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OVERVIEW

In order to support new services such as broadband Internet access, cable TV and telephone operators have been deploying fiber optic networks closer and closer to the subscriber. Fiber advocates conclude that the logical result of this evolution is to install fiber all the way to the customer premises – to businesses and homes. Fiber to the Home can be considered to be the “Holy Grail” of residential access networks .

FTTH networks differ from past residential telecommunications infrastructure such as the telephone and the cable TV networks. Those networks were built to support specific applications - telephone service and cable television. Nowadays, cable modem and DSL technologies are used to adapt these existing networks to provide broadband Internet access.

In contrast, FTTH is designed to be a full-service networking platform that supports a variety of communications and information services, including voice, video, and Internet access. FTTH is intended to be a flexible communications infrastructure that supports present as well as future services.

Why FTTH, Why Now?

Fiber-to-the-Home (FTTH) has become a reality. More than a million consumers.

now use direct fiber optic connections in the United States, more than 6 million in Japan, about 10 million worldwide.

FTTH is also widely recognized as the optimal solution for providing broadband to new and existing communities alike. In fact, hundreds of FTTH communities are flourishing here. Why? FTTH offers more bandwidth and more flexibility than alternatives, at a similar price. It cost \$84 billion for the cable companies to pass almost 100 million households a decade ago, with a technology that offers far less than FTTH in every respect – lower reliability, lower bandwidth. For the same \$850 a household – really less in today's dollars – the phone companies, public utilities, and even some cable companies have been installing future-proof fiber.

The basic technological and economic Based on the immense capacity of fiber – already the foundation of the world's telecommunications system – FTTH is now being deployed around the country and around the world. Almost all large developers are putting fiber in their new developments. Independent telcos are deploying it in rural America at an increasing rate. Municipalities in the U.S. and elsewhere are finding FTTH can be a feasible solution today that positions their communities for tomorrow's jobs and economic growth.

Wireless alternatives such as WiFi and WiMAX can't deliver HDTV – and in fact have trouble delivering standard-definition television. Variants of DSL, and even the latest cable and satellite links, can deliver HDTV only with difficulty, low reliability, and high operating costs. And that's today . What about the demands we see even five years down the road?

There's no problem for optical fiber In fact, one bundle of fiber cable not much thicker than a pencil can carry ALL of the world's current communications traffic.

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So why should there be any confusion? Different types of people have different things in mind when they talk about FTTH.

- Engineers talk about bandwidth, as if raw capacity to move bits and bytes of data is an end in itself.
- Consumers think about the products and services that bandwidth can provide NOW. They can't demand services they don't know about, or that have not been invented.

- Political leaders, corporate economists and academics often have a third view: Bandwidth as publicly available infrastructure, a utility that makes it easier for people to develop new products or start entirely new businesses.

Public infrastructure also makes private property more valuable. A house, for instance, is generally worth much more if it has access to a public street, water, and sewer services, public schools and other “utilities” than if it does not.

We want to communicate... The advantages of Fiber to the Home.

The Advantages of FTTH

This primer covers the key economic and technical issues surrounding fiber to the home. It explains why we believe you will agree that:

- FTTH – that is, Fiber to the Home – is the only technology that will deliver enough bandwidth, reliably and at a low enough cost, to meet the consumer demands of the next decade.
- FTTH is affordable now, which is why hundreds of companies using hundreds of different business cases worldwide are racing to install it in thousands of locations.
- FTTH is also the only technology that will meet the needs of the foreseeable future, when 3D, “holographic” high-definition television and games (products already in use in industry, and on the drawing boards at big consumer electronics firms) will be in everyday use. Think 20 to 30 Gigabits per second in a decade . Copper can’t do even 1/1000th of that bandwidth, and then not for more than a few hundred yards.
- FTTH will enable products that we have yet to conceive of, but that we are certain will become necessities for living well and working well in the decades ahead. Look what just the past few years has brought: Mobile video, iPods, HDTV, telemedicine , remote pet monitoring... and thousands of other products.

