Comcast Underground:

Innovative Fiber Deployments Over Existing Underground Critical Infrastructure

A Technical Paper prepared for SCTE by

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1. Abstract

London Underground or the 'Tube' began as a modest steam rail system over 150 years back and is now a sprawling transit system transporting over 5 million people daily. Similarly, Comcast began modestly but today has a large and growing optical footprint with fiber getting deeper into the network often leading to challenging underground fiber construction in the neighborhoods. Just as generations of Tube engineers innovated on their predecessors' plans deep underground and grew their rail network, Comcasters innovate on critical infrastructure built by our cable predecessors and provide higher capacity to match current demands and future needs.

In this paper, we report on the use of innovative technology that enables us to use existing underground critical infrastructure and make fiber deployments in the neighborhoods simple, cost effective and minimally customer impacting. Cable companies have been laying underground RF cables inside conduits, in vast sections of cable builds since the mid 1990s. This process, called Cable in Conduit (CiC) has a fraction of the conduit occupied by the RF cable with a contiguous empty space in the conduit. Recently, fiber manufacturers have come out with 'micro-fiber' cable that bundles of up to 72 optical fibers occupying a diameter of only a few millimeters. This new fiber cable bundle is supple, affords tight bend radius and has good tensile strength. With existing rod-rope-pull equipment this micro-fiber can now be deployed within the existing conduit alongside the RF Cable cost-effectively, quickly and with minimal impact on the customer experience, all without the need for trenching or boring.

The paper describes details of trial activities on CiC in one of our divisions and the economics of this technology. Skillful use of this technology and innovative optical systems being developed bring fiber to the last active, simplify other architectures such as Full Duplex (FDX), improve performance and capacity overall and help propel new optical architectures such as Switch on a Pole/Pedestal (SOAP). Since this technology provides large fiber counts at RF tap locations very close to our customers, it provides great long-term opportunities to span the last few meters and reach customer homes (FTTH) when needed.

2. Introduction

As the largest broadband company in the US, Comcast serves millions of customers and businesses coast to coast. All of this is the result of a large optical network that spans core, metro and access layers as illustrated below [1].

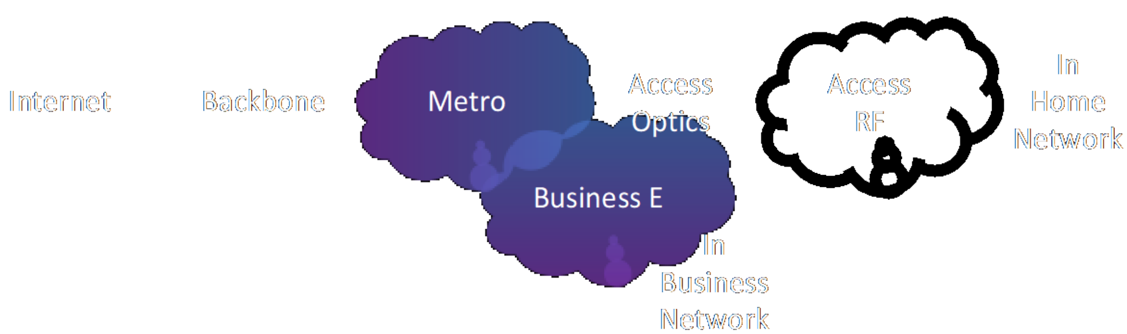

Figure 1 – Comcast Network at a Glance

While the Core and Metro layers are all-optical circuits interconnected by ROADMs fed by large routers, the access layer comprises hybrid fiber and coaxial (HFC) cable network, some fiber to the home (FTTH) all optical networks and wavelength specific all optical very high-speed commercial connections. While the HFC and FTTH networks serve primarily residential customers and small-medium business customers, the commercial optical networks primarily serve 1, 10 or 100Gbps commercial enterprises with Metro Ethernet and cell tower back haul and 5G front-mid and backhaul links. Very often the HFC, FTTH and Commercial services are carried in the same fiber sheath, and over time could share the same access fiber. Over the years, Comcast has innovated on its access plant and through node splits and network expansion, driven fiber deeper into the network. In this context Cable in Conduit could be a valuable additional tool assisting in the fiber journey.

3. What is CiC?

At this point, Comcast has an almost equal share of aerial and underground plant overall. Due to varied plant practices many regions out West have a predominantly underground plant while in the Northeast a predominantly aerial plant exists, although there is an admixture of underground (UG) and aerial (AR) per node across the country. When new fiber is deployed, AR plant can more easily be converted to fiber since the infrastructure of overlaying fiber over coax cable is fairly well known and there is a high degree of infrastructure reuse. Such is today not the case however when underground fiber has to be deployed. Deploying UG fiber is a cumbersome process that requires digging up the streets or front and back lawns and is generally much more time consuming and much more expensive than of AR fiber deployment.

While both AR and UG plant require permitting and traffic management the nature of AR permits are of weight studies of additional cables being strung, but of underground are much more complicated and time consuming due to the need of non-interference between cable, telephone, power and natural gas infrastructure that is also buried below ground.

