Fiber Optic Cable

FTTH deployment options for telecom operators

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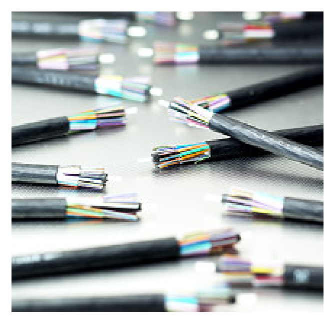
Abstract



To realize the Government of India's goal to have 20 million broadband subscribers by year 2010, it is essential to drive Fiber To The Home (FTTH) technology along with other broadband access technologies for providing broadband access. Today, majority of broadband connectivity is offered through Digital Subscriber Line (DSL), Cable Modem and to the limited extent with Wireless technology. FTTH provides enormous bandwidth and long reach offering Triple Play services (Data, Voice, Video) on a single fiber. FTTH is future proof solution for providing add-on services such as Video on demand, Online Gaming, HDTV. Advancement in the electronic equipment coupled with falling prices of fiber and equipment make FTTH deployment an affordable choice for the telecom operators that result in long term returns. This paper details various FTTH architectures available for deployment, key developments and trends that are suitable for the current system configurations.

Whitepaper

Introduction

Growing demand for high speed internet is the primary driver for the new access technologies which enable experiencing true broadband. Traditionally telecom companies have been offering T1 lines and DSL to small businesses, houses for applications such as voice services, high speed data, internet and video services. T1 lines are often expensive and DSL's performance issues limit availability of these services. DSL Copper networks do not allow sufficient data rates due to signal distortion and cross talk. Cable modem is another competing technology for broadband services. In cable modems only few RF channels are assigned for data and most of the bandwidth is dedicated to video channels.

FTTH offers triple play services with data speeds ranging from 155 Mbps to 2.5 Gbps Down stream (Network to User) and 155 Mbps to 1 Gbps Up stream (User to Network) range of services due to high bandwidth and though the field trials and technology development for fiber in the access loop started in late 1980s, real deployments did not happen as the deployment costs were very high at that time. In the last 20 years enormous progress is made in optical networking equipment and production of high quality optical fibers associated with falling prices are driving forces for fiber to the home (FTTH).

The recent telecom bubble burst also had hard hit on the big telecom players and the revenue generation from the long haul core networks are falling. This lead to shift in the business strategy for maximizing the revenue generation from access loop and wireless. While there is no standard definition for broadband, definition of broadband has become country specific. In Japan more than 1 Mbps is defined as broadband and in India bandwidth more than 256 Kbps is specified as broadband.

Table 1 shows some potential future residential applications and their bandwidth requirements.

Table 1

Application	Bandwidth (Mbps)
1 High Definition Video Session	20
2 Standard IP Video Session	7
1 Web Surfing Session	1
Internet Appliances	1
1 Internet Gaming Session	2
2 Video Conferencing Sessions	2
4 High Quality Audio Sessions	0.5
Total	33.5

FTTH Architecture

Active and passive are two commonly used FTTH architectures fro FTTH deployment. Active Architecture is also called as Point 2 Point (P2P) and Passive Optical Network (PON) architecture is called Point to Multi Point (P2M). Choice of active or passive architectures for deployment depends on the type of services to be delivered, cost of the infrastructure, current infrastructure and future plans for migrating to the new technologies.

ACTIVE Technology

Active Ethernet also called Ethernet Switched Optical Network (ESON) or Point to Point (P2P) Network Architecture provides a dedicated fiber to the side from the central office exchange shown in the figure 1. A P2P architecture is a very simple network design.

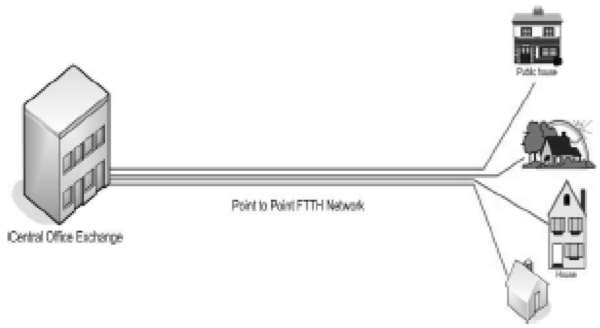


Figure 1

Since the fiber is dedicated, operation, administration and maintenance of the content and trouble shooting become easy. Active FTTH solutions are implemented in many different ways, through both standard and proprietary methods.

