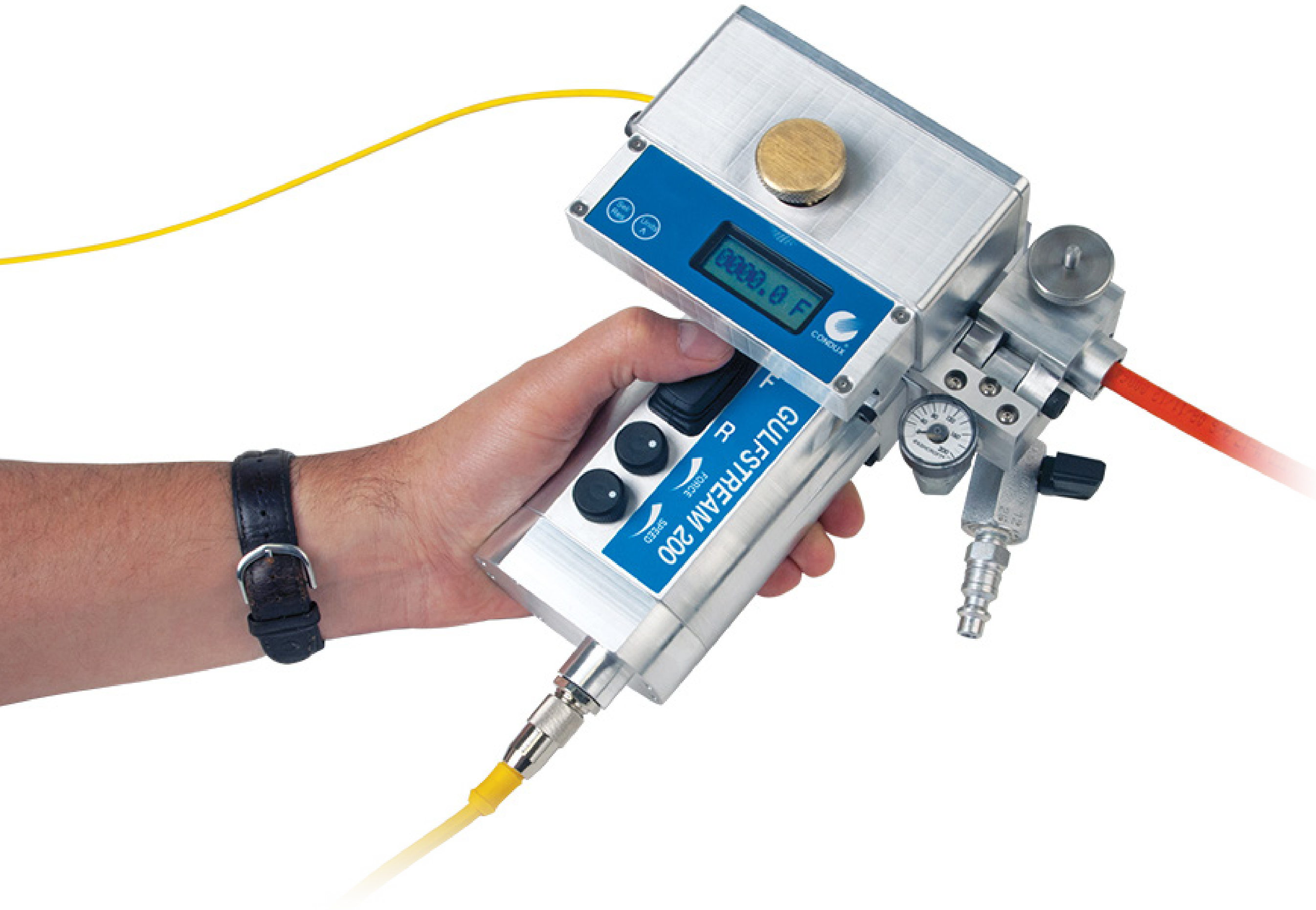
Pushable fiber can be installed to, and within, practically any kind of premise. There are only a couple of factors that restrict its usage. Operators are limited by fiber count – pushable fiber can, typically, accommodate only up to 24 fibers; by duct diameter - at time of writing, pushable fiber is limited to a duct bore of around 6mm, but new, smaller duct-compatible cables are anticipated; and by route length – without the addition of air assistance, fiber won't push more than 150m.

During outside plant installations, due to the relatively low fiber counts achievable, pushable fiber is typically employed (in Passive Optical Networks) from the primary splitter node/fiber distribution hub to a drop point splitter and then from the drop point splitter the property itself. >>



Within buildings, such as mutliple dwelling units (MDUs) and commercial properties, low smoke zero halogen or Riser rated pushable fiber is typically used throughout a building optical network, from the centralized optical distribution boxes all the way through and into individual apartments, offices, or other users. >>





There are two ways in which pushable fiber can be deployed in the field: pushed by hand or by machine. Obviously, hand pushing has the advantage of requiring minimal capital investment. However, the technique only works effectively over shorter distances. The further the cable has to be hand pushed, the greater the resistance to movement and the more laborious the process.