And so, it would seem that if a solution could be found for reuse of UG cable infrastructure, both the cost of fiber deployment as well as the time of fiber deployment would come down significantly. Furthermore, if such a solution were easy to deploy and in use in some way, it would immensely aid in pushing fiber deeper and accelerate our fiber journey by providing an additional high-speed lane. Such is the case with a technique that Comcast has started using called Cable in Conduit (CiC) also called sometimes internally called fiber override in the neighborhood.

3.1. The Basics

In a large portion of the Comcast UG cable plant West of the Mississippi built after around 1985~1990, the RF cable was laid inside of a conduit, and the RF cable then surfaces to pedestals containing amplifiers and nodes, hence our name for this approach “Cable in Conduit” (CiC). While the prevalence of CiC is high in the West due to the already high UG plant there, there are areas in Central and the Northeast divisions that are also CiC based. But a fair amount of Cable plant and particularly some of the older plant across the country is what is directly buried (DB) several feet under the ground and the RF Cable surfaces to taps and pedestals. Accordingly, we have three types of plant AR, CiC and DB that together describe the total Comcast RF plant today.

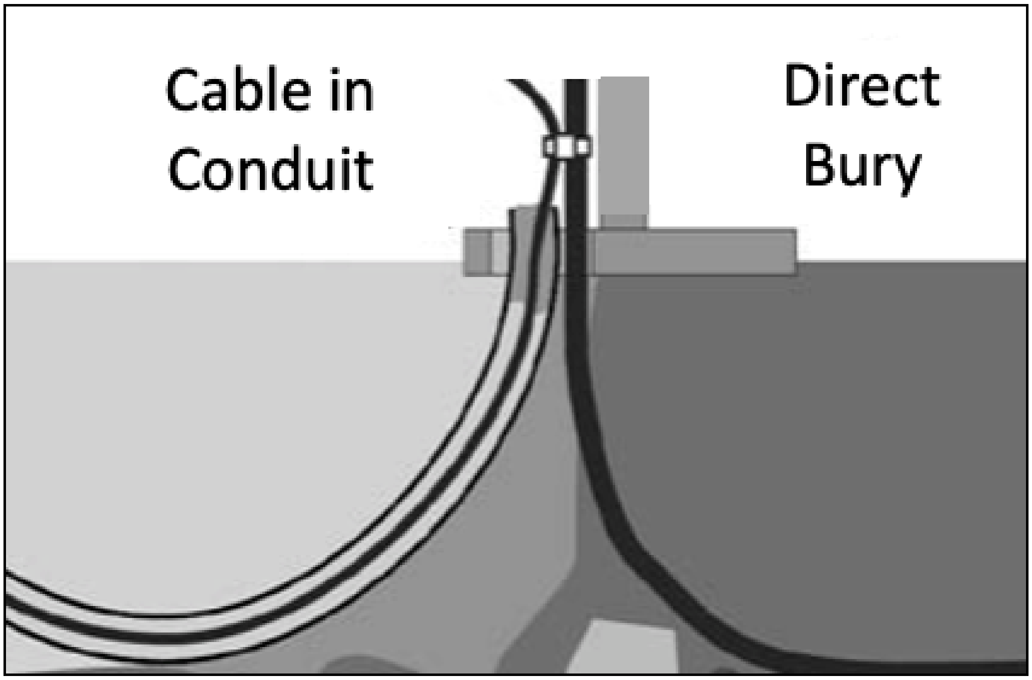

Figure 2 – Cable in Conduit and Direct Bury Cable [2] (Comcast)

The picture above illustrates CiC and DB underground plants. Here, we have shown DB as a larger hardline cable, while CiC a slimmer hardline cable contained within a conduit. With the above illustration, it is easy to see that the skinnier the cable and larger the conduit, the easier it might have been to sneak the cable into the conduit and surface it at required intervals to service pedestals that hold taps, amplifiers and passives.

