International Journal on Emerging Technologies **3**(1): 130-136(2012)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Optical Fiber Cable Substitute of Copper or Radio Link for High Speed Internet Access

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(Recieved 15 April, 2012 Accepted 10 May 2012)

ABSTRACT : This paper present current research on Fibre To The Home for the last mile access , which has a target of providing broadband everywhere in India. Several related technologies, such as OFDM-based PON and carrier distributed upstream signal power equalization, fiber access network with self-healing functions, have been studied. We also describe the need of optical fiber cable up to customer premises.

Keyword : Optical Fiber, Data Communication, PON.

I. INTRODUCTION

To get idea of fiber to home, we first need to understand basic difference between communication over conventional copper, wireless mediums and next of fiber.

The biggest problem in using copper in communication is "noise". Copper pairs get noisy over distance, apart from getting too much effect of interference from nearby environment.

Now to carry more bandwidth, one needs to use really high frequencies, and high frequencies are effected by noise even more. Imagine noise as road block interrupting traffic, and high frequency as car running at high speed.

Till now there has been no way out to the noise problem of copper. A lot of research work is still going on, but till now all we see is multiple bonding of pairs for increasing speeds. Next, if you look at wireless communication due to limited spectrum, overall capacity is very much limited and one can't provide high speed broadband for very low rates to everyone. That is what makes 3G, EVDO and other stuff expensive.

In case of fiber, communication is done using light which travels in whole fiber via a simple Physics rule called total internal reflection. Principle is quite simple, but it makes communication very effective as fiber is NOT prone to interference by any external element like other wires, apart from that loss of signal per Km is way too less in fiber as compared to copper. This makes fiber a very good "Physical" medium for carrying high bandwidth [3].

Considering those simple physical properties, it seems like fiber is really awesome, and should be used everywhere. Well there are few other important things when we discuss copper vs fiber like it's very hard to splice fiber, one needs a dedicated team of trained technicians to splice fiber, apart from that if a fiber gets damaged, it's again hard to fix it as compared to just rejoining copper.

FTTH, (Fiber To The Home), refers to fiber optic cable that replaces the standard copper wire. FTTH is desirable because it can carry high-speed broadband services integrating voice, data and video, and runs directly to the junction box at the home or building. For this reason it is sometimes called Fiber To The Building, or FTTB.

Recently, because of demand from high data rate triple-play services, the deployment of fiber to the home (FTTH) and the related standardizations are becoming increasingly important. FTTH is a broadband network technology that delivering triple-play (data, voice and video) services with a high speed to the home or business via optical fiber cable. FTTH is the major role in alleviating the last mile for next generation broadband optical access network. Today, FTTH has been recognized as the ultimate solution for providing various communications and multimedia services, including, high-speed Internet access, digital cable television , and interactive two-way video-based services to the end users. Owing the very high capacity of optical fibers, FTTH can deliver greater capacity as compared to copper-based technologies [3]. FTTH technology using passive optical network (PON) with P2MP configuration or tree topology is the most promising way to provide high quality broadband access.

The bandwidth offered by DSL networks has been NOT enough for users' demands for now. the nature of the traffic that flows through the Internet is changing.

New technologies, such as VDSL2 and WiMax, increase the array of possibilities, but also the uncertainty on the best way to proceed. It is clear, though, that none of these other technologies can provide the bandwidth that fiber does, making it the ideal medium for high-bandwidth applications and/or as the backhaul of wireless and DSL networks.

FTTH can be installed as a point-to-point architecture, or as a passive optical network (PON). The former requires

that the provider have an optical receiver for each customer in the field. PON FTTH utilizes a central transceiver and splitter to accommodate up to 32 clients. Optical electric converters, or OECs, are used to convert the signals to interface with copper wiring where necessary [1].

FTTH differs from Fiber To The Curb (FTTC) in that FTTC does not run directly to the home or building. Instead it runs to the curb, and the last leg of wiring to individual buildings remains copper wire.

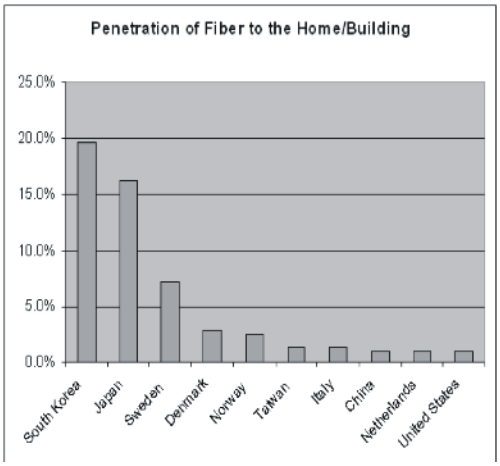

Fig. 1. Country wise analysis of Fiber.