Since the distances of the central node an remote sites are known, estimation of power budget, trouble shooting the faults in the network would be easier. Transmission in P2P configuration, is more secure, since all transmissions are physically separated by fiber.

Only the end points will transmit and receive information, which is not mixed with that of any other customer.

Active Network Architecture and Components

Core switch, aggregation switch and Optical Network Terminal (ONT) are main building blocks of a P2P network. The core switch is a high capacity Ethernet switch that communicates to aggregator switches using standard GbE optical signals. The aggregator switch interfaces this data stream to multiple Premises Gateways called Optical Network Terminals (ONT). Each ONT interfaces a 100 Mb/s signal in a standard 100 BaseFX format, which is 100 BaseT Ethernet format on an optical fiber. The core switch interfaces multiple content and service providers over an MPLS-based Metro or Regional network to deliver data, video, and voice services to the users on the access network.

Aggregator switch resides in both standard CO and in building entrance and in outside plant cabinets to meet the environmental needs of the network provider. The aggregator switch delivers traffic to the subscriber in accordance with the specific bandwidth requirements from 1 Mb/s to 100 Mb/s (symmetrical) per subscriber. A typical connectivity diagram of Active technology in the access network is shown if figure 2.

Glance at FTTH Technologies	
BPON	*622 Mb/s down — extended BPON 1.25 Gb/s. Deployed and ready, provides options for radio frequency. Matured technology.*
EPON	*1.25 Gb/s Symmetric. Japanese carriers pushing for adopting EPON*
GPON	*1.25 Gb/s has the potential to reach 2.5 Gb/s. Most major vendors are preparing to build GPON in anticipation of a shift from BPON.*
Active	*100 Mb/s to each home. Flexibility and scalability the tradeoff for active electronics at the edge.*