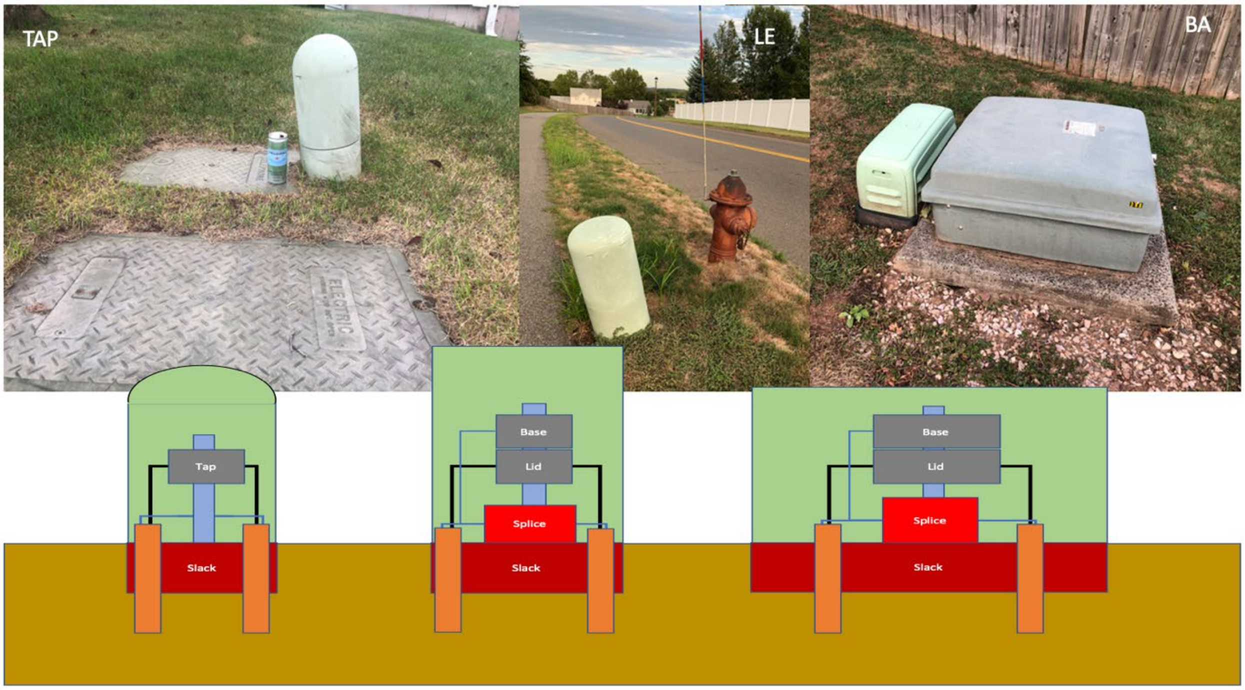

Figure 3 – Illustraing pedestals in the neighborhood

The picture above illustrates various pedestals and enclosures that interconnect RF cables. These are roughly about 100ft to 250ft in distance. The pedestal on the left is the tap enclosure typically in the front lawn of homes, a San Pellegrino can is shown next to it for an indication of its size. A handhole from the local telephone utility is show along-side it, sometimes Comcast itself may have handholes nearby as well. The middle pedestal is a bullet type enclosure that sometimes may contain RF amplifiers, a fire hydrant (in need of some paint work) is shown along-side of it for size comparison. The one on the right is a pedestal that might hold a node. In each case if CiC is the mode of deployment, the cable comes out of the conduit from each side and connected at two ends to appropriate devices.

3.1. Pervasiveness of CiC

In previous sections, how pervasive CiC could be in Comcast plant. To get a feel for it in real terms, we elected to check this out across the West division. We analyzed all the nodes in West and looked at their plant composition. This would include all hardline cabling in AR and UG plants, but NOT any of the drop cables. Drop cables connect homes to tap ports on the RF plant and are of varying lengths, but crucially these could be AR, DB or CiC.

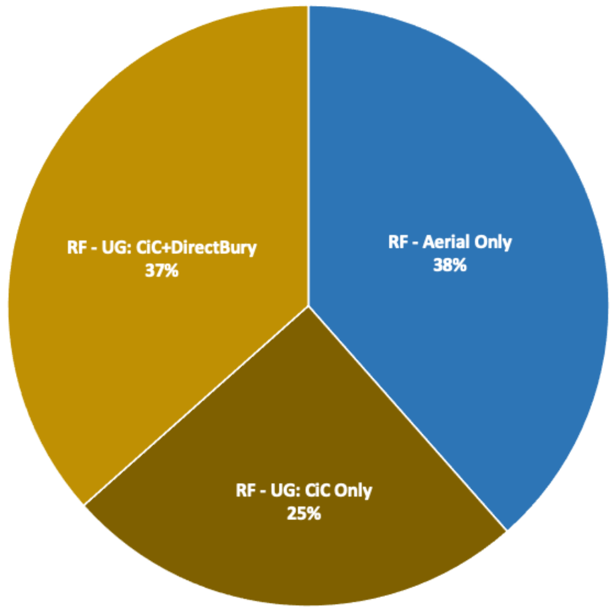

Figure 4 – Illustrating the West Division Plant Composition

Comcast plant is a conglomeration of many acquisitions over the years and the relentless growth fueled by node splits and plant extensions. While documentation of hardline fiber plant necessarily follows the original plant, plant extensions genarally follow modern guidelines. Presented above is the plant composition of the entire West division. One can see that the AR plant is only around 38% of the total while the remaining 62% of the plant in UG. Around 25% of the total plant is clearly marked as CiC, but 37% of the plant is a mixture of CiC and Direct Bury, with no easy way of demarcating the builds. This is somewhat an artefact of the aformentioned acquisitions that results is a loss of clarity.

Still the results are quite revealing. In general, labor costs for fiber construction dominate over the cost individual fiber costs. And UG fiber construction cost per foot is about 10 times the cost of AR construction. This is not surprising, as already mentioned, the labor cost of trenching and boring along with the more involved permitting and traffic control costs dominate over the more AR plant constrcution costs. So in that context, the total constrcution cost here could have been 0.38x + 0.62*10x = 6.58x. As will be show later, the CiC process brings down the cost of construction in UG plant by around 7 to 10 times less that current UG deployment and bringing the CiC costs closer to AR deployments. In this context, the total cost of construction would have been 0.38x + 0.25x + 0.37*10x = 4.33x. This is a 34% reduction in constrction cost overall ! For construction budgets running into billions of dollars and spread out over years, these types of savings are quite impressive.

We would also stress again the importance of the time to upgrade types savings - using an existing duct infrastructure as compared to new trenching/directional boring construction in underground areas, and would also note that reentering the existing duct requires fewer permits, less traffic control and less restoration to the areas resulting in lower downtime and better customer experience.

