Plugging In the Fiber Home

A Technical Paper prepared for SCTE/ISBE by

Mike Grice
CTO
All Systems Broadband
1791 Varsity Drive, Suite120
Raleigh, North Carolina 27606
919.809.8421
m.grice@go-asb.com

Greg Calton
Director of Marketing
All Systems Broadband
6567 Brisa Street
Livermore, California 94550
925-449-2740
g.calton@go-asb.com

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

Table of Contents

Title **Page Number**

Introduction 3

Fiber to the Home, and in the Home 3
1. Fiber Deeper in the Network 3
2. Background on FTTH Installations 4

Indoor and Desktop ONTs 5
3. Types of Indoor ONTs 5
4. Economics of Customer Self-Installs 7
5. Considerations of In-home Fiber Installations 9
6. Prequalification and Link Verification 11

Conclusion 12

Abbreviations 12

Bibliography & References 13

List of Figures

Title **Page Number**

Figure 1 - Migration of fiber deeper in the network 4

Figure 2 - Different Types of ONT Designs 6

List of Tables

Title **Page Number**

Table 1 - Standards for Home Networking 7

Table 2 - ONT Vendors 8

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

Introduction

Self-installation has become a popular method for consumers to connect their in-home services. In fact, Comcast claims on its website that well over 20 percent of all new connects are self-installations. Having the consumer place and connect their own set-top boxes and modems brings benefit to both the service provider and the customer. Among these is a significant reduction in “truck rolls” which saves the company money, while also having the added benefit of minimizing harmful greenhouse gas emissions. Comcast indicates that self-installs resulted in approximately 1 million fewer truck rolls in 2011. Undoubtedly that number is even higher today.

An increasing number of service providers are investigating bringing fiber not only to the premises, but are actually beginning to create service level agreements (SLAs) that call for fiber to be run “to the desktop” (FTTD) in residential applications. These business models look to promote consumer self installs of the Optical Network Terminal, or ONT. The ONT is the device within the home that performs the optical to electrical conversion, allowing the home’s connection to a service provider’s optical network, and also providing the necessary interface to home networking gear such as a router.

While the experience of Comcast would indicate that many consumers are comfortable with such a self-install arrangement, there are implications with a fiber-based model that differ from a customer install in a pure copper environment. This paper will investigate the emerging trend of fiber self-installs, and its implication on the physical fiber plant. Among the topics to be analyzed are:

a. A survey of the various technologies available to bring fiber to the desktop

b. Safety implications of laser

c. Economics of customer self-installs

d. Transition boxes and their role in providing slack storage as well as safe connectivity

e. Link verification: In-home versus remote

We will discuss two different general approaches to indoor Optical Network Terminals (ONTs) along with the practical considerations of each. Additionally we will describe some of the new installation challenges of bringing fiber into the home and some products that may be considered to address such an installation.

Fiber to the Home, and in the Home

1. Fiber Deeper in the Network

As operators seek to satisfy the need for increased bandwidth, lower latency, reduced maintenance cost, and higher reliability, fiber continues to move deeper into the access network. An increasing number of service providers have become comfortable with using Passive Optical Network (PON) deployments to satisfy this need. Thus, PONs are more common and can work well as an overlay to existing networks.

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

PON systems, as the name suggests, distributes bi-directional traffic without the need to support electrical power in the field. International standards have been developed which allow for various services to coexist over the same fiber by allocating bandwidth windows for each.

Although there are several attractive technologies to complete the pathway to the customer once the fiber has been terminated in the network, fiber to the home (FTTH) has been increasingly deployed over the last ten (10) years as a future-ready play. Figure 1 illustrates the historical progression of fiber deeper into the access network, with the next logical step bringing it all the way into the home itself (FITH).