Do we really need FTTH in India ?

Well, that's a hard question. Answer varies.One thing we always talk about is Internet speed or bandwidth. Fiber has very high bandwidth, and there is no other alternate. It's true, but question is - do we really need to deliver that much high bandwidth to all end users ?

Using an advance DWDM equipment, one can carry as high as 10 Gbps over single wavelength in a fiber. There are 160 possible wavelength, and thus in theory, one can give as high as 1.6 Tbps over single fiber pair. (In real that is quite less due to limitation from switches, protocol running on top etc).

Firstly I would like to say 100Mbps, 1Gbps sounds very "awesome" speed, but fact is in real people HARDLY need that much speed and we can't ignore that fact specially when we are demanding for really expensive technologies.

Well, at 16Mbps, one can download 2 MB every second. If you look at average web-page size, you will see average page on modern sites are well below 500 KB, thus he can get whole page in 250 ms. An average Youtube video is around 20-25 MB, and can get that in 10-12 seconds on DSL. Even for heavy downloading work (although he doesn't really do that), he can get a 1 GB file in 500 seconds (even less then 10mins).

Now people hardly do anything "new" or "fast" in real world on speeds beyond 10-15 Mbps. Unless you plan to share that bandwidth up on multiple computers. Again, I am talking about bandwidth requirement on average computer.

But yes, there's a big problem in DSL - very slow upload speed. It is due to fact that co-axial wires are tightly packed in big copper trunks as they get out from exchange and they are spliced further so on as they reach end user. So when a end user sends some data to central exchange (upload…) the weak signal (because of low power consumption by CPE) goes on, and as it gets more closer to exchange, it becomes even more weak, apart from fact that it gets into tightly bundled 100 pair trunks which are carrying data for lot of other users. This causes "cross-talk" and even reduces signal strength degrading upload speeds. He had 16Mbps download while 500 Kbps upload DSL connection, while now he has 100 Mbps (up and down symmetrical) and one can surely tell difference in 500 Kbps vs 100 Mbps upload speed.

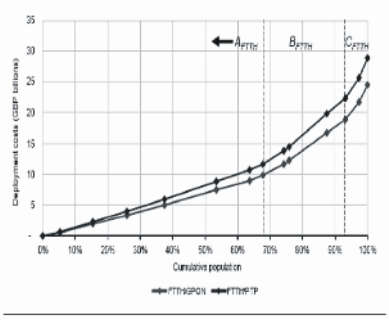

Fig. 2.

Coming back on point - if one needs 5-10 Mbps, we can easily get it on existing DSL connections, and we don't really need FTTH. Problem comes when more and more subscribe to 10Mbps plan, and it increases cross talk further degrading speed. But such cases are possible when a whole colony/street/apartment is demanding for high speed broadband and remember in all such cases it is economically feasible to bring fiber close to that street and from there back on copper.

This is known as FTTB/C - Fiber to the Building/ Fiber to the Cabinet. From that cabinet, one can carry signal over copper via VDSL or even conventional cat5 ethernet. Such hybrid fiber-copper models are really good in bringing down cost of expensive FTTH technology.

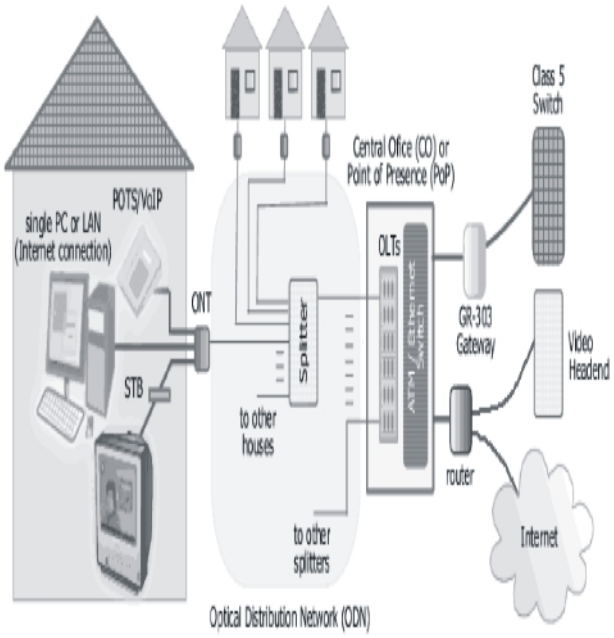

Fig. 3. FTTH.