3.1. The Fiber Journey … Underground and in the Air

In previous papers [3,4] we have discussed that a move towards all fiber network across the country is a journey with multiple rest stops and not a single one-off event. And this is more so because of many interesting developments in technology that enable the industry to serve customer bandwidth needs without an exclusive move to all-fiber solutions at once. Recent 10G industry moves help unlock RF cable potential via efficient and bi-directional use of RF spectrum and are of critical importance to our customers.

A point to note here is that each extra step in driving fiber deeper towards the customer has a force multiplying effect. Driving fiber to a node (which is N+x or N+0) is easier than driving fiber to the last active (FTLA), which in turn is easier than driving fiber to the curb (FTTC), which is easier than driving fiber to the home (FTTH).

By way of clarification, while N+0 and FTLA both have no actives save the nodes in the plant, but a crucial difference between the two is that N+0 reimagines the RF plant and with optimum node placement and RF modifications achieves the elimination of actives. In the FTLA however, the entire RF plant remains as before including the node and amplifier locations. By connecting up he nodes and each amplifier via optical fibers, each of the amplifiers is upgraded to a node (or a mini-node) and serves the existing homes attached to the said amplifier. FTTC entails running fiber to the current tap location and terminating it in micro-nodes and using existing RF drop cables to home, whereas FTTH requires an all-fiber circuit to the home and terminating it in analog or digital customer premise equipment (CPE).

As mentioned before, Comcast plant is today AR and UG, so a move towards deeper fiber should accommodate both plant types, else the end result cannot be accomplished. So, there is a need to optimize UG construction so that the entire process of fiber deployment become simple cost effective and predictable.

4. CiC Prameters

In this section, we define some important parameters that explain the CiC and discuss the ways in which CiC is implemented. In the picture below, the orange ring represents the conduit. The black circle on the left indicates the RF cable ensconced in the conduit when the UG plant was laid out originally. One can see here that there is an empty space in the conduit not utilized by the RF cable that might be big enough to accommodate an extra cable comprising optical fibers.

For many years, on short sections of conduit, folks sometimes SST fiber bundles. These SSTs were rectangular shaped stiff fiber build that held just 12 fibers. The peculiar geometry of the bundle and very limited fiber counts made it difficult and less attractive to consider this for a wider deployment. Recently, there has been a slew of development in so called micro-fibers that enable up to 72 count fibers in a diameter of just ~4.5mm! The middle picture above shows how such a fiber would look relative to the RF Cable. To compare these micro-fibers to what is generally used in AR plant the armored cable has a 48 count fiber with a total diameter of ~11.7mm. As can be seen, the wider the conduit and smaller the cables, the easier it is to accommodate within the conduit.

Of course, Comcast plant changes from place to place, but for purposes of discussion, we have considered here a 0.625in Coax in 1-1/4 Conduit for a good portion of our analysis and trial. For these conditions, the conduit inner diameter is ~1.4in, while the Coax outer diameter is ~0.85in.

4.1. Linear and Area Fill Ratios

In the left picture, the ratio of RF cable outer diameter to the conduit inner diameter is called the linear fill ratio (LFR) while the ratio of the respective cross-sectional areas is the area fill ratio (AFR). In the above example, the LFR is ~61%, while the AFR is ~37%. What this means is that with the cable in the conduit, the conduit still has an empty space that can accommodate an appropriately small fiber cable inside of itself in addition to the existing RF cable. The smaller the LFR and AFR, the easier it is to get additional cables in. As the LFR and AFR grow, the accommodating space becomes smaller and friction and geometry start acting up and limit the addition of additional cables into the conduit.

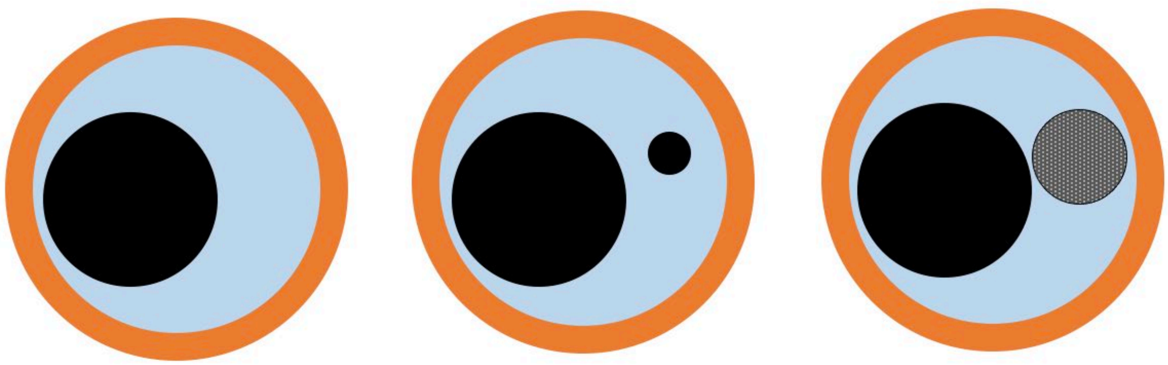

Figure 5 – Illustrating CiC Linear and Area Fill Ratios for various cables

Consider the right picture above, where we are looking the typical conduit trying to accommodate an RF Cable along with a ~11.7mm armored 48 count cable. The LFR here which is the sum of the two cable diameters relative to the conduit inner diameter is 94%, while the AFR which here is the ration of the sum of the cross-sectional areas of the two cables relative to the inner cross-sectional area of the conduit is 48%. So, while there is a bunch of space (52%) in the conduit, it is not possible to pull or push the armored cable thru the conduit while also the RF cable rides the same conduit. The friction of the two cables is too much, some of it with the conduit walls, others thru the RF Cable itself. If on the other hand, one considers a ~5mm micro cable, the LFR is 76% and the AFR is 39%, which is considerably better