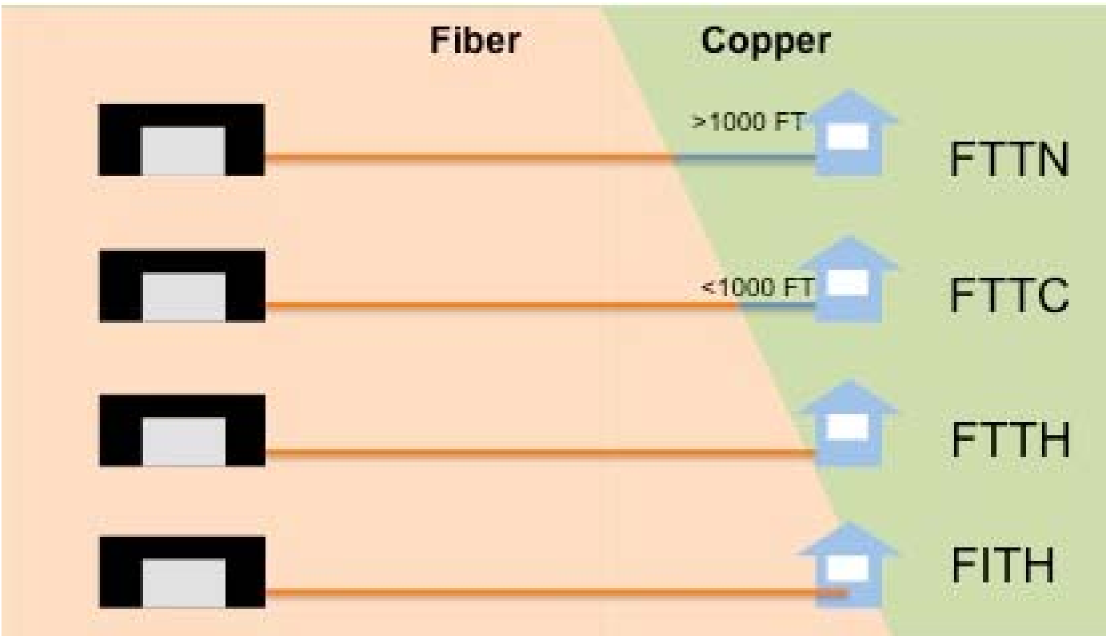

Figure 1 - Migration of fiber deeper in the network

2. Background on FTTH Installations

In the early years of FTTH deployments many issues were uncovered, resulting in the development of new products or techniques to meet these challenges. Today there are several technologies and approaches to help develop a deployment plan that yields acceptable return on investment (ROI). Some of the more notable developments have been the move to fibers that did not exhibit water peak issues, fibers that were less sensitive to bending losses, and new fiber connectors.

Traditionally, ONTs have been placed on the homes exterior and provide the same approach to service as does the network interface device (NID) used in classic copper telephony systems. Outdoor placement ensured that a service provider had access to the equipment whenever needed for troubleshooting and/or maintenance purposes. These early fiber systems were often more expensive than desired and therefore difficult to justify based on the ROI. . High costs were due to factors such as the need to use outdoor rated electrical components as well as the inefficiency of low volume manufacturing typical of a new product.

A study for the Fiber to the Home Council by CSMG indicates that FTTH cost reductions occurred as a result of three major factors:

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

1) Field efficiency improvements through improved procedures, training and innovative labor-saving methods.
2) Cost reductions of materials through increased purchase volumes and manufacturing efficiency
3) Fixed cost allocation across a larger number of passed households and subscribers

In a review of three separate carrier's FTTH deployment models, CSMG identified annual deployment cost reductions of anywhere between 6% and 10% over multi-year periods.

One possibly significant cost saving in fiber access which has not yet been widely explored nor utilized is the ability to allow customers to self-install their fiber-based service if they are at a location where such services had previously been provisioned. The stipulation that previous service to a home is required to ensure that fiber is inside the premises and either already active, or can be remotely activated. Today there are several manufacturers that produce an indoor ONT that is suitable to be considered for use in just such a customer self-install scenario.

Indoor and Desktop ONTs

3. Types of Indoor ONTs

Indoor ONTs are available in different designs from several manufacturers. Units can be found that support the various protocols defined in the international standards. Two categories of design, as illustrated in Figure 2, create different installation and use models:

Model A – ONT with standalone gateway/router.

This unit utilizes a jack inside of the home, which contains a powered interface for optical-to-electrical conversion. The gateway/router is connected to the ONT using Cat5 or similar cable.

Model B – ONT with integrated gateway/router

This unit is fiber-fed inside the home for inbound signal. The single unit contains all functional parts needed to activate a customer. The entire unit must be plugged into a power source to achieve the necessary optical to electrical conversion.