A fiber optic access network delivers multiple types of services to subscribers'homes. Fiber optic cable has long been used in backbone network, that's the network that interconnects telephone switches and data centers. Fiber optic cable is selected due to the advantages it has over other transmission media. It carries information as optical pulses (not electrical signals as in twisted pair or coax), therefore it is immune to interference (EMI and RFI), crosstalk, and noise. It can deliver information over longer distance than copper or coax. It has abundant bandwidth for carrying information, limited only by the equipment that lights the fiber.

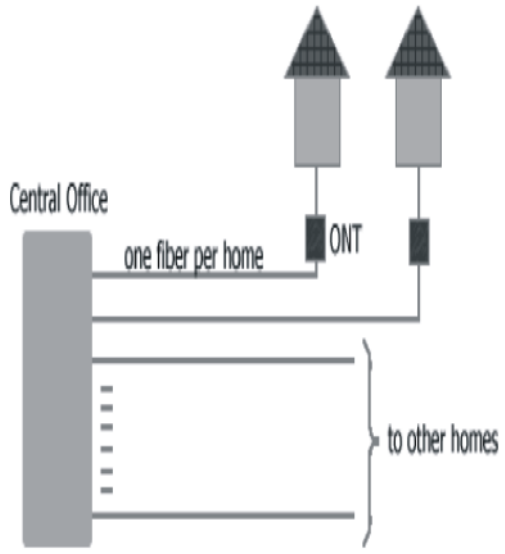

Fig. 4. Home Run Fiber A dedicated fiber from the CO to each subscriber home.

FTTH or FTTP (Fiber To The Premises) brings the fiber optic cable deeper toward customer premises if compared with FTTN (Fiber To The Node) or FTTC (Fiber To The Curb) that is commonly used for delivering ADSL/VDSL or cable TV. Due to the price decrease of fiber optic cable and equipment (among other reasons), in recent years more telcos and independent service providers have started the deployment of FTTH networks, targeting those people not satisfied with DSL/cable Internet experience. With competitive pricing and SLA (Service Level Agreement), most heavy Internet users would love to switch to FTTH.

An FTTH operator or internet provider delivers multiple type of services from the Central Office (CO) or Point of Presence (PoP) via a fiber optic strand to a subscriber home. The types of service that can be offered via FTTH network include VoIP, lifeline POTS, RF video, MPEG video, IPTV, HDTV, video-on-demand, pay-per-view, high speed Internet, and numerous other services. Generally speaking, FTTH is the medium of choice for delivering triple play services (voice, video, and data) [3].

The CO or PoP is fed with content from Video Headend and the Internet. It has interfaces that connect it to content sources, such as ATM/Ethernet switch, router, and GR-303 voice (PSTN) gateway. From the CO, the content mix in the form of electrical signals is converted to optical pulses before being transmitted over the Optical Distribution Network (ODN) toward subscriber homes. At each subscriber home, a CPE (Customer Premises Equipment) converts the optical pulses back to electrical signals.

A fibre to the home (FTTH) network constitutes a fibre-based access network, connecting a large number of end users to a central point known as an access node or point of presence (POP). Each access node contains the necessary electronic transmission (active) equipment to provide the applications and services, using optical fibre to the subscriber. Each access node, within a large municipality or region, is connected to a larger metropolitan or urban fibre network.

Access networks may connect some of the following :

(*i*) Fixed wireless network antennae, for example wireless LAN or WiMAX.

(*ii*) mobile network base stations.

(*iii*) Subscribers in SFUs (single family units) or MDUs (multi-dwelling units).

(*iv*) Larger buildings such as schools, hospitals and businesses.

(*v*) Key security and monitoring structures like surveillance cameras, security alarms and control devices.

The FTTH network may form part of the wider area or access network.

FTTH network environment

The deployment of fibre closer to the subscriber may require the fibre infrastructure to be located on public and/ or private land and within public and/or private properties.