4.1. Micro-Fiber Details

Recent developments in micro-fiber technology have enables CiC. Previously only SST fibers accomodating just 12 fibers were in use, today these cables can accomodate 72 or mode fibers. Typically these fibers have a core strength memebr in the midle and 6 tubes arranged around it. Each tube contains 12 SMF fibers. Therefore a typical micro-fiber can have upto 72 fibers. There are options that may provide more or less fibers depending upon the geometry and population of fibers in the cable. Many of the micro-fibers have a rip cords on the side that enable easier peeling of the cable to expose required fibers. The entire 72 fibers with 200um buffer along with all cabling has an outer diamter of just 4.5mm and is an impressive achievement. In case of the standard 250um buffer with all cladding requires a 5.5mm buffer. Both these fibers have a 200lbs/ft pull and crush strength. Another type of 72 count fiber cable with tensile and pull strength that rivals traditional 48 count armored cable at 600lbs/ft is now available with 9.1mm diameter as compared to the 11.7mm of the standard cable.

4.2. Fiber Strength and Micro-ducting

It should be easy to see from the above section that lower fill ratios help in CiC deployments, but in broad terms, the fibers are pulled thru the conduit. Such pulling of micro fibers could result in fiber breakage in which case it will reset the entire CiC process on a bad path since it will end up needing a large amount of fiber splices in tight spots and significantly increase deployment time. So to prevent that we select lower fill ratios, but also fibers which have a suffuenct pull or tensile strength. A fiber of 600lbs/ft of pull strength should be able to handle most of the pulling encountred in the CiC deployment. In addition to the pull strength, we will also need to have good crush strength. This crush strength is super important for AR deployment generally so that the fiber can handle the periodic wiring holds on the fiber. But crush strength is important even in CIC in case wher the CIC integrity is less than optimal or in case of tight bends and dents that might form over time. Typical crush strength ranges from 200 to 600 lbs/ft. The armored cable for example has a crush strength of 600lbs/ft, while the micro-fiber has a 200lbs/ft.

This is where the idea of micro-duct comes as an additional tool in simplifying CiC. Micro-ducts which are typically 8mm outer diameter and 6mm inner diameter are a bigger than the micro-fibers with LFR of 84% and AFR of 42% and with the same tensile strength as the micro-fiber. At first glance it appears to be not that great of a bargain in using micro-duct with its higher FRs without any consequent increase in tensile strength. But the main reason this is so useful is that the micro-duct does not have any fiber of its own, so pulling the micro-duct and having it break while inconvenient is not a show stopper. One could repair the micro-duct and continue one with micro duct deployment. For this reason, one can tolerate a higher FR in the case of a micro-duct. Once the duct is installed, the 4.5mm micro-fiber itself may be very easily blown in, this time without any extraordinary effort and risk of fiber breakage in installation. Incidentally, one could use the arrive at the FRs for a micro-fiber in a micro-duct which itself is inside a conduit with an RF cable in it already. These FRs for the micro-duct referred to above are an LFR of 75% and AFR of 56%.

Table 1 – Table of Basic Attributes and Ratios [5,6,7]

Construction Description	ID Conduit/ Duct (in)	OD 0.625 in RF Cable (in)	OD micro-fiber / micro-duct (in)	LFR micro-fiber / micro-duct	AFR micro-fiber / micro-duct	Pull Strength micro-fiber / micro-duct (lbs)	Crush Strength micro-fiber / micro-duct (lbs/in)	Bend Radius micro-fiber / micro-duct (in)	Weight micro-fiber / micro-duct (lbs/kft)
CiC Basic with just RF Cable	1.4	0.85		61%	37%				
+ 11.7mm 48ct armored fiber (for comparison only)	1.4	0.85	0.46	94%	48%	600	125	4.6	80
+ Rodder (for initial install support only)	1.4	0.85	0.38	88%	44%				
+ 8.5mm/6.0mm micro-duct	1.4	0.85	0.33	84%	42%	100	125	3.3	18
+ mXT 4.5mm 72ct micro-fiber in micro-duct						200	30	3.3	30
+ mXT 5.4mm 72ct micro-fiber in micro-duct						200	30	3.3	35
+ LMHD 9.1mm 72ct micro-fiber Only	1.4	0.85	0.36	86%	43%	600	125	5.0	44

Above, we have summarized several options (we thank Duraline, Corning and AFL) and FRs for each of the options, again the smaller the FRs, the better is the outcome for CiC. It is however critical to remember that there are many more conduits of various diameters and different micro-ducts and micro-fibers available and a table including many more possible combinations might be needed as we proceed more into CiC. Note here that although all the optical fibers illustrated here are from Corning, the are micro-fiber cables and micro-ducts could be from multiple manufacturers.