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

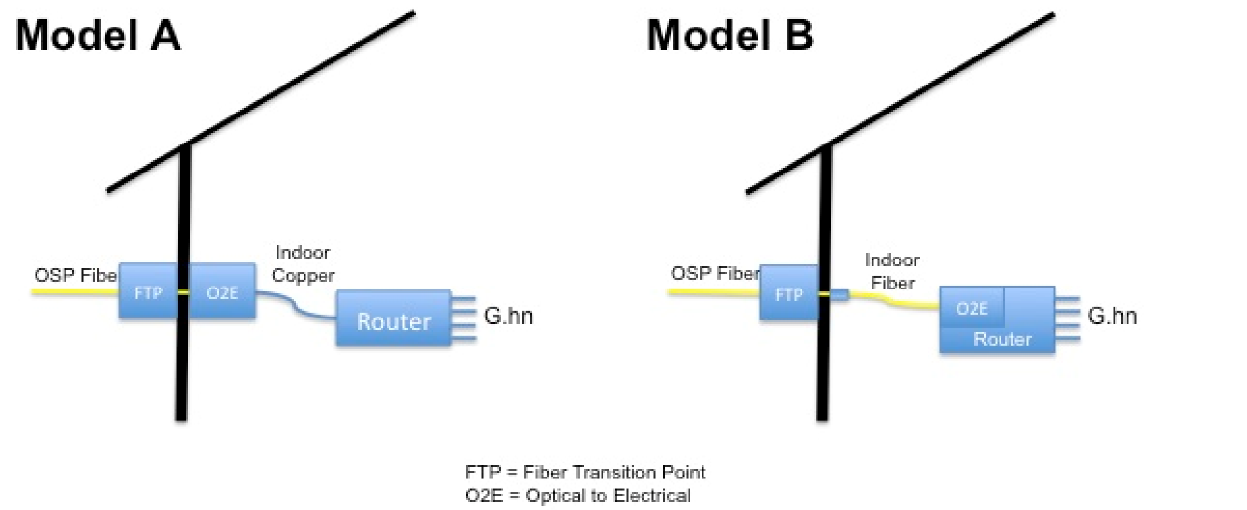

Figure 2 - Different Types of ONT Designs

Both consumer self-install models lend themselves to the familiar approach used today with cable modems. By placing the unit indoors, outdoor-rated components as well as additional weather hardened closures are not necessary.

Note that in both models a fiber transition point (FTP) exists which facilitates the interface between outdoor "drop" fiber and indoor fiber.

In today's cable modem deployment model, when considering equipment placement within the home, service providers must consider each of the following parameters:

1. Best placement in the home to ensure good wireless coverage for integrated router/wifi functionality
2. Best placement for ease of first installation reducing overall craft time spent at a location
3. Best placement for connectivity to all of the components that comprise a customer's in-home network

Likewise, fiber customer self-installs must answer each of these same parameters

Once installed, in addition to WiFi, operators may leverage different in-home networking protocols that are best summarized in the ITU G.hn recommendation. This protocol defines rates up to 1 Gb/s over existing types of in-home legacy wires. Additional home networking and other standards, which may need to be considered when building a fiber in the home solution, are outlined in Table 1.

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

Table 1 - Standards for Home Networking

Standard	Pertains to:
G.HN	Twisted Pair
MOCA 2.0	Coaxial Cable
HomePlug AV	Power Line
TIA 570B	Residential Fiber & Copper
National Electrical Code	Wiring Safety
Underwriters Laboratory	Product Safety

4. Economics of Customer Self-Installs

The decision to place the ONT inside of the home is primarily driven by economics. Many of the same costs that apply to the cable modem in today's environment would also extend to an ONT. These would include cost of the equipment itself, costs to install and/or qualify drops into the home, etc.

In order for a consumer self-install model to be successful, the equipment needs to be easily identifiable in the home and simple enough to install by untrained customers. Fortunately an ever-growing number of consumers are moving along a self-education curve and are becoming more comfortable with installation and use of well-designed, intuitive electronic products.