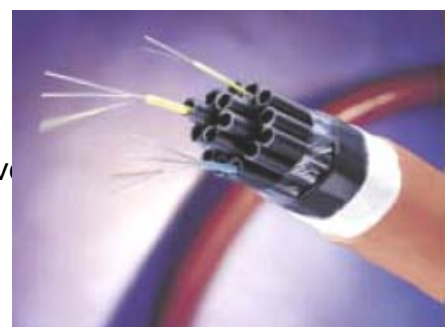
The Limitations of FTTH

For customers

- Not widely available yet
- Monthly and installation costs may be prohibitive
- Needs battery back-up in case power goes out

For providers

- Uncertainty over willingness of residential customers to pay for it since most people don't need that much bandwidth capacity
- Easier to deploy in new neighborhoods rather than existing ones because of cost and inconvenience of laying cable (using sewer or electric lines may allow providers to overcome this obstacle).



FTTH Versus Other Types of Fiber Networks

In September 2006, the FTTH Councils for Europe, Asia and North America standardized the definitions for Fiber-to-the-Home and Fiber-to-the-Building (also called Fiber to the Basement). They are:

Fiber-to-the-Home (FTTH):

A fiber-optic communications path that extends from the operator's switching equipment to at least the boundary of the home living space or business office space. The definition excludes those architectures where the optical fiber terminates before reaching either the home living space or business office space and where the access path continues over a physical medium other than optical fiber.

Fiber-to-the-Building (FTTB):

A fiber-optic communications path that extends from the operator's switching equipment to at least the boundary of the private property enclosing the home(s) or business(es). In this architecture, the optical fiber will terminate before reaching the home living space or business office space. The access path will then continue over another access medium – such as copper or wireless – to the subscriber.

There are also other definitions commonly used by people in the industry.

Fiber-to-the-Node or Fiber-to-the-Neighborhood (FTTN):

FTTN is not defined by the FTTH Councils. But in general it refers to a system where fiber is extended to a point – typically a street-side or on-pole cabinet – to within 1,000 to 5,000 feet of the average user. From there, copper or wireless serves the user.

Typically, the service is through a variant of DSL (Digital Subscriber Line).

FTTN should not be confused with Hybrid Fiber Coax (HFC), used mainly by cable companies to implement DOCSIS, the standard that allows data to be transmitted over cable TV systems. Each DOCSIS node, typically served by fiber, with coax extending to users, passes 100 to 500 homes.

Fiber-to-the-Curb (FTTC):

Like FTTN, except that the fiber is brought much closer to a user premises – typically closer than 1,000 feet and often closer than 300 feet. In addition to DSL, FTTC installations may addition to DSL, FTTC installations may use Ethernet (over copper cable or wireless) to bring the signal from the fiber termination point to the user. Point-to-point wireless is sometimes used in rural areas simply to bring a signal from the roadway to a home that could be a mile or more away.

FTTH and FTTB Network Architectures

The “family” of optical networks has two major branches – PON and AON – and many technical variants within those branches.

PON stands for “passive optical network.” It refers to the fact that there are no active electrical devices between the central office and the end user. All the handling of the light beams that carry the signal are done with mirrors, prisms and fiber. There are no electrical devices needed.

AON stands for “active optical network.” As the name implies, there are electrical devices between the user and the central office. These devices are routers and switches, almost always using the Ethernet standard. But these days, the “active electronics” are not in a remote cabinet; they are in the central office itself. Thus, the industry has begun to call active networks “point-to-point” or P2P networks. This refers to the fact that each end user gets a dedicated fiber (or several dedicated fibers) extending from the central office.

Because each fiber requires its own laser, P2P networks require more power and space within the central office. But because they do not require fiber distribution hubs (containing optical splitters) in the field, they tend to be simpler to operate.