Although standard techniques exist for AR construction, the use of micro-fibers and micro-ducts can still be extended there if needs be. For starters, micro-fibers weigh a lot less than traditional armored fibers, so with sufficient strength micro-fibers, either by themselves or in micor-ducts these fibers may find spots in AR constrcution. We see from the above table that traditional armored cable suitable for AR lash might weigh ~80lbs/kft but an equivalent micro-fiber or micro-duct and micro-fiber combination might be just half of the equivalength weight. This reduced weight will also be useful while seeking permits for AR construction.

As an aside, 'squirrel chew' the issue of pesky rodents determined to sharpen their teeth is a well known issue in construction. The ability to deter rodents will be a prime consideration ! Armored cable has long been important for this effort, but so also the use of non-toxic bittering agents in the fiber cabling and micro-duct construction to deter squirrel chew would be helpful.

5. CiC in a Green Sandbox – The Control Trial

With the above understanding, Comcast and our partners decided to try CiC out in an outdoors trial location. Our microfiber partner Corning and micro-duct partner Duraline together elected to test out the CiC concept at the Corning Green Acres facility. Our many thanks to the partners and their dedication to see this work amongst the pandemic restrictions. This is an impressive outdoor underground plant laid out in a grid fashion over several acres. This facility has handholes with conduits connecting them up, and several of these conduits are the 1-1/4 sized. In addition, several of these conduits also have cables that are similar to the 0.625in RF Cable. As such a trial in this location could mimic Comcast plant.

Presented below is a grid diagram of the plant we had, on the left is the way we began with CiC on the first day, across 5 sections of plant of various lengths, the second day is represented by the middle picture where we installed CiC in 3 sections and on the third day we installed 2 sections with CiC. Each day we tested different concepts, and cumulatively we had tested our ability to install a single micro-fiber, two micro fibers and micro fiber installation in a micro-duct. At the same time important questions about slack, bend radius were answered, as we questions about the total thruput of CiC per day with a crew of 4 installers. All installations were manual installations, and towards the end of the trial, several mechanized versions of installations were discussed. These are described in detail next.

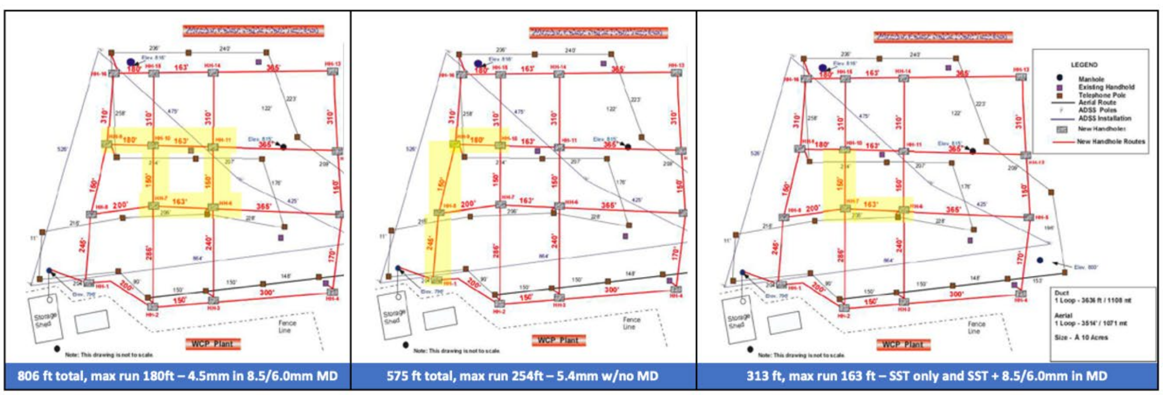

Figure 6 – Controlled trial: Day 1, 2 and 3

5.1. Basics of CiC Deployment

The basics of CiC deployment begin with selection of the RF Cable present and micro-fiber or micro-duct to be installed based on the FRs described earlier. Once that is done, a strong fiber glass "Rodder" of a diameter bigger than the micro-fiber or the micro-duct is inserted in the conduit. A nard bullet is affixed to the start of the rodder and is then pushed into the conduit until it surfaces at the other end of the conduit which may be 125 to 200 ft away. In doing so, the RF cable has been gently pushed aside and a continuous passageway has been opened inside the conduit.

At the surfaced end of the conduit, a cable pulling sock is attached to the rodder and the other end of the sock grabs on to the micro-duct or micro-fiber. The rodder is then pulled back the same way it went in, but at the other end, the micro-fiber or the micro-duct is then surfaced and thus the first phase of installation completed. This installation process is called the rod-and-rope method. During the many installations of the CiC, the Corning Green Acres trial clearly showed that re-entering the CIC using the rod-and-rope method was a viable solution.

Figure 7 – Illustraing the Rod-and-Rope process and blowing fiber into the installed micro-duct

The fiber or the duct is slacked and the next section is then begun. In practice one could go rather long distance fairly quickly if regular opportunity for surfacing the rodder are available. Notice that in this whole process, we never really had any reason to dig up the ground. Once the requisite length is reached, and if a micro-duct is used the fiber is simply blown in for the whole length, thus completing the process.

Figure 8 – Finished micro-fiber and micro-duct installed

The figure above shows the installed micro-fiber on the left and the installed micro-duct on the right.