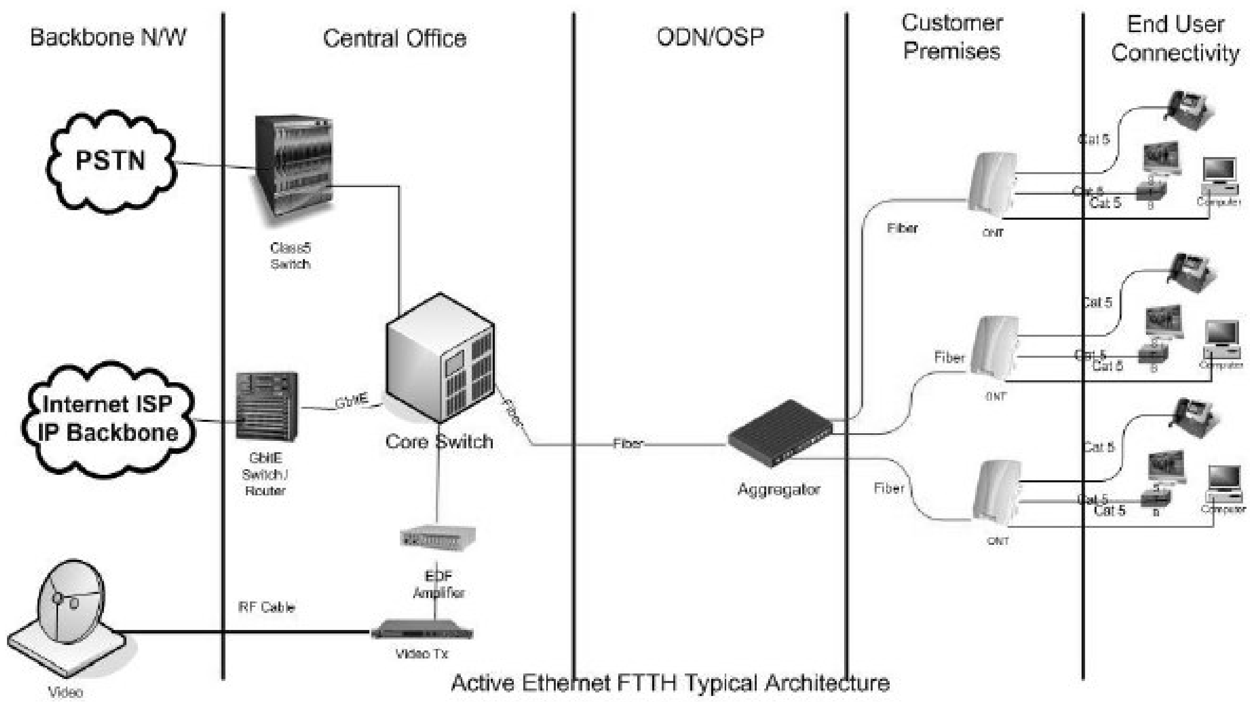


Figure 2

PON Technology

PON is a point to multipoint (P2M) network. Each customer is connected into the optical network via a passive optical splitter, therefore, no active electronics in the distribution network and bandwidth is shared from the feeder to the drop. The advantage of FTTH PON is the fact that they use purely optical passive components that can withstand severe and demanding outside plant environment conditions without the need to consumer energy between in the central office exchange and the customer premises. The benefit to telecom operators is that low maintenance requirements of these passive optical components will

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significantly reduce of the cost of upgrades and operating expenditures. Passive systems utilize a common shared connection with the centralized electronics. PON architecture uses unidirectional splitters. PON FTTH solutions are driven by two key standards:FSAN/ITU and EFMA/IEEE, and solutions can be built with either standard. The PON architecture can reduce the cable cost as it enables sharing of each fiber by many users. There are different PON technologies available today.

Typical PON architecture is shown below, Figure 3.

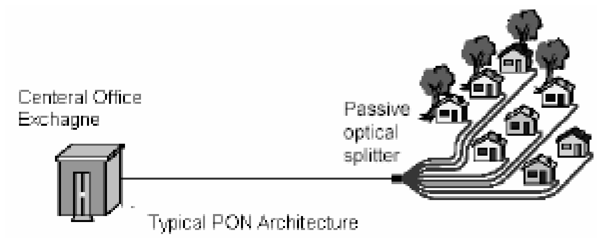

Figure 3

Deployment of active technology is picking up with many municipalities in USA (Utopia, iProvo) offering services over the active P2P technology and is competing with PON technology. Table-2, details the similarities and differences of active and PON architectures.

Table 2

Parameter	ACTIVE (Point to Point / P2P)	PASSIVE OPTICAL NETWORKS (Point to Multi Point / P2M)
Topology	Ethernet Switched Optical Networks (ESONs) contain an active electronic element, a switch aggregator, between the central office (CO) or head-end switch and the Customer Premise Equipment (CPE).	Passive Optical Networks (PONs) do not contain any electronics between the CO switch and the CPE. In a PON, the active optoelectronics are situated on either ends of the passive network.
Standards	It is based on IEEE 802.3 standard. The recent completion of the 10 Gigabit Ethernet standards (802.3ae) provides a seamless transition from 1 Gigabit to 10 Gigabits.	There are three main varieties of PON today. APON/BPON: ITU-T G.983, EPON: IEEE 802.3ah, GPON: ITU-T G.984
Networks Supported	IP	IP, ATM, TDM
No. of Homes Served	ESON systems can serve up to 48 homes, on each fiber run, and isolate information streams and faults to each subscriber. As more homes are served additional bandwidth is added and up to 50,000 homes can be served from a single core switch centrally located.	Conserves fiber resources. It uses a technique called power splitting and can only serve 32 homes from one fiber run with BPON and EPON. 64 homes with GPON technology.
Bandwidth	Only the content destined for a particular CPE is delivered to that subscriber. Even if a rogue CPE device is installed in an active network, no content is delivered to it.	In a PON the entire downstream bandwidth is transmitted to the power splitter, and a portion of the optical power is delivered to each subscriber. Since bandwidth in a passive system is not dedicated to each subscriber, each user shares the total capacity of the system.
Content Distribution and backhaul	Video stream is launched from the core switch to the aggregation switch when a service is ordered. If multiple subscribers order the same	All subscribers are exposed to all downstream content, however, the OLT communicates with valid ONT only by