Evolution of PON Standards:

Within the general category of passive optical networks, there are two branches. One is based on Ethernet, the same standard that is used in home and corporate local-area networks. The Ethernet branch has been standardized by IEEE – the Institute of Electrical and Electronics Engineers. The other is based on “carrier” standards, from the ITU – International Telecommunications Union – and are more “telephone-like.”

The ITU Family:

You may occasionally hear about an early member of the family, **APON**. It stands for “ATM” PON.

Just as end users have Ethernet-based networks, telephone companies and other long-range data carriers used ATM.

BPON (for “Broadband PON”) replaced APON. It also is based on ATM, with a top speed to users of 622 Mbps and upstream speed of 155 Mbps. But it allows the use of a separate wavelength of light to support video services.

In North America, the first large Fiber-to-the-Home network deployments used **BPON**. This version is being replaced by **GPON**, which allows 2.48 Gbps downstream to the user and 1.24 Gbps upstream.

GPON supports ATM, Ethernet, and TDM (the protocol phone companies use for ordinary telephone service) by “wrapping” or “encapsulating” the data packets with some extra bits. This is called **GEM**, which stands for “GPON Encapsulated Mode.”

The GPON standard was finalized early in 2004, but it was not until early 2006 that inexpensive electronic chips to implement it became widely available in volume.

The Ethernet Family:

There is another branch of the family tree, the Ethernet branch. Ethernet is also used for “active” P2P networks.

The first Ethernet PON (EPON) standard was released by the IEEE a few months after the GPON standard in 2004. The standard was quickly upgraded to 1.25 Gbps, twice the original bandwidth, as new electronic parts became available. Networks using that speed are sometimes called EPON and sometimes called GePON (for Gigabit Ethernet PON).

A point of confusion: Although P2P networks are said to be “active,” the typical implementation is also Ethernet. And in an Ethernet P2P, there are usually no active electronics between the end user and the central office. In that sense, there’s no difference between P2P and PON. But in a P2P network, each customer is served by at least one dedicated fiber. Each fiber (and thus each customer) has its own laser to generate the pulses of light. In a “passive” optical network, one central office laser might serve up to 64 customers.



GPON OLT.

The Light Fantastic: Three Reasons

The key concept is this: Fiber optic cable carries information by carrying pulses of light. The pulses are turned on and off very, very fast. Multiple streams of information can be carried on the same fiber at the same time by using multiple wavelengths – colors – of light.

The pulses of light are created by lasers. The equipment to do that keeps getting faster, so the same old fiber can be used to carry ever more information. New equipment is just slipped in.

The ability to carry information is called bandwidth. Lots of bandwidth allows lots of information to be carried. Fiber has a lot of advantages over copper wire or coaxial cable, as it is easier to maintain and delivers far more bandwidth. Three of the biggest advantages are:

- 1- Signals travel a long distance inside fiber cable without degradation – 20 miles or more under some circumstances. In contrast, as the distance traveled by a signal in copper wire or coax increases, the bandwidth decreases. Short lengths of coax, for instance – the lengths typically found in a small building – can carry 1 Gbps.

That's a thousand times more bandwidth than typical broadband service using DSL over copper wire, and 200 times more than typical broadband over cable TV coax. But those speeds are impossible over longer distances. The closer fiber gets to a building, the faster the service that is available to the building's residents and businesses. Service providers have been bringing fiber closer and closer for years, and now they are bringing it inside end users' buildings.

- 2- Fiber cable is thin. It can, in fact, be made thinner than a human hair. It can be carried on a thin ribbon, or inside a "microduct" of hollow plastic only an eighth of an inch wide. One typical fiber cable configuration with about 200 super thin strands is about the thickness of a standard coax cable. That fiber cable could theoretically carry enough bandwidth to handle all the information being sent on Earth at any one time today. The bottom line: Fiber can be "hidden" easily on the surfaces of walls in old construction.
- 3- Once installed, fiber is upgraded by changing the electronics that creates the light pulses, and not by replacing the cable itself. The fiber is amazingly reliable. Nothing hurts it except a physical cut, or the destruction of the building it is in. Passive optical networks, or PONs, are the most common type of network. They use a minimum of electronics. In fact, there are no electronics at all between the provider's central office and users. This vastly improves network reliability.