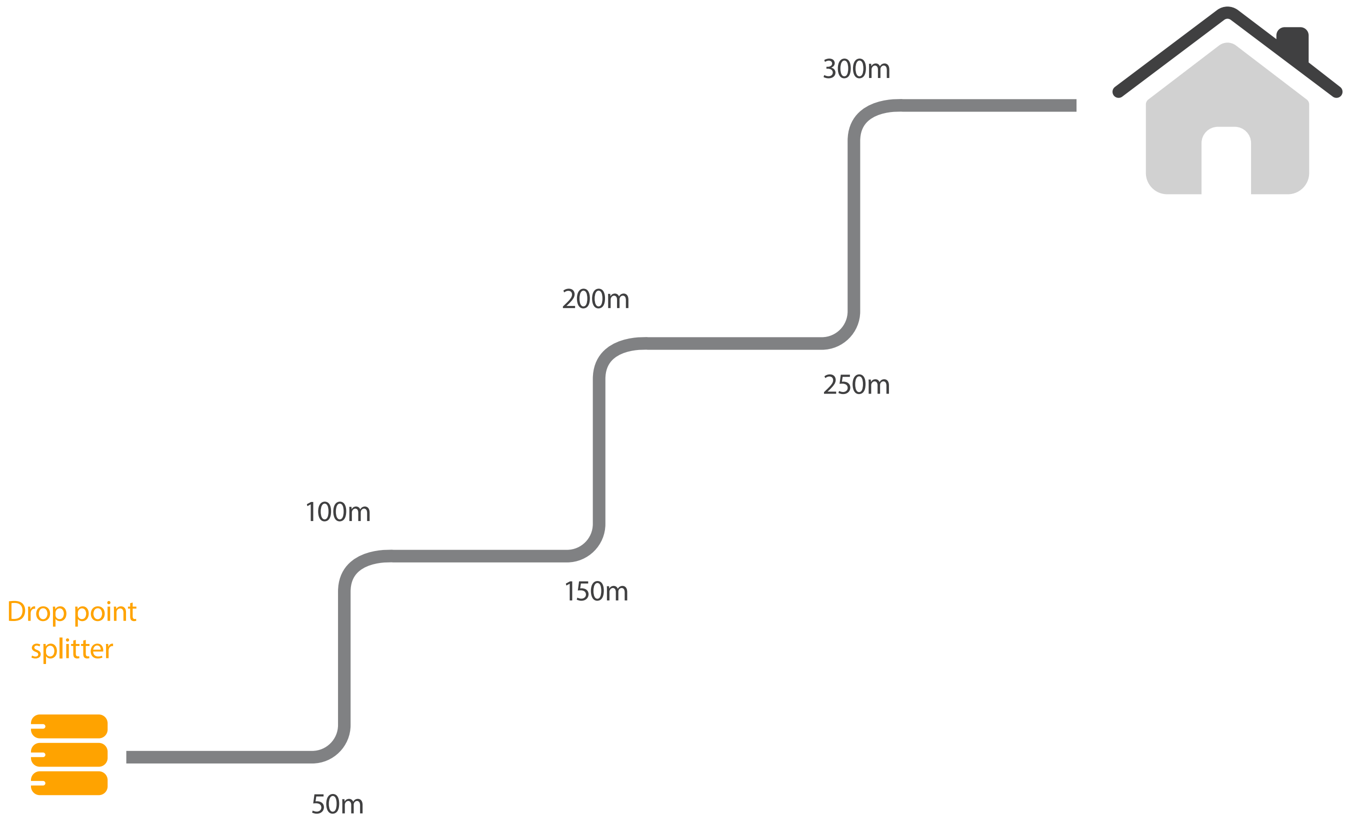
Handheld machines are available from international manufacturers. They typically accept cables from 2 to 6mm in diameter and ducts from 3 to 10mm in diameter. The units use a belt or driven wheels to propel the cable into the duct with adjustable torque to prevent buckling and a speed control for precision. Self-contained units with a built-in motor are preferable, but units that are driven by an external electric tool can be used. For convenience and safety, battery-driven devices are recommended (usually a 12 or 14V rechargeable unit). Machine-supported installations are, in most cases, much quicker than hand push installs. >>

The distance achievable by pushing alone depends on a number of factors:

- The diameter of both the cable and the inside of the duct
- The weight of the cable
- The cable's stiffness and inherent "undulations"
- The coefficient of friction between the cable and the duct
- Bending degree: how many bends, their severity (radius) and extent (degrees of bending), as well as their location
- Finally, the equipment used (if any) is key since each type will be able to exert a different degree of push force

Field experience in over 50,000 installations, coupled with theoretical modelling on the following factors, allows us to estimate maximum real world installation distances. Consider an installation scenario with the following components:

- A cable 8g/m in weight, with a 3mm diameter and a stiffness measure of 0.01 Nm2
- A duct with an inside diameter of 6mm
- A hand pushing machine with a 50N push force
- And a route with six 90 degree bends each with a 0.25m radius and located at 50, 100, 150, 200, 250 and 300 meters >>



Installation Lengths

With no air used, these are the installation lengths:

Cable type	PPC Miniflex cable	PPC Miniflex cable	Standard hard jacketed cable	Standard hard jacketed cable	Indoor cable (LFH)
Duct type	PPC DVC lined duct	Standard silicone based lined duct	Standard silicone based lined duct	Longitudinal grooved duct liner	Standard silicore lined duct
Maximum installation length (m)	150	120	100	100	70

If low pressure air of approximately 4-5 bar is used, a significant improvement is seen. Note that for higher friction combinations the addition of air causes less improvement. It is therefore important to use high quality cable and duct:

Cable type	PPC Miniflex cable	PPC Miniflex cable	Standard hard jacketed cable	Standard hard jacketed cable	Indoor cable (LFH)
Duct type	PPC DVC lined duct	Standard silicore lined duct	Standard silicore lined duct	Longitudinal grooved duct liner	Standard silicore lined duct
Maximum installation length (m)	1100	900	350	250	200

The coefficient of actual ducts and cables is shown below. It should be noted that friction determination is not an exact science - indeed, it is not a constant factor along the entire route:

Cable / duct	Friction Coefficient	Comment
PPC cable, optimised DVC lined duct.	0.05 – 0.10	Highest specification duct/ PPC Miniflex cable
PPC cable, standard silicone based lined duct	0.10 – 0.12	Same cable as above, but mainstream Siliconex duct
Regular duct and pushing specification cable	0.14 - 0.16	–
Regular duct, non-pushing regular cable	0.16 - 0.25	Mainstream fiber cable, mainstream Silicone duct
Indoor cable (LFH) and regular duct	0.30 - 0.60	With regular duct and liners, some indoor cables perform poorly

Effective machines include the Condux GS 200 (belt drive/own motor), Ultimaz (wheel drive, external, motor required), as well as machines from CBS.

Although handheld machines can be used by semi-skilled engineers, they must still be handled with care. If a handheld machine is accidentally set to maximum speed and torque, for example, it will damage the cable that is stored within it.

The Pushing Process

The precise process depends on which, if any, machine is selected but some common steps apply:

- Set up the machine by setting the clutch (if present) to the conditions specified by the manufacturer. This may involve a "crash" test to limit the torque to an acceptable level.
- If the duct that has been placed contains a pre-installed draw-string, it will need to be removed by simply pulling it out.
- Most machines have user-selected duct and cable inserts including O-rings. The inserts and O-rings appropriate to the duct and cable diameters respectively must be fitted to the pushing unit.
- If the pushing unit has its own motor, a rechargeable battery (typically 12-14V) should be fitted according to the supplier's instructions. If it is a non-motorised unit, a variable speed battery powered drill should be attached, ensuring the chuck has the correct geometry to attach to the free spindle in the machine.
- Where the duct exits the route it should be brought up to ground level since it is easier to conduct the pushing above ground rather than insider a chamber.
- The duct end should be cut perpendicular to the length of duct and this end should be fixed firmly in the duct insert according to the manufacturer's instructions.
- The cable then needs to be fed through the cable insert and seal, through the machine and fed a short way (a meter or so) into the duct.
- Most machines have a speed and distance counter which should be reset to zero.
- It is sensible to start the installation slowly, making sure there is no obstruction. If all proceeds well the installation speed can be ramped up to, typically, 50m/min.

Conclusion

Pushable fiber is the best option for the multiple short distance installations that make up the typical FTTP project. Unlike the alternatives on the market, pushable fiber can be implemented quickly and cost-effectively. No skilled labor or expensive equipment is required. Given that labor accounts for 80% of the cost of a typical FTTP implementation this is a huge advantage.

Hard, stiff but flexible, pushable fiber takes all the hassle out of last drop installations. When paired with low friction duct, fiber cable can be pushed in excess of 100 meters. With a hand-held machine and a bit of compressed air assistance, that distance can exceed 1000 meters.

With the demand for fiber connections to homes and business rising all the time and the inherent challenges operators face when trying to install those connections, pushable fiber's advantages make it ideal. Pushable fiber will likely play a leading role in the future development of the fiber optic industry.

About PPC

PPC is a global leader in connective technology with a worldwide reputation for technical leadership. We have developed many industry firsts including pushable fiber, universal crimp and compression connectors, continuity connectors, integrated weather sealing connectors, among our many innovations.

As a Belden brand, PPC also accesses Belden's powerful position within the signal transmission solutions space to offer a very unique end-to-end solution to its customers.

If you would like to discuss your FTTx challenge or any of the topics in this eBook, please contact us directly. We'd be delighted to hear from you.

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