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bandwidth utilization	service, it is electrically split at the aggregation switch and delivered to the second subscriber – and only to the second subscriber. Thus, backhaul bandwidth is more efficiently used and content is not delivered to unintended CPE devices.	verifying the password. When a subscriber orders a video service of 5 Mbps, for example, a separate information stream is launched from the OLT to each subscriber. Therefore, 10 orders for the same content spawn 10 streams of 5 Mbps down to all subscribers.
Range	Ethernet to the Subscriber platforms can be located up to 120 km from each other without any geographic restrictions, or variations in the platforms. Active Ethernet use standard-based Small Form Factor Pluggable (SFP) optical transceivers.	Two main factors restrict the total reach of PON deployments. The first is the total available optical power budget, which is a factor of the OLT laser port and the total loss budget, including the fiber feeder and splitters. Secondly, because ONUs share the optical feeder and OLT port, a sophisticated algorithm is required within all the devices to prevent more than one ONU from transmitting at the same time, which would cause traffic collisions rendering applications like video unusable. APON and EPON are limited to a maximum of 20 Km between the OLT and the ONU.
Scalability	ESONs can be initially provisioned to deliver 20 Mbps to each subscriber and later remotely upgraded to 100 Mbps.	PONs must physically restrict the number of subscribers on a power splitter to achieve higher throughputs. If the total network capacity is exhausted, then the electronics at each end (CO and CPE) must be upgraded to a newer technology.

APON / BPON

ATM Passive Optical Network: APON was initiated in 1995 by ITU/FSAN and standardized as ITU-T G.983. In 1999, ITU adopted FSAN's APON standard. APON was the first PON based technology developed for FTTH deployment as most of the legacy network infrastructure was ATM based. There are different PON technologies available today. Since the services offered by this architecture are not only the ATM based serviced but also video distribution, leased line services and Ethernet access and to express the broadband capability of PON systems APON is renamed as BPON. Broadband Passive Optical Network (BPON) was standardized by ITU recommendations G.983.1, G.983.2, G.983.3. BPON has two key advantages, first it provides 3rd wavelength for video services, second it is stable standard that re-uses ATM infrastructure. ITU-T recommendation G.983.1 defines three clauses of performance namely Class A, Class B, Class C.

GPON

The progress in the technology, the need for larger bandwidths and the complexity of ATM forced the FSAN group to look for better technology. Gigabit Passive Optical Network (GPON) standardization work was initiated by FSAN in the year 2001 for designing networks over 1Gbps. GPON architecture offers converged data and voice services at upto 2.5 Gbps. GPON enables transport of multiple services in their native format, specifically TDM and data. In order to enable easy transition from BPON to GPON, many functions of BPON are reused for GPON. In January 2003, the GPON standards were ratified by ITU-T and are known as ITU-T

Recommendations G.984.1, G.984.2 and G.984.3. The GPON's uses Generic Framing Procedure (GFP) protocol to provide support for both voice and data oriented services. A big advantage of GPON over other schemes is that interfaces to all the main services are provided and in GFP enabled networks packets belonging to different protocols can be transmitted in their native formats.

EPON

Ethernet equipment vendors formed Ethernet in the First Mile Alliance (EFMA) to work on a architecture for FTTH as Ethernet is a dominant protocol in Local Area Network. EPON based FTTH was adopted by IEEE standard IEEE 802.3ah in September 2004.