Now, as we noted above, bandwidth providers are increasingly bringing fiber optics all the way to customer premises. That technology, FTTH or fiber to the home (also called FTTP, for fiber to

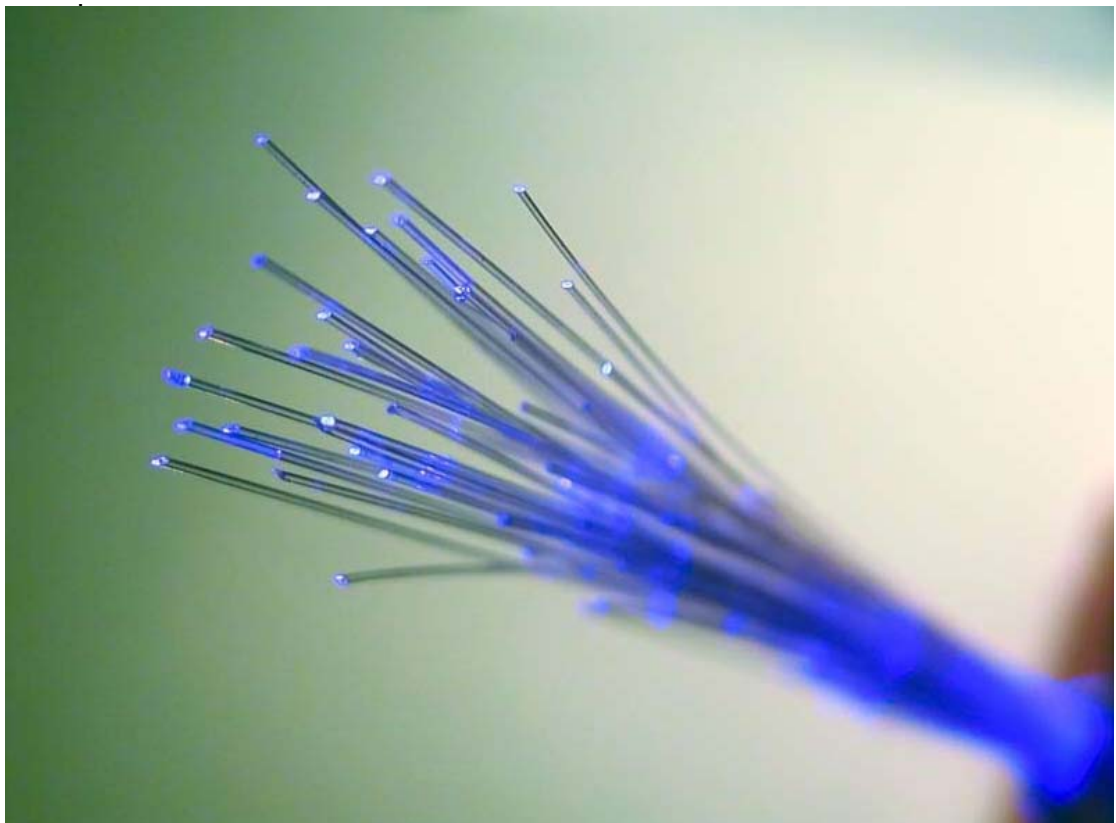
the premises or FTTx for fiber to everyplace) is the “gold standard.” But in cases where the population density is too low, or where high-quality coaxial cable or copper networks exist, it may make sense under some circumstances to bring fiber only partway to the customer. The fiber is then connected to the existing copper for the last jump to users’ premises.

As time goes on, fiber is moved closer and closer to the customers, to provide more bandwidth. That approach is called FTTN for fiber to the “neighborhood” or “node” or (for greater bandwidth) fiber to the curb (FTTC).