ONT equipment that aligns with either of the two basic model types described earlier in this paper make it possible to create a customer self-install model. The two models have several cost saving advantages in common. Both allow for either all or a portion of the deployed ONT to be returned to the service provider when no longer needed due to service termination. This returned equipment then becomes available for re-deployment to the next new subscriber. All of these units are fairly lightweight and compact, allowing the use of efficient parcel service for customer delivery and returns. ONTs specifically designed for the self-install model are available from several different manufacturers. Table 2 lists many of the vendors currently manufacturing indoor ONTs. Those that appear to be built with a customer self-install are noted with an asterisk.

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

Table 2 - ONT Vendors

Manufacturer	Product Name
Adtran	Total Access Series
Alcatel Lucent	7368 ISAM ONT
Calix	Gigapoint
Commscope	CS-9004A, CS9014A
D-Link	DPN-510
Dasan Networks USA	H680GW, H640SFP, H670GR
Genexis	Fibertwist*, Hybrid*
Huawei	HG8240, MA5671A
Pacific Broadband Networks	PM520, PM120, CE120
Sumitomo Electric Lightwave	FTE6083
Tellabs	705GR, 709GP
Tilgin	MSA970*, MSA974/975, MSA980*
Zhone Technologies	Multiple

Although models A and B have many features in common, there is one key difference in how they are installed in a customer's home and utilized over time.

Model A, in which the optical to electrical conversion is installed permanently in the home, has the advantage of not having a consumer challenged with making an optical connection. In this model the connectivity link that must be customer-installed is made with the more familiar and robust Cat5 or similar cable. One product noted in the market that fits in this model has a detachable base that stays permanently fixed to the consumer's wall, while only the router module is attached to this base by the customer during a self-install. The downside of this model is that not all equipment is recovered during customer churn. It may also require tying in a jack that has both optical and electrical connectivity requirements.

For Model B, the value proposition described above for Model A is basically reversed. All CPE can be transferred from one active customer to the next, but the connectivity link presented to the customer is an optical link. Such an approach can present some challenges based on the products currently available in today's market.

It should be remembered that a major difference exists between the cable modem consumer install model used by MSOs such as Comcast today versus a subscriber fiber install. This difference is that most

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

modern homes already have the physical infrastructure (usually coax) necessary to connect a cable modem and/or set top box. This makes it easy for the cable operator to simply supply the consumer the equipment and instructions to perform the installation, and the support to help troubleshoot remotely should it be necessary. Conversely, almost all North American homes do not already have fiber inside the structure, meaning the service provider must visit the home to establish the in-home fiber presence.

The service provider's costs to bring a fiber directly into the home can be assumed to be a slight incremental increase over the cost to run a fiber drop to the outside of the home today. A study by CSMG several years ago looked at the costs to provide a fiber drop to the outside of a home. Their analysis looked at actual deployments of FTTH providers including Verizon, Jaguar Communications, and Hiawatha Broadband. Estimated costs for a fiber drop ranged from $650 - $750, with roughly half of this being the cost of the ONT ($330).

It is reasonable to assume that costs will be higher to bring fiber into the home than they are to merely place it on the side of the home. Incremental costs to bring a fiber drop into the home are estimated as follows:

	Model A	**Model B**
Materials		
FTP	$ 23.00	$ 23.00
ONT	$ 330.00	N/A
Indoor Fiber	$ 9.00	$ 9.00
Labor	$ 120.00	$ 70.00
Total	**$ 482.00**	**$ 102.00**

Note that an ONT is not included in the cost of providing a drop for Model B since the consumer will install this when they are ready to turn up service. Likewise, labor costs of Model A are slightly higher to account for the added costs of placing the ONT inside the home at the time the drop is installed.

Once the fiber drop has been placed inside the home, since the drop itself is "passive," it should be usable throughout the churn that occurs in most dwellings. Over time, technology change outs of the ONT may be necessary from time to time.