Adopting Ethernet technology in the access network would make uniform protocol at the customer end simplifying the network management. Single protocol in Local Area Network, Access Network and Backbone Network enables easy rollout of FTTH. EPON standards networking community renamed the term 'last mile' to 'first mile' to symbolize the importance and significance access part of the network. EFM introduced the concept of Ethernet Passive Optical Networks (EPONs), in which a point to multipoint (P2MP) network topology is implemented with passive optical splitters. EPON, is largely vendor-driven standard and it is fundamentally similar to ATM-PON but transports Ethernet frames/packets instead of ATM cells. It specified minimum standardization and product differentiation, also it has decided *not* to standardize the Bandwidth Allocation Algorithm (DBA), TDM and ATM support, Security, Authentication, WDM Overlay Plan, support for Analog Video Protection, Diagnostics, Monitoring, Compliance with existing OSS leaving these to the vendors to choose the best.

WDM PON

Wavelength Division Multiplexing Passive Optical Network (WDM PON) is the next generation in development of access networks and offer highest bandwidth. Though it will be some time before there are affordable WDM PONs some vendors are introducing products that can put more wavelengths onto a PON. Wavelength Division Multiplexing (WDM) is either a Coarse (CWDM) or Dense (DWDM) depending on the number of wavelengths multiplexed onto the same fiber. Vendors are of the opinion that a CWDM PON can support 3 to 5 wavelengths, while supporting more than 5 wavelengths requires a DWDM overlay. In WDM PON architecture ONTs operate on different wavelengths and hence higher transmission rates can be achieved. Much research was focused on enhancing WDM PONs ability to serve larger numbers of customers in attempt to increase revenue from invested resources. As a result, some hybrid structures have been proposed where both WDMA and TDMA modes are used to increase the number of potential users. For DWDM, the ONTs require expensive, frequency-stable, temperature-controlled lasers. The OLT puts all the wavelengths onto the shared feeder fiber and the splitters replicate the wavelengths to each home.

PON Architecture and Components

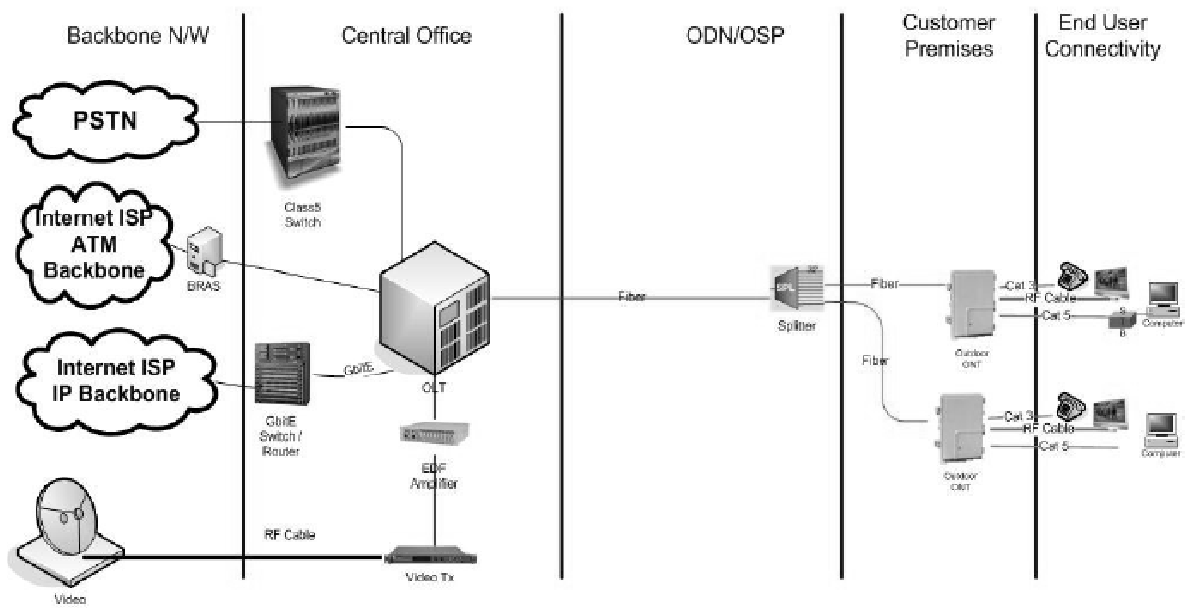
The Optical Line Terminal (OLT) is the main element of the network and it is usually placed in the Local Exchange and it's the engine that drives FTTH system. Optical Network Terminals (ONTs) are deployed at customer's premises. ONTs are connected to the OLT by means of optical fiber and no active elements are present in the link. A single ONT can serve as point of access for one

