Passive Optical Network: A Review

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Abstract
The main objective of this paper is to know about Passive Optical Network.It is a type of network based on Optical Fibre. Passive optical network is used for reliability and high data rate. This network enables the service providers to get the unlimited virtual bandwidth for transmitting video, audio and data simultaneously. In this paper we shall study about evolution, architecture, technologies, advantages and disadvantages of passive optical network.

Keywords
PON, ONU, FSAN, OLT, APON, BPON, GPON, EPON

I. Introduction

Most of the broadband services around the world are delivered through the copper access network, optical access technology has been commercially available for several years and is being deployed in large amount in some countries [3]. The rapid growth in both use and size of computer networks has arouse a new interest for increasing the networks capabilities to transport more traffic with higher speed. Over recent years optical communication networks have been deployed widely across the globe. With excessive bandwidth offerings of optical networks in metropolitan and wide area networks (WANs), there still exists a restricted access between Local Area Networks (LANs) and the service provider's networks. This has a reflective impact on the design of next-generation optical network architectures and technologies. Optical fibres are widely used in telecommunications, since they allow sending large amounts of data at a great distance and having higher bandwidths (data rates) than other forms of communication. They are the transmission medium par excellence to be immune to electromagnetic interference and because signals travel along them with less losses. This transmission mode allows the transport of a multitude of information, used for applications such as broadband Internet, telephone and cable television, through more effective signals than copper wires. There are two major set of fibre-based technologies to be deployed in the access networks. One is active optical networks and other is Passive Optical Networks (PONs). The former depends on active components in the subscriber loop (from CO to users) and in PON, there is no active device in the signals path between CO and subscribers. High capacity feature of multi-access optical networks with comparison to other access network technologies like cable, DSL and wireless access is the main motive of passive optical network exploitation [4].

II. Evolution of PON

Fiber-to-home and -business was a consideration from the earliest days of the optical fiber technology development. In the late 1970s point- to- point substitution of copper by the fibre was being considered as a way of delivering broadband services to customers. For the future evolution of the optical networking high performance mode fibre optical components should be made. One component that became available easily with the arrival of single mode technology was the fused fibre directional coupler. These splitter or couplers can be cascaded and any size of splitter or star couplers can be made. These optical splitters were the major components behind the passive optical netw fiber was being considered as a way of delivering broadband services to customers. These early system was predicted on multimode fibre technology. The first consideration of Passive Optical Network approach for the access network was around 1982 when single mode fibre technology was being seen as a possible new way for a forward optical communications. Single mode fiber offered many advantages as compared to multimode fiber ork concept. In the first half of the 1980s the passive optical network concept was centred on wavelength switched networks. To interconnect network terminations and wavelength selection to route path [10] across the network star couplers are used. At the same time ideas of using the couplers as simple passive splitters for broadcasting television signal were also being considered [11]. In the mid1980s BT (British Telecom) became interested in the possibilities presented by optical access and this led to a refocusing of passive optical network approach. The operational unit brought a much needed business focus to the research and challenged the research team to develop a system that could be economical for telephony. This was a service with a known revenue structures opposed to the unknown revenues from future broadband services. This approach became known as "telephony entry strategy" and led to invention and development of "TPON" (telephony over passive optical network) system [9- 8]. TPON was TDM based and the early system had a limited bandwidth of 20 Mbit/s, adequate for telephony and ISDN but not for broadband. Broadband would be added later, as an upgrade, by addition of extra wavelengths. To facilitates this a blocking filter was supplementary to the TPON ONUs, which only pass the original TPON wavelength and block all others, enabling addition wavelengths to be supplementary to the PON at a later stage without troubling the original telephony only customers. However, the system was never rolled out on any important scale the upgrade system (called BPON at the time) was never developed into a commercial product. At the end of the eighties BT was developing an ATM version of Passive Optical Network called APON. Also around this time optical amplifiers were emerging as a network component. At the end of eighties and early nineties numerous experiments were performed at BT Labs that confirmed the real potential of passive optical networking approach and culminate in the publication of initially a 32 millionway split network delivering 12 wavelength at 2.5 Gbit/s each [9]. During the early nineties BT continued with the design and development of a practical amplified PON architecture, it became dubbed as Super PON. This examined the design and execution option of a passive optical network that could service a split of up to 3000 and have a geographical range up to 100 km. The capacity was 1.2 Gbit/s downstream and 300 Mbit/s upstream. At the time these bit rates were very striving for optical access and were considered to be the limits for low costs customers equipment. In the mid nineties BT, Deutsche Telekom and NTT decided, with other operators, to set up a consortium to enlarge and standardized PON requirements and systems , this discussion became FSAN [7]. In recent years, PON systems have continued to be developed, largely along FSAN (Full Service Access Network) guidelines and mainly in the small/start up company arena. More recently Japan, Korea and the US have re-energized interest in the supply industry and PON access solutions are once becoming the access solution of

choice as FTTH (Fibre To The Home) deployment progresses into 21st century.