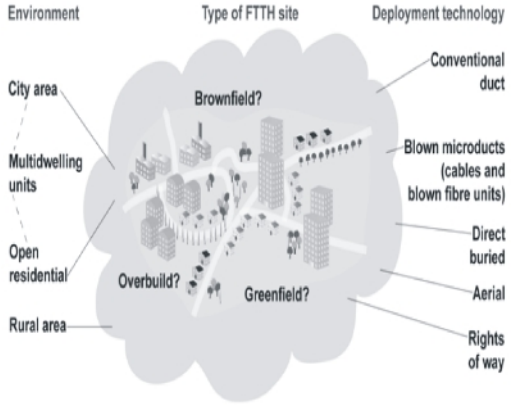

Fig. 5. Type of FTTH site.

The physical environment can be broadly split into:

(*i*) City.

(*ii*) Open residential.

(*iii*) Rural.

(*iv*) Building type and density - single homes or MDUs.

Not only does each environment offer different customer densities (per sq km), but this also varies by country.

The nature of the site will be a key factor in deciding the most appropriate network design and architecture. Types include:

(*i*) Greenfield – new build where the network will be introduced at the same time as the buildings.

(*ii*) Brownfield – where there are existing buildings and infrastructure but the infrastructure is to a lower standard.

(*iii*) Overbuild – adding to the existing infrastructure.

The main influences on the method of infrastructure deployment are:

(*i*) Type of FTTH site.

(*ii*) Size of the FTTH network.

(*iii*) Initial cost of the infrastructure deployment (CAPEX).

(*iv*) Running costs for network operation and maintenance (OPEX).

(*v*) Network architecture, for example PON or Active Ethernet.

(*vi*) Local conditions, for example, local labour costs, local authority restrictions (traffic control) and others.

The choice of fibre deployment method and technology will determine CAPEX and OPEX, as well as the reliability of the network. These costs can be optimised by choosing the most appropriate active solution combined with the most appropriate infrastructure deployment methodology. These methods, which are described later, include:

(*i*) Conventional underground duct and cable.

(*ii*) Blown micro-ducts and cable.

(*iii*) Direct buried cable.

(*iv*) Aerial cable.

(*v*) “Other rights of way” solutions.

Key functional requirements for a FTTH network will include:

(*i*) Provision of high-bandwidth services and content to each customer.

(*ii*) A flexible network architecture design with capacity to meet future needs.

(*iii*) Direct fibre connection of each end subscriber directly to the active equipment, ensuring maximum available capacity for future service demands.

(*iv*) Support for future network upgrade and expansion.

(*v*) Minimal disruption during network deployment, to help fibre networks gain acceptance from network owners and to provide benefit to FTTH subscribers.

When designing and building FTTH networks, it is helpful to understand the challenges and tradeoffs facing potential network owners and operators. Some of these challenges may present conflicts between functionality and economic demands.

The FTTH network builder must create a profitable business case, balancing capital expenses with operating costs while ensuring revenue generation. A more detailed analysis of the main influences on the business case for FTTH networks is available in the FTTH Business Guide.

II. FTTH ARCHITECTURE

In order to specify the interworking of passive and active infrastructure, it is important to make a clear distinction between the topologies used for the deployment of the fibres (the passive infrastructure) and the technologies used to transport data over the fibres (the active equipment).

The two most widely used topologies are point-to-multipoint, which is often combined with a passive optical network (PON) technology, and point-to-point, which typically uses Ethernet transmission technologies.

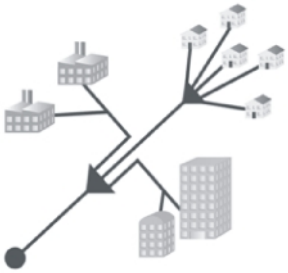

Fig. 6. Passive optical network.

Fig. 7. Active Ethernet network.

Point-to-point topologies provide dedicated fibres between the POP and the subscriber. Each subscriber has a direct connection with a dedicated fibre. Most existing point-to-point FTTH deployments use Ethernet, which can be mixed with other transmission schemes for business applications (*e.g.* Fibre Channel, SDH/SONET). This topology can also include PON technologies by placing the passive optical splitters in the access node.

Point-to-multipoint topologies with passive optical splitters in the field are deployed in conjunction with standardized PON technologies - GPON is today's frontrunner in Europe with EPON being the most popular in Asia - making use of time-sharing protocols to control the access of multiple subscribers to the shared feeder fibre. [6]

Active Ethernet technology can also be used to control subscriber access in a point-to-multipoint topology requiring the placement of Ethernet switches in the field.