Today, the looming bandwidth needs are so large, and FTTH construction prices so reasonable, that going straight to FTTH makes more economic sense.

In the US until now, single-family homes have been the easiest to equip with FTTH. Apartment buildings and other multiple-dwelling-unit (MDU) structures in the US started to be served with FTTH in really large numbers only in 2006.

MDU fiber service is already common in Europe and Asia, however. Thus, there is no “technology risk” in specifying FTTH now, in any c



How does FTTH work?

The Internet "backbone" is made up of fiber optic cables (very thin glass filaments) that have enormous bandwidth and use light pulses to carry information. Most customers, however, connect to the backbone through copper-based technologies like twisted pair and DSL or Hybrid Fiber Coax cable, which have limited bandwidth and limited capacity to carry integrated voice, video, and data services. This creates a speed and service bottleneck in the "last mile," the distance between the fiber optic backbone and customers.

Some providers are beginning to deliver integrated services over fiber optic cables that go from the Internet backbone directly to customers' homes or businesses. These cables may be buried, strung overhead or run through existing structures like sewer lines.

Providers primarily offer FTTH through two types of architectures, point-to-point and passive optical network (PON). Point-to-point requires providers to install an optical transceiver in the provider's central office for each customer. PON uses a single transceiver with a splitter to serve up to 32 businesses and residential customers who share the bandwidth. The splitter is located up to 30,000 feet from the central office, and a single strand of fiber can carry the signal another 3000 feet to the customer. Once the fiber reaches the customer's home or business, an optical electrical converter (OEC) on the side of the building converts the optical signal to an electrical signal that can interface with existing copper wiring. The current standard for PON is the Asynchronous Transfer Mode (ATM)-based ITU-T G.983.

Some providers are also using Gigabit Ethernet over fiber to provide customers with broadband access.

The telecom research firm Communications Industry Researchers (CIR) asserts that 16,000 U.S. homes currently have FTTH connectivity. It will likely be 10 years or more before FTTH becomes widespread.

How fast is FTTH?

Fiber optic cables can currently carry information at speeds greater than 2.5 gigabits per second. Residential/business FTTH typically offers speeds from 10 mbps to over 100 mbps, which is a hundred times faster than most cable or DSL service and over twice as fast as a T3 connection.

Are there distance limitations?

Using PON, providers install splitters up to 30,000 feet from a central office. Splitters send the signal another 3000 feet to customers' homes or businesses.

Gigabit Ethernet over fiber has a range of about three miles.

Fiber and Bandwidth

Q: What is bandwidth?

A: In a network, bandwidth is the ability to carry information. The more bandwidth you have, the more information can be carried in a given amount of time.

Q: How much bandwidth – or information – do we need?

A: A standard-definition television signal requires a bandwidth of about 2 Mbps – two million bits (zeros and ones) per second. HDTV requires as little as 4 Mbps if the image is rather static – a person being interviewed, for instance. But fast action, such as some sporting events, requires more – as much as 8 Mbps, even with new compression technology such as MPEG4.

Q: What about data?

A: Bandwidth requirements are exploding for many kinds of data. Most new digital cameras create images that contain 2 to 15 megabytes. At the upload speeds generally available to people using a cable modem or DSL, it takes well over a minute to transmit a 10-megabyte picture. That is, 10 megabytes = 80 megabits, which at 1 megabit per second (Mbps) equals 80 seconds. It normally takes even longer because the network sends extra bits to help route the network traffic and to provide security. At dialup speeds, it would take at least 20 minutes.

Q: Why is fiber preferred to copper? After all, copper has been around a long time.

A: Optical fiber is unique, in that it can carry a high-bandwidth signal enormous distances. Copper can support high bandwidth, 20 Mbps or more – but only for a few hundred yards. The longer the distance the signal travels on copper, the lower the bandwidth.

Fiber uses laser light to carry the signal. Under most circumstances, the signal can travel 15 miles (more than 25 kilometers) without degrading enough to keep it from being received.