(Fiber to the Home) or multiple (Fiber to the Block or Curb) customers and be deployed either at customer's premises (Fiber to the Home or Block) or on the street in a cabinet (Fiber to the Curb).

Splitters in outside plant are important in signal distribution. The ITU G.983.1 standard recommends splitting the signal up to 32 users. The final splitting ratio can be achieved using a single splitter device, a single 1X32 splitter or a cascaded series, such as 1X8 + 1X4 or 1X16 + 1X2. To split the incoming signal from the Central Office to subscribers, the passive optical splitter need to have the following characteristics:

- Broad operating wavelength range
- Low insertion loss and uniformity in any conditions
- Minimal dimensions
- High reliability
- Support network survivability and protection policy

In PON the transceiver in the ONT is the physical connection between the customer premises and the central office OLT. WDM triplexer module separates the three wavelengths 1310 nm, 1490 nm and 1550 nm. ONT receives data at 1490 nm and sends burst traffic at 1310 nm. Analogue video at 1550 nm is received. Media Access Controller (MAC) controls the upstream burst mode traffic in an orderly manner and ensures that no collision occur due to upstream data transmission from different homes. Video receiver circuitry converts the 1550 nm downstream analogue signal to 75 ohm co-axial signal. The Customer Premises Equipment (CPE), also known as the Optical Network Unit (ONU), has POTS (Plain Old Telephone Service), 10/100 Base-T Ethernet and RF video interfaces. Figure 4 shows the typical PON architecture connectivity.



Typical PON network Architecture

Figure 4

Video Delivery

Video in FTTH network can be delivered as either video over IP or RF overlay. Video over IP has definite advantages over RF overlay but requires a set top box interface to connect to TV sets. Today, many carriers are offering data services over IP protocol. Delivery of video over IP will make integration and managing the service easy. Video over IP enables interactivity between content provider and the subscriber. The ITU-T G.983.3 specifies an Enhancement Band (EB) of between 1539 nm and 1565 nm which allows the use of wavelengths in addition to those specified in G.983.1. Schematic of RF overlay is shown figure 5. RF overlay overcomes the bandwidth limitations of the network but has limitations on interactivity. It is not easy to provide Rf return path in RF overlay. ONTs with RF interface enables the customer to directly plug the TV sets without need for a set top box. The main blocks in BPON network with RF overlay are depicted in figure 5. At the Central Office (CO), video is coupled from the head-end into the optical distribution network (ODN) via a WDM filter or a 2XN coupler. The head-end consists of a continuous wave laser diode at 1550 nm, and the signal is passed through an erbium doped-fiber amplifier (EDFA) fro increasing the optical power. At the ONT, the video signal is optically demultiplexed. Both analog and digitally modulated channels can be viewed (the latter with a set-top box). The up- and downstream data paths are carried in different wavelength bands (respectively in 1260-1360 nm and 1480-1500 nm), and are also separated by WDM filters. Figure 5 shows typical architecture of video over RF overlay.