5. Considerations of In-home Fiber Installations

In the case of deploying an ONT several considerations must be taken into account:

i) Type of fiber used to reach the home and the type used inside the home

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

ii) Transitioning between the outdoor and indoor fiber and penetrating the home
iii) Indoor fiber routing and concealment
iv) Safety concerns and user perception about optical laser light inside of the home

Types of Fiber

Fiber selection is a significant consideration and will drive some of the supporting products needed to complete a successful installation. For the outside approach to the home, several drop style optical cables have been developed that can be successfully used in either a buried or aerial approach. These style of cables are typically robust in their construction which leads to fairly large coiling requirements should the need to store cable overlength arise. Overlength storage for outside drops typically arises when a pre-connectorized drop is used. This method was introduced over a decade ago and has the appeal of being a plug-n-play architecture in which the drop extends from optical terminals that may be placed in the access network for making that link from the street to a subscriber's home. Alternatively a solution may be to work with cut-to-length segments of drop cable and make the connection to the inside fiber using a field termination method. Today there are more products than ever that can be chosen for this connection point. They include both fusion and mechanical splices along with fusion and mechanical field-installable connectors.

Outdoor to Indoor Transition

For maximum flexibility the fiber transition point (FTP) into the home may need to include the possibility of addressing not just one, but all of these different methods. For example, although first installations may occur with pre-terminated drop cable, follow up work might convert the installation to a spliced option during a repair. The FTP will need to have the capability to store excess fiber, such as that which would exist when standard-length drop cables are used. The fiber transition point also needs to be sensitive to space and appearance on a customer's home and allow for easy mounting to a wide array of home finishing surfaces. Ideally the FTP will allow for varying methods to safely enter the home such as out the back surface of the enclosure or through a port.

In all cases the indoor fiber will need to be small and more discreet when compared to the ruggedness of an outdoor rated fiber drop. Fortunately there are several fiber types that have been developed for in-home routing to meet these needs. Almost all of the modern indoor fiber types are small, flexible, and more robust. This is largely due to enhanced capabilities to manufacture bend insensitive fibers in recent years. These fibers, initially introduced in 2007, have steadily improved as more has been learned about the manufacturing process.

Indoor Fiber Concealment

Selection of the indoor fiber will also drive many of the supporting products needed during the initial installation process. In order to reduce the time to install fiber to the desired location several techniques have been developed to conceal fiber routing on the wall surface instead of inside the wall. Some products feature the ability to be applied with concealing molding in an attempt to blend in with the architecture of the home. Another clever approach introduced in the last several years is to use a very small transparent fiber that can discreetly follow the seam line of either trim boards or at corners. These fibers are typically placed with adhesive or in very small tracks that have been placed on the wall.

Safety concerns and user perceptions

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

Once fiber routing is complete, an interface needs to be installed for the fiber connection point (FCP) that a consumer will use to connect the CPE during a self-installation. In its simplest form, this is a wall jack that needs to provide certain capabilities. It needs to be clearly distinguishable from other type of wall jacks and connections. It also represents a good opportunity for product or company branding. This jack is where the concern over customer safety from laser light is presented. It must be remembered that the devices used in PON equipment are Class 1 lasers, which are considered safe by the medical community. Still, minimizing the risk of exposure, and thus easing consumer fears, makes sense.

From a pragmatic sense, the amount of optical power in a PON network would be at its lowest, and therefore safest, levels inside of the home. Still, the design of this interface should include blocking the possibility of someone looking directly at the end point of the fiber interface. Similarly the connection must also provide protection from both dust and contact with objects other than the intended connector. There are a growing number of products used as connection points that feature "shuttered adapters" designed to address these issues. Of course, the ONT that will be placed in the home also transmits a laser signal upstream, back to the Optical Line Terminal (OLT) located in a node or head end. This factor will primarily present a concern in those applications where the consumer actually handles the ONT, as represented in our Model B. ONT manufacturers must address this concern as part of their products design.

When looking at the challenges presented in creating this optical link between this FCP and the CPE, it becomes obvious that the existing fiber connector standards we have in place today are insufficient for this application. While there are proven connectivity methods, they are designed for use by industry professionals and contain sensitivities that require training for their use. So, much in the same way that the need for hardened fiber optic Connectors (HFOC) and adapters (HFOA) arose from fiber to the home deployments, we believe a new standard for fiber in the home deployments needs to be developed. With plenty of work occurring in this space today, there are some companies that have proposed various proprietary designs for this link. These early efforts will likely lead to an eventual connector standard for the FCP.