III. DIFFERENT FIBRE TERMINATION POINTS

Various access network architectures can be implemented:

A. Fibre to the home (FTTH)

Each subscriber is connected by a dedicated fibre to a port on the equipment in the POP, or to the passive optical splitter, using shared feeder fibre to the POP and 100 BASE-BX10 or 1000 BASE-BX10 transmission for Ethernet connectivity or GPON (EPON) in case of point-to-multipoint connectivity [3].

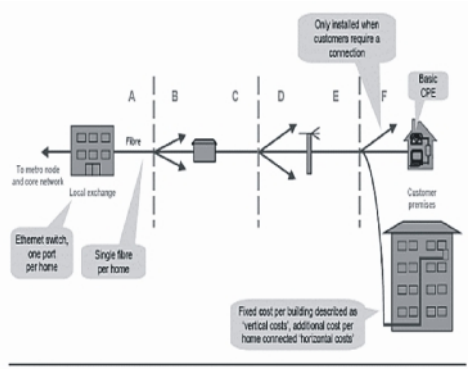

Fig. 8.

B. Fibre to the building (FTTB)

Each optical termination box in the building (often located in the basement) is connected by a dedicated fibre to a port in the equipment in the POP, or to an optical splitter which uses shared feeder fibre to the POP. The connections between subscribers and the building switch are not fibre but can be copper based and involve some form of Ethernet transport suited to the medium available in the vertical cabling. In some cases building switches are not individually connected to the POP but are interconnected in a chain or ring structure in order to utilize existing fibres deployed in particular topologies. This also saves fibres and ports in the POP. The concept of routing fibre directly into the home from the POP or through the use of optical splitters, without involving switches in the building, brings us back to the FTTH scenario.

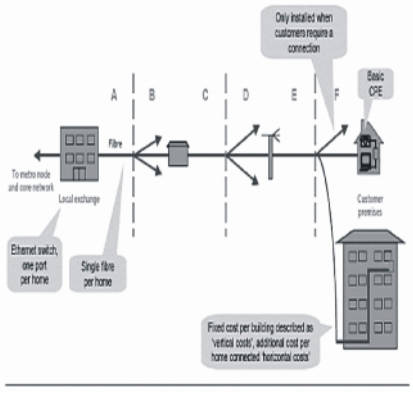

Fig. 9.

C. Fibre to the curb (FTTC)

Each switch / or DSL access multiplexer (DSLAM), often found in a street cabinet, is connected to the POP via a single fibre or a pair of fibres, carrying the aggregated traffic of the neighbourhood via Gigabit Ethernet or 10 Gigabit Ethernet connection. The switches in the street cabinet are not fibre but can be copper based using 100 BASE-BX10, 1000 BASE-BX10 or VDSL2. This architecture is sometimes called “Active Ethernet” as it requires active network elements in the field [3].

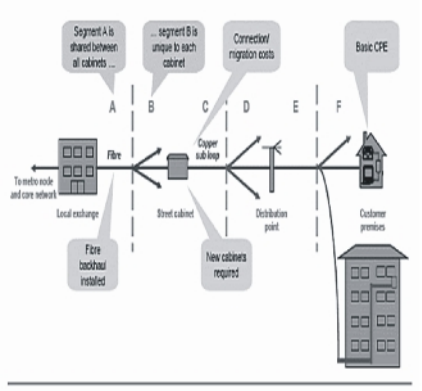

Fig. 10.

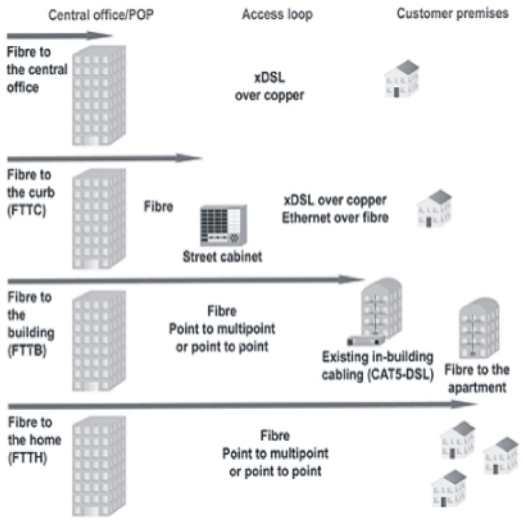

Fig. 11. Different FTTx networks.