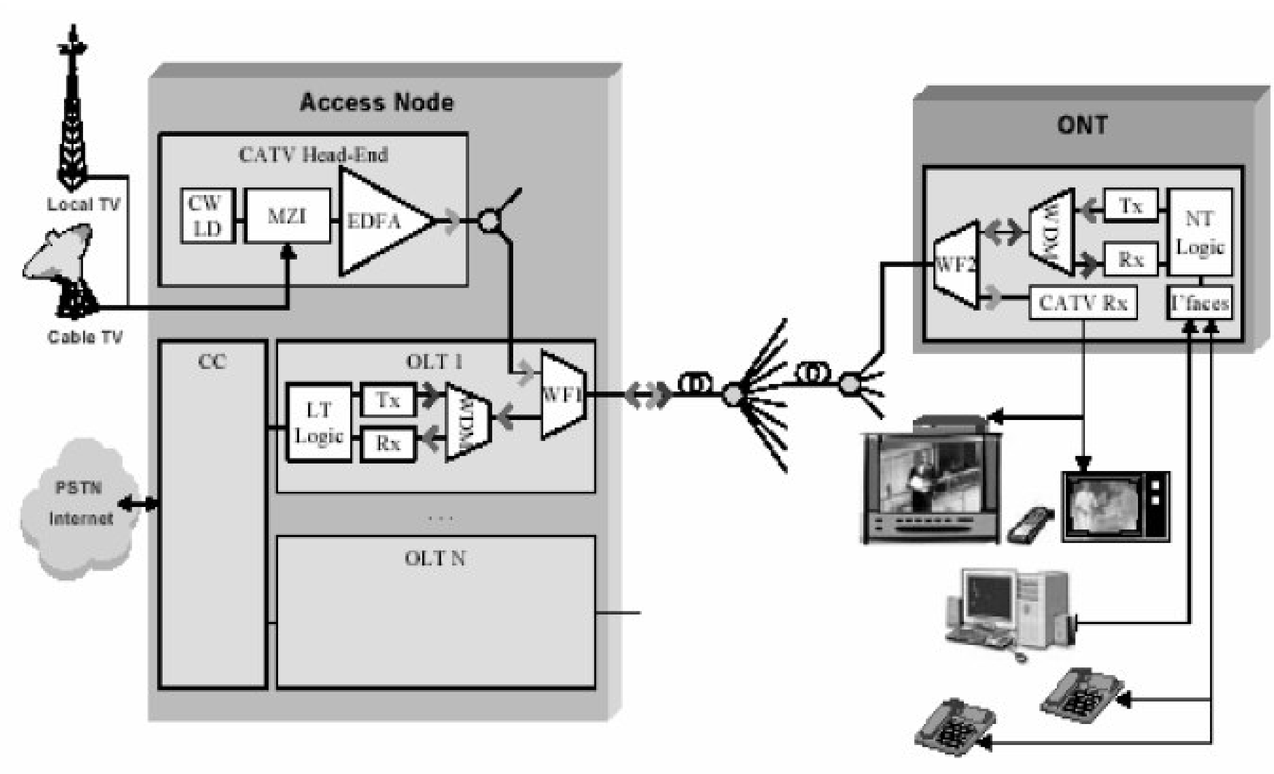


Figure 5

Cable Segments in FTTH Network

Access network Out Side Plant (OSP) cabling can be categorized into three segments, namely Feeder cables, Distribution cables and Drop cables. Figure 6 illustrates cable configurations.

Feeder and Distribution Cables

Optical fiber cables running from central office exchange to the Local Convergence Point (LCP) are termed as feeder cables. Distribution cables start from LCP and run to the entrance of the neighborhood. A single feeder cable serves several distribution cables loose tube design cables are most popular in feeder and distribution segments of access network. Loose design cables offer several benefits – stress free movement of fibers under varying environmental and mechanical conditions. Midspan access for branching out the fibers can be conveniently done with loose tube cables.

Drop Cables

The portion of the cable connecting Network Access Point (NAP) to the subscriber premises is called as drop cable. Usually drop cables have less fiber count and length ranges upto 100 mts. Drop cables are designed with attributes such as flexibility, less weight, smaller diameter, ease of fiber access and termination. Typical drop cable cross section, used for aerial applications, is shown in figure 6.