6. Prequalification and Link Verification

The last significant concern to be addressed is how to remotely verify that optical light is present at the home jack in those cases where fiber in the home services had previously been deployed. This is where Model A deployments will have a distinct advantage. Since the optical to electrical conversion portion of the CPE is left installed when a subscriber moves away, the fibers endpoint will be active and easy to identify from a remote location.

Perhaps the most prevalent example of fiber in the home today are the Google Fiber deployments. They demonstrate a simple and productive approach to link verification and service turn-up. Their approach to the market follows Model A. The optical to electrical conversion takes place in a device they refer to as a "Fiber Jack." This device, essentially an ONT, is installed on a home's interior wall adjacent to a power outlet. This work is performed by a Google technician prior to service turn up. To activate fiber service, the consumer plugs the Fiber Jack into the power outlet. The ONT then verifies and establishes a fiber connection back to Google's head end using a pre-mapped scheme. When the connection is established, the "Fiber Jack" ONT illuminates a blue light that glows on its faceplate. Once this is complete, the consumer then connects Google's "Network Box" – essentially a router with several RJ45 ports as well as Wi-Fi capability to the Fiber Jack using an Ethernet cable. Other than plugging in the power connection

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

of the Fiber Jack, the entire process closely matches the cable modem model already in widespread use by cable companies.

Model B style installations, on the other hand, have a "passive" endpoint and therefore the fiber connection is more difficult to remotely verify. This is another key area where new solutions are being explored to find a practical, inexpensive solution.

Today, loopback products provide one way to detect the end of a fiber run. However, fiber assurance is typically set using a policy of not reallocating fiber links to other homes after a service disconnect. The downside to this approach, of course, is less than optimal efficiency of the optical line terminal (OLT) used in PON architectures. That subject, however, is beyond the scope of this paper.

Conclusion

In order to achieve the new levels of services required to remain competitive, service providers are taking fiber optics deeper into the access network than ever before. In fact, as demonstrated by Google Fiber and others, fiber into the home is rapidly moving towards reality. This significant expansion toward the customer presents opportunity to build new service level agreements along with the new products that are needed for them. New products and techniques will serve to cost-effectively create efficient, and repeatable, installation models. The technology in fiber optics continues to improve and align well with reaching all the way inside of the consumers home.

By building on the currently established cable modem and set top box self-install models, both the service provider and the end-user will realize benefits. Once a service provider is past the initial costs of bringing fiber into the home, the advantages of in-home optical CPE are significant. New products, such as Fiber Transition Points, customer-installable indoor ONTs, complementary routers, will need to be more fully developed, and perhaps even standardized. Likewise, the procedures to use all of these elements need to be more fully developed to optimize the business case for widely deployed fiber in the home.

Abbreviations

CPE	Customer Premise Equipment
FCP	Fiber Connection Point
FITH	Fiber in the Home
FTP	Fiber Transition Point
FTTC	Fiber to the Curb
FTTD	Fiber to the Desktop
FTTH	Fiber to the Home
ITU	International Telecommunication Union
NID	Network Interface Device
ONS	Open Network Summit
ONT	Optical Network Terminal
PON	Passive Optical Network
RF	Radio Frequency
SLA	Service Level Agreement

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.

Bibliography & References

Ben-Tovim, Erez (February 2014). "ITU G.hn - Broadband Home Networking". In Berger, Lars T.; Schwager, Andreas; Pagani, Pascal; Schneider, Daniel M. *MIMO Power Line Communications: Narrow and Broadband Standards, EMC, and Advanced Processing*. Devices, Circuits, and Systems. CRC Press. ISBN 9781466557529.

ONSproject.org White Paper, Central Offices Re-architected as Datacenter – CORD, June 3, 2015

GR-3120, Generic Requirements for Hardened Fiber Optic Connectors (HFOCs) and Hardened Fiber Optic Adapters (HOFAs), Telcordia.

FTTH Deployment Assessment – CSMG (for the FTTH Council), October 13, 2009

Malik, Om Gigaom.com How much will Google's Fiber Network Cost? February 11, 2010

Lunden, Ingrid TechCrunch.com Analyst: Google Will Spend $84M Building Out KC's Fiber Network to 149K Homes; $11B If It Went Nationwide April, 8, 2013

© 2016 Society of Cable Telecommunications Engineers, Inc. All rights reserved.