III. Passive Optical Networks

The Passive Optical Network is one of the most extensively deployed access networks due to its exclusive benefits, including transparency against data rate and signal format as well as high data rates and reliability [2]. The PON is type of access network which based on Optical Fibre. It is designed to make available unlimited bandwidth to the subscriber. A Passive Optical Network uses a passive optical splitter to divide the signal towards individual subscriber.

Fig. 1 depicts a common PON architecture supporting different FTTx scenario. Only passive components are used as optical elements in such networks, such as fibres, splitters/couplers optical path that consists of these components is called Optical Distribution Network (ODN). The Optical Line Terminal (OLT) resides in CO (Central Office) and connects the optical access network to an IP, ATM, or SONET backbone. An Optical Network Unit (ONU) is placed at the curb or Optical Network Terminal (ONT) is located at end user location (FTTH, FTTB solution) and to provide broadband voice, data and video services with surely reaching all the way to customer premises, FTTC may be the most inexpensive deployment today leaving room for alternatives technologies such as DSL or even wireless to implement the last drop.

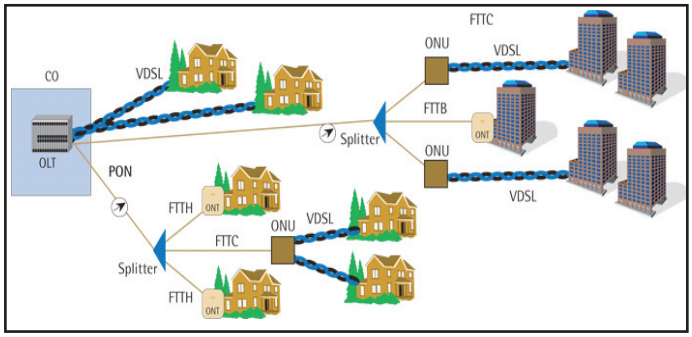

Fig. 1: PON Architecture [2]

All transmission over the ODN of the PON starts from or towards the OLT, as ONUs or OLTs do not communicate directly with each other. The P2MP transmission from the OLT to ONUs/ ONTs is called downstream and the P2MP transmission from the ONUs to OLT is called upstream transmissionThe upstream and downstream are carried on the same fibre. To understand why FTTx architecture is based on PON network, it is necessary to make a direct comparison between the point-to-point (P2P), passive point-to- multipoint (PON) and active point-to-multipoint networks (AONhree types of network configuration cited above, that clearly defend the use of FTTx PON compared to other configurations.

Due to passive interconnection of nodes, and shared medium among users, a multiple access scheme is required to avert collision. In all networks, multiple access schemes are accomplished by resource sharing in either of space, the time, the frequency, or the code domains. The four basic multiple access techniques that have been broadly investigated and applied to current optical fibre networks are comprised of, wavelength Division Multiple Access (WDMA), Subcarrier Multiple Access (SCMA), Time Division Multiple access(TDMA) and Code Division Multiple Access (CDMA) schemes [6]. Multiple access optical networks grasp best of both optical and electrical worlds, i.e. the routing and transport from optics and buffering and processing from electronics.

IV. PON Technologies

There are four type of PON-based technologies namely Broad band PON (BPON), Ethernet PON (EPON), Gigabit PON (GPON), APON.

A. APON

It was the first network that was defined by FSAN (Full Service Access Network). APON bases its transmission downlink in bursts of cells ATM (Asynchronous Transfer Mode) with a maximum rate of 155 Mbps shared between the ONT numbers that are connected. Its initial problem was the imitation of 155 Mbps which later was increased to 622 Mbps. In each ATM cell is introducing two more cells, responsible of indicate the addressee of each cell and for maintenance. These networks are referred to as APON (ATM Passive Optical Network), and are standardized under ITU-T standard G.983.1.

B. BPON

The Broadband passive optical network (BPON) was the first effort towards a PON standard. It is governed by the ITU-T and is designated as ITU-T G.983. It established the general needs for PON protocols. BPON use Asynchronous Transfer Mode (ATM) as the underlying transport mechanism to carry used data. BPON did not gain much popularity due to lack of bandwidth and extensive use of Ethernet protocol.

C. EPON

The Ethernet passive optical network (EPON/GE-PON) is governed by IEEE and is designated as IEEE 802.3ah. EPON is based on Ethernet, unlike other PON technologies which are based on ATM. It provides simple, easy-to-manage connectivity to Ethernet-based IP equipment both at the customer premises and at central office. It is well suitable to carry packetized traffic as well as time-sensitive voice and video traffic. It offers 1.25Gbps data rate for both upstream and downstream. EPON supports 1:16 split ratio i.e. 16 ONUs at a range of 20 km can be connected with a single port of OLT.