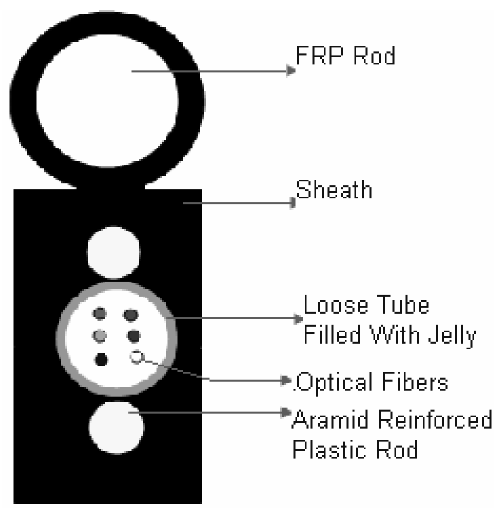


Figure 6

In non-aerial applications, the following type of flat drop cable is used, figure –7.

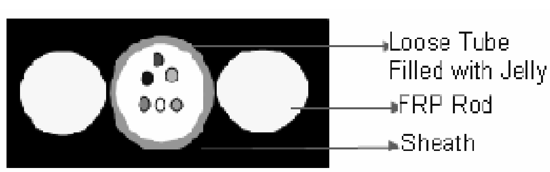


Figure 7

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Whitepaper

World Wide FTTH Deployments

Japan

Japan has the largest and most successful fiber-to-the-home (FTTH) deployments in the world till date. The Japanese Ministry of Public Management estimates that by Marhc 2006 there will be 7.73 million households connected to the Internet by means of the optical fiber in Japan. While the Japanese carriers have initially adopted ATM based BPON architecture and the growing demand for higher bandwidth has forced them to look for alternative option. Now Japanese carriers have started embracing EPON solution also called as GE-PON.

USA

In US, majority of the carriers are launching FTTH services with BPON architecture. With the development and availability of GPON, many of the carriers have planned for migration to GPON architecture.

Korea

In Korea, 74% of the population already has a broadband connection to the Internet and main telecommunications companies are investing heavily in the optical infrastructure in order to maintain their competitive edge.

Europe

In Europe broadband access is getting more and more attention. The “eEurope 2005” program was launched by the European Council in 2002. Its agenda is primarily concerned with promoting broadband Internet in member countries.

China

In recent years China has been catching up with the leaders. Chinese telecommunication carriers are still at the stage of testing and promoting FTTH without actual commercial applications. Throughout the promotion stage, FTTx, as just one of several broadband access technologies, has faced fierce competition from xDSL. In 2004, a more complete FTTH demonstration project was undertaken in order to verify FTTH technology and product maturity, and serve as the foundation for future FTTH applications. In particular, the Optics Valley of China in Wuhan city is a nearly complete demonstration of an FTTH testing point.

India

Ministry of Communications & Information technology has recognized the need to increase the broadband penetration in the country. Broadband policy-2004 puts FTTH as the one of the major broadband options. Many carriers have already deployed fiber to the curb. Finalization of FTTH drop cable specifications by TEC is the first step in this direction. Private and public

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Whitepaper

telecom operators are already in the process of conducting trials on broadband on FTTH network.

Conclusion

One of the major hurdles for the mass deployment of FTTH is the relatively high cost of CPE/ONT. Equipment vendors efforts to integrate various functions into a single IC would bring down the cost of ONTs. Carriers have a large installed base of TDM based legacy infrastructure. There is no right or wrong FTTH technology, rather the technology choice primarily depends on the existing network operator infrastructure. With ambitious plans of Govt. of India to increase the broadband availability, making a parallel start of FTTH would only make achieve the targets set by the Govt. Both the architectures of FTTH: P2P and P2MP offer scalability and flexibility for FTTH, though ultimately, the choice of network architecture is typically driven by the demand for that which offers the greatest service capabilities at the lowest costs.

Glossary of Terms

APON: ATM Passive Optical Network
ATM: Asynchronous Transfer Mode
BPON: Broadband Passive Optical Network
EPON: Ethernet Passive Optical Network
GPON: Gigabit Passive Optical Network
IEEE: Institute of Electrical and Electronics Engineers
OLT: Optical Line Terminal
ONT: Optical Network Terminal
ITU: International Telecommunications Union
EFM – Ethernet in First Mile
EFMA – Ethernet in First Mile Alliance
FSAN: Full Services Access Network
ESON: Ethernet Switched Optical Network

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