D. PONs

PONs have a tree topology in order to maximize their coverage with minimum network splits, thus reducing optical power loss. This is important, since a passive distribution network has no amplifiers or regenerators.

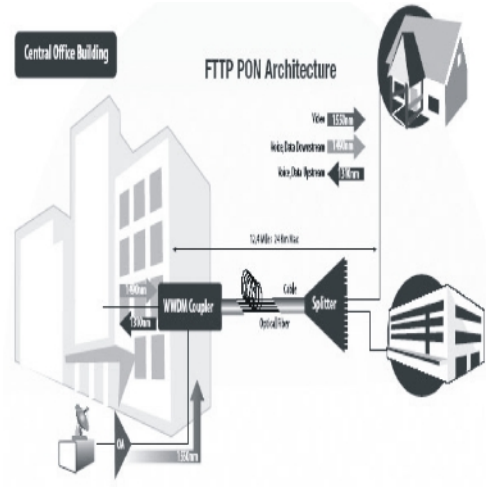

Fig. 12. FTTP PON Architecture.

There are three standardized versions of PON: Ethernet PON (EPON), Broadband PON (BPON) and Gigabit PON (GPON). They all use two wavelengths, one for downstream and one for upstream data traffic. These wavelengths are time-shared among users, making them Time Division Multiplexed PONs (TDM-PONs). The total bandwidth available per user is thus limited by this time-sharing, especially if the connection is going to be used for CBR applications. A third wavelength can optionally be used for downstream analog video broadcasting (RF). Wavelength Division Multiplexing (WDM) can be used in PONs to increase the overall throughput. The cost is, however, usually much higher due to the use of tunable and wavelength-sensitive optical components. WDM-PONs are regarded as the next step after TDM-PONs, and are currently

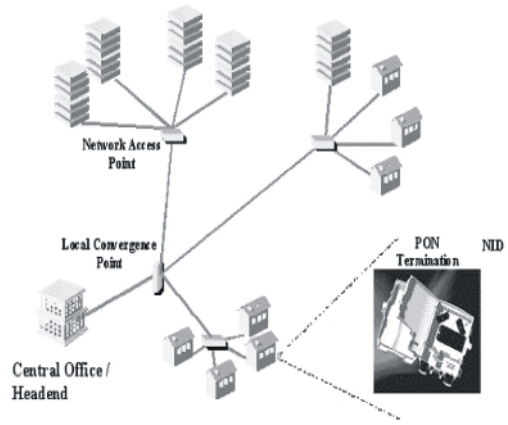

Fig. 13. PON based Fiber-to-the-Home Architecture.

E. GPON

In GPON, the encapsulation is done using the Generic Framing Protocol, a flexible method for both bursty and CBR traffic. The GPON standards are in development, having the physical and transmission layers already well defined. Since the OAM and other higher-layers have not been defined yet in the standards, operators are reluctant to deploy them for now [4].

F. EPON

A separate PON standardization effort was started based on the IEEE Ethernet protocol. The idea here was to make use of the huge base of low-cost Ethernet designs to allow for simpler, less expensive technology to be used in PONs. The downside is that Ethernet is mostly engineered for bursty data and not for CBR or TDM services. EPON was developed and formalized in the IEEE 802.3ah standards. The scope of these standards is limited to the physical transmission layer and thus the interoperability of the higher layers is not guaranteed. The maximum rate for EPON is nominally 1.25 Gbit/s, but due to the use of 8B/10B coding, it is effectively 1 Gbit/s [2].

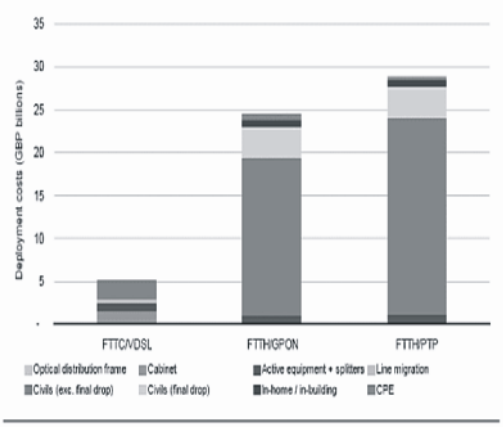

Fig. 14.

IV. CONCLUSION

The current research of FTTH, were presented and discussed. Several related technologies are reviewed, including upstream signal power equalization technique, and OFDM-based PON. It is also concluded that hybrid fiber-copper models are really good in bringing down cost of expensive FTTH technology.

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