D. GPON

The most recent PON standard is the ITU-T G.984 GPON(Gigabit PON) standard, which offers 2.488 Gbps bandwidth and direct support of both TDM(POTs & E1) and Ethernet traffic at the edge of the network with possible triple play voice, data and video services on the same PON. GPON can support ONU that is located as far as 30 Km from the OLT. GPON offer higher split ratio of 1:32/64/128 which results in an OLT reduction by more than a factor of 2 over EPON. GPON is a more advanced system than EPON from the technological parameters point of view. It provides higher bandwidth efficiency and higher splitting ratio but generally costs more than EPON.

V. Multiplexing PON Technology

A. WDM PON

The wavelength division multiplexing passive optical network is the next generation in the growth of access networks and offers high bandwidth. In WDM PON architecture, ONUs operates on different wavelengths and hence higher broadcast rates can be achieved. Much research has been resolute on increasing WDM

PONs ability to serve large numbers of customers in an attempt to increase revenue from invested resource. As a result, some hybrid structures have been planned where both WDMA and TDMA are used to enhance the number of potential users. For DWDM, the ONUs needs expensive, frequency stable, temperature controlled lasers. The OLT puts the entire wavelength on to the feeder fibre and the splitter replicate the wavelength to each [5].

VI. Comparative Analysis Among xPON Standards

In the previous sections an analytical data of different standards xPON standard has made. These data can be condensed and completed in the table 1.2

VII. Advantages of PON

Many of the PON properties are given by the use of fibre, and of course, of the passive elements that compose the network, which added to the specific configuration of a star or tree give it certain advantages over other topologies. This gives to PON two undoubtedly important advantages: cost savings in implementation and the capacity and bandwidth of passive optical networks. However, these advantages are not the only ones, and among other, the most relevant are listed below

- A Passive Optical Network allows for longer distances communication between central offices and customer premises. While with the Digital Subscriber Line (DSL) the maximum distance between the central office and the customer is only 18000 feet (approximately 5.5 km), a PON local loop can operate at distances of over 20 km [6].
- There is the possibility that every information source can be provided in different wavelength, avoiding the mixing of signals to each other, and facilitating diffusion from the OLT to the different ONTs. Therefore, signals voice and data are managed by so-called P-OLT, which operates in second window wavelengths, and video signals in diffusion are managed by the so-called V-OLT, operating in third window wavelengths. This fact gives scalability to PON transmission system, given the variety of wavelengths to use for the same by CWDM / DWDM.
- The use of passive elements in the network provide a cheaper cost of implementation. On the one hand it diminishes the cost of installation of active elements, and on the other hand the cost of passive element itself, which is much lower.
- The installation of PON from these elements is much more cost-effective, and prevents operation and maintenance costs, such as absence of falls or maintenance of the network feeds.
- Finally, it is notable that the high bandwidth allowed by systems based on PON architectures which can reach the 10 Gbps rate down to the user. The need to increase the bandwidth and the speed is now a days just another justification for the use of PON. This is an essential support for services such as HD Video, services called “on demand”.

VIII. Disadvantages of PON

Despite the many advantages that have the PON to own intrinsic configuration, there are some disadvantages connected with it. However, they are not significant enough to avoid choosing PON as the best possible configuration.

- One of the first disadvantage is because of the distribution of information from the OLT to the different ONTs. The fact that a divisor distributes information from the OLT to all ONTs that are connected to the same stage or distribution tree, it causes a drop in network efficiency.
- The total capacity is divided into many ONT connected to the splitter, so that the efficiency of the channel is lower than that of a point-to-multipoint link. In addition, because PON has a preset speed, it is forced to work at that speed but offering different speeds to the customer service. For example, an ONT that provides 100 Mbps to the customer is required to work at higher speed rates: 1.25 Gbps or 2.5 Gbps.
- Moreover, the fact that all information flow through the same physical channel increases the likelihood of sniffing on the network, losing security, and forcing to establish a high level of encryption.
- Regarding security, PON architecture is sensitive to external sabotage. This problem is produced by the nature of the transmission medium itself. Injection of constant light to a particular wavelength masks all communication and service tends to fall.
- Another important aspect is the fact that a stage or distribution tree, depend exclusively on a single OLT. A fault in the OLT header produces a high affect on the network, since all the ONT and splitters connected to it are affected. However, the installation of few OLT provide a cost reduction of network deployment enough considerable.

The ONTs of PON are quite sensitive to the level drops, and in many cases, the power budget of the network is quite limited. This budget is directly related to:

- The capacity of splitters. When the number of users are large, less power reach from the OLT to each users.
- Maximum distance to achieve. The greater the distance between the OLT and end users, lesser power will reach the corresponding ONTs.

However, despite the disadvantages mentioned above, the most advantageous configuration for the deployment of FTTx is PON. Two of the most important conditions that justify the use of this architecture are:

- The economic savings obtained from deploying PON networks regarding other two configurations (point to point and active optical network).
- The flexibility of the network, which allows a large number of user to use the channel.

IX. Conclusion

This paper is a review of passive optical network. The passive optical network is one of the most extensively deployed access networks due to its exclusive benefits, including transparency against data rate and signal format as well as high data rates and reliability. It is designed to make available unlimited bandwidth to the subscriber.

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