5.2. Identified Challenges

In general, factors to consider for successful CiC include distance of the conduit system and the spacing between the handholes, the age of the system, condition of the conduit and blocks or damages, condition of the pedestal and space avaiable around, terrain of the build and its proneness to rocks, elevation and ice. While none of these on their won are showstoppers, it is wise to prepare countermeasures ahead of time.

Most of the rodders also have a tonal strip, one that enables the exact path of the rodder to be known from above ground using tone detection equipment. So if the rodder is stuck or unable to proceed further, the exact spot of may be dug up and the conduit unblocked and the procedure continued. This is a way to precisely dig up only a small spot and limit impact. In our trials and tests we did not encounter this specific obstacle.

5.1. The Power Touch vs. the Human Touch

With a crew of 4 we spanned around 1700 ft of CiC spread over 10 sections, yielding an average of 170ft/section although, there was a section that was 245ft long. Based on these we estimate that a 200ft of CiC could be spanned by a crew of 4 within 20-65 minutes depending upon specific challenges. Rodding could be accomplised between a minimum of 10 to 40 minutes depending upon the conduit, pulling back the fiber our duct could be between 5 to 20 minutes and creating a fiber slack before proceeding to the next rod-and-rope could be about 5 minutes and if a micro-duct was used, blowing the fiber into it would be less than 5 minutes, but this last process is done after the micro-duct is installed thru all the sections.

We note here that if fiber is to be taken out of the micro-fiber cable, appropriate splice enclosures that can handle splices and the associated slack must be considered. In addition a good fiber management strategy should be adopted, one where tube colors and individual fiber colors in the tubes must be used as identifiers. The time associated with that process is part of node/network commissioning and not included here.

With this in mind a 4700-5000 ft of CiC could potentially be installed in one day with an 8 member crew. This is an important observation as the regular plant for an average sized node is about a mile (or 5200ft), and if it were in a planned development then that node could be fiberized to FTTC within a day in ideal conditions. Note here that there is no disruption of services as the fiber installation procedure has no impact on RF and power signals running on the cables.

There are power tools that could help the rodding and pulling process and all such equipment along with the fiber blower could be accommodated on a standard pickup truck, thus improving mobility and alleviating traffic concerns.

6. The CiC Trial out West

A decision was made to take the learnings gained from controlled testing that already had occurred and deploy it in an existing network. The market in the Denver area and the home of Comcast West Division office was selected as a suitable location. This market was selected as it has had a planned community with continual growth each year over the last thirty plus years. An important factor in performing this trial in the real world is determining where CiC has been deployed if mapping information did not capture conduit usage.

6.1. Locating the Trial

We were able to check neighborhoods by age of houses and using local knowledge of when CiC began widespread usage. Although CiC had been introduced in the 1980's the adoption amongst the multiple MSOs that existed at that time varied. There were variations of adoptions within the geographic areas of MSOs as well that affect what areas can be targeted for fiber override of existing conduit. After a couple attempts, we found consistent CiC usage in neighborhoods built after the year 2000. We did not go further in this area to narrow down what year CiC became prevalent but that information can be useful for particular geographic areas.

6.2. Dividing the Trial

For the field trial we decided to expand slightly over the controlled trial and push the application to gain additional data. Three different approaches were taken that are shown in the two pictures below that would give us additional data.

Location #1 what we called the outside left was an express run which would push the distance between each pedestal. Our plan here was to use the microduct being placed by rod and rope technique to establish the path for a final blow in of fiber.

Location #1 down the middle met the spacing consistent with what had been done in the controlled trial but here we would use a micro fiber with traditional six hundred pound pull strength. For deployment we would use rod and rope technique with no conduit, directly pulling the fiber in over the existing conduit.

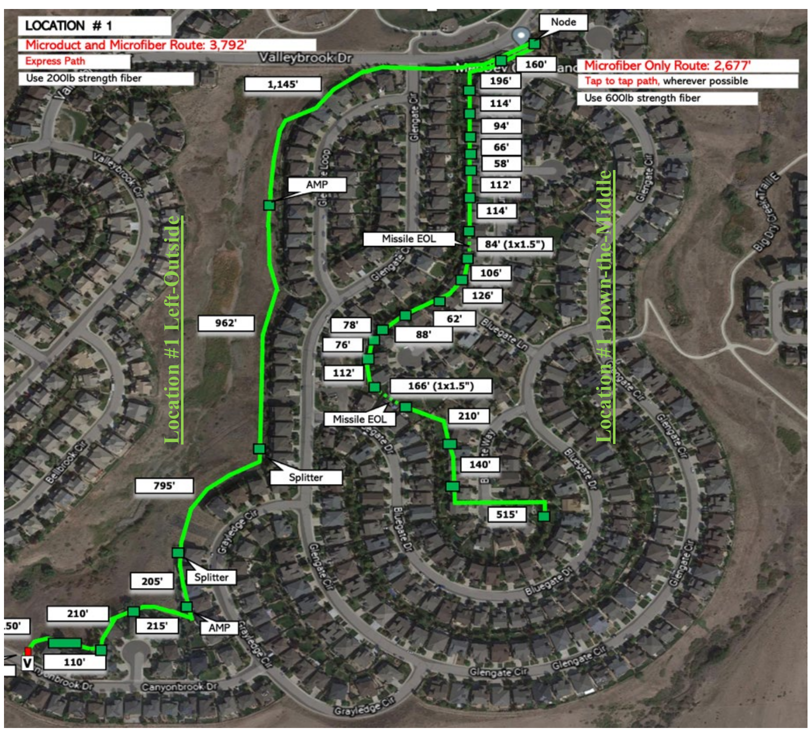

Figure 9 – Location #1 with "Left-Outside" and "Down-the-Middle"

Location #2 most fit what had been done in the controlled area and this was used to validate the lessons from the controlled trial. Pedestal distances were what we considered normal, the rod and rope technique was used to pull in micro duct to prepare for blowing in of fiber.