What's more, the equipment necessary to send the light signals keeps getting better.

So equipping an existing fiber network with newer electronics and with lasers that pulse light faster, or lasers using different wavelengths of light, can vastly increase the available bandwidth without changing the fiber itself. That's why fiber networks are said to be "future proof."

Q: How close to the home does fiber come in DSL and cable systems, and why does that matter?

A: There is a marked relationship between the distance and the available bandwidth when you are using copper. The latest version of DSL is called VDSL2. It can carry a signal of more than 200 Mbps, but only for about 750 feet. At a distance of 1,500 feet, it can carry a signal of only 100 Mbps. Over a distance of a mile, it can deliver only about 30 Mbps. And that's the theoretical limit. In practice the real bandwidth is less.

Service	Medium	Mb/s Down	Mb/s Up	Max. Dist at Full Rate (km)	Standard
ADSL	Twisted pair	8	0.64	2.4	ITU G.992 series
VDSL	Twisted pair	40	6.4	0.4	ANSI T1E1, etc.
ADSL2+	Twisted pair	16	1.0	1.5	ITU G.992.5
HFC	Coax	57	9.2	25	DOCSIS 2.0
BPON	Fiber	155 or 622	155	20	ITU G.983 series
GPON	Fiber	1244/2488	155–2400	20	ITU G.984 series
EPON	Fiber	1250	1250	20	IEEE 802.3ah

Comparison of various forms of DSL, cable modems, and passive optical networks.

DSL bit rates are per subscriber and HFC and PON bit rates are shared among subscribers.

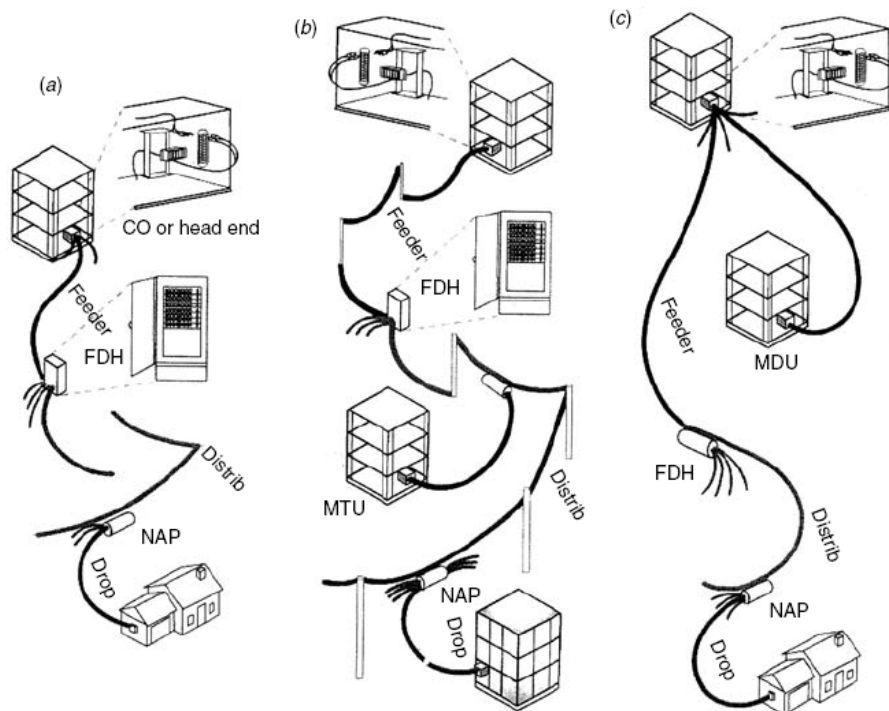


FIGURE 4.1 Maps of typical FTTH systems: (a) to an individual residence, (b) to a residence and an apartment building, and (c) to small businesses. CO = central office or head end, FDH = fiber distribution hub, NAP = network access point, MTU = multitenant unit, and MDU = multiple dwelling unit [Corning].

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