Figure 10 - Location #2 Real World Comcast trial matching the Control Trial

In each case, appropriate amounts of slack were rolled in into as part of construction. An important part of the trial was also the ability to identify fibers apart from RF cables. While this might look like a trivial part of the trial, getting this right is important to prevent needless fiber cuts by well-meaning techs out and about as they troubleshoot the RF plant. Some identification techniques work better than others and were incorporated in the builds.

Figure 11 – Location # 2 Left: Blowing of fiber, Right: Conduit spliced in ped for blowing continuity

Figure 12 – Location #1 down the middle direct pull of micro fiber with 600 pound pull strength

6.1. Trial Highlights

- No damaged conduit encountered in 7,924ft of CiC deployment
- Max length of conduit that can functionally be overridden is around 250ft (before rising above ground) this was determined in location #1 outside left. For distances longer than 250ft Rodder either became stuck or the micro-duct broke with too much pull force exerted on it
- 600-pound pull strength fiber is handled like BAU fiber today does not require any micro duct placement. We did experience scrapping of jacket making footage readings difficult from the jacket. Note that the 600-pound pull strength can be lashed in aerial plant like existing fiber (but this cable does not have armor)
- 200-pound pull strength fiber will require micro duct placement. Business Partners require additional skills and installation equipment not common to CATV construction. 200-pound pull strength cannot be placed aerially without micro duct, requires additional processes
- Both types of fiber cables can be successfully placed but must be operationalized for proper deployment
- Preliminary indications confirmed the significant reduction in cost indicated earlier relative to regular underground trench and bore in this location. Therefore cost savings can be substantial and time to deployment can be substantially decreased as well

6.2. Operational Considerations

- A new Statement of Work would likely be required to operationalize CiC across the footprint. This is because the amount of fiber that can be deployed and the speed of deployment are both different than for standard UG constrsuction. From a strategic point of view, a new SOW focusing on CiC would also reduce conflict of interests within the builder community and help focus on CiC when that is better or regular construction when that is the only option available

- If smaller pedestals are in delpoyment, the CiC construction process and slack preparation would be longer and potentially impact construction costs. At this trial we encountered a number of smaller pedestals and considered upgrading them along the way

- Storage length and placement in each pedestal needs to be specified and documented. Identification of fiber vs. Coax needs to be vividly documented. Appropriate training material for maintenance and fulfillment teams would need to be developed

The technique of CiC fiber override has been introduced within Comcast as an option for local construction groups to use. This does require them to work with their business partner (contractor) to ensure they are properly prepared to execute this technique with adequately trained staff. Fiber over ride is not a one size fits all but the trial has proven that this is a viable technique which becomes another arrow in the quiver for the construction crews to use.

6.3. Fiber Portfolio

In other papers in this conference, we have presented on Hollow Core Fibers [8], this is a new type of fiber that enables light to be guided in a hollow core as opposed to the standard light being guided in solid core fibers. As light travels much faster (300,000km/s) in air than in glass (200,000km/s), there is a fundamentally large reduction in latency. This helps in important latency sensitive applications such as high frequency trading and 5G. In this context, CiC could play a major role in helping roll out fiber in UG plant. Recall that most micro-fibers have 6 tubes within with 12 fibers each in each tube. In this case, one or more tubes could be dedicated to hollow core fibers while others are for standard fiber and a portfolio of fibers may be installed when the conduit is re-entered. This type of innovative deployments may help overall to bring fiber to the neighborhood where high-capacity latency sensitive endpoints may be located.

7. Conclusions

In this paper, we reported on the use of innovative technology that enables us to use existing underground critical infrastructure and make fiber deployments in the neighborhoods simple, cost effective and minimally customer impacting. With innovations in fiber cabling and availability of higher count fibers, the ability to reuse existing conduit infrastructure opens up quicker ways of deploying fiber, all without the need for trenching or boring. As our own trials show, skillful use of this technology when combined with innovative optical systems could bring fiber to the curb (FTTC) and support the industry’s 10G efforts and provide great long-term opportunities to span the last few meters and reach customer homes (FTTH) when needed.

Abbreviations

AFR	Area Fill Ratio
AR	Aerial
bps	bits per second
CiC	Cable in Conduit
DB	Direct Bury
FDX	Full Duplex
FEC	forward error correction
FTLA	Fiber to the Last Active
FTTC	Fiber to the Curb
FTTH	Fiber to the Home
HCF	Hollow core fiber
Hz	hertz
K	kelvin
LFR	Linear Fill Ratio
SCTE	Society of Cable Telecommunications Engineers
SOAP	Switch on a Pole
UG	Underground

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