COMPARATIVE INVESTIGATION OF PASSIVE OPTICAL NETWORKS

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ABSTRACT

Passive Optical Networks (PON) can be a better solution for the networks accessed in the future, due to their property of high bandwidth availability and energy saving. PON is a point to multipoint mechanism and provides applications like data transmission and reception (IP), video and voice (triple play). For the support of symmetric, high-speed and perfect bandwidths for future services like high definition TV quality and traffic patterns that include video and image services other than voice and text, we require passive optical networks. This paper presents the architecture, PON technologies and detailed discussion on scope of various passive optical networks.

Keywords: APON, BPON, EPON, GPON, Optical access networks, Passive optical networks (PON).

I. INTRODUCTION

The communication has been a prime necessity for the mankind throughout its history. Telecommunications is perhaps the fastest evolving field of study. To communicate at longer distances, a number of ways were used such as copper wires, co-axial cables for a long period of time. There was major evolutionary change in the communication system with the invention of optical fibre [1]. Optical networks have knocked the doors of communication world with their great ability to sustain robust conditions. The design of optical broadband access networks is the main focus for providing solution for next generation networks. Passive optical networks (PON) dominate among all the access networks for providing high speeds (up to 10 Gbps for XGPON) at longer distances to the end subscribers.

A PON is a point to multipoint, fibre to the premises network design in which the unpowered optical splitters are used to enable an optical fibre to serve multiple premises typically 32-128 in number [2]. PONs topologies are classified as Point to Point (P2P) and Point to Multipoint (P2MP) topologies. In P2P topology, there is direct fibre link between CO and end user, which is very expensive. To reduce the installation costs, P2MP architecture is used where different users transmit/ receive data using single fibre link.

To control the P2MP fibre network, Multi-Point Control Protocol (MPCP) is used. MPCP performs bandwidth assignment, bandwidth polling, auto-discovery and ranging, and is implemented in MAC layer [3]. Starting in 1995, work on FTTH (fibre to the home) architectures was done by the Full Service Access Network (FSAN) working group, formed by the major telecommunications service providers and system vendors. The International Telecommunications Union (ITU) did further work, and then standardized two generations of PON. The older ITU-T G.983 standard was based on Asynchronous transfer mode (ATM), and was referred to as APON (ATM PON). Further improvements to original APON led to final version of G.983 standard which is known as broadband PON (BPON).

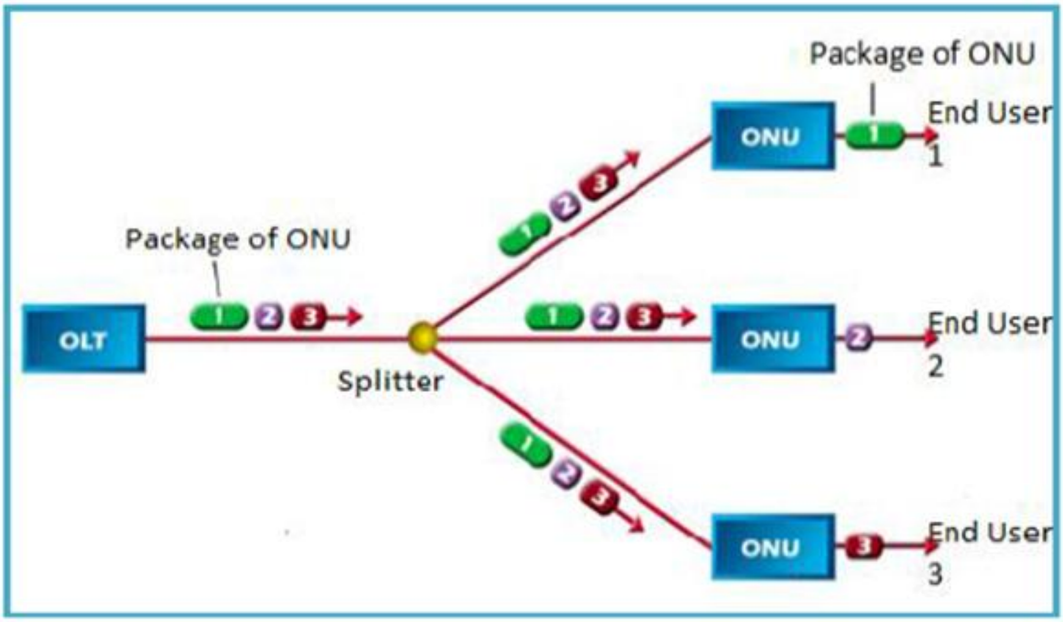

Figure 1- Basic PON architecture

The ITU-T G.984 Gigabit-capable Passive Optical Networks (GPON) standard represented an increase in both the total bandwidth and bandwidth efficiency through the use of larger, variable-length packets, compared to the BPON. The standard gives a speed of 2.488 gigabits per second (Gbit/s) of downstream bandwidth, and 1.244 Gbps of upstream bandwidth.

II. PON ARCHITECTURE

Moving from the network to the user, it can be said that PON architecture consist of the following equipments : Optical Line Terminal (OLT) at the service provider's central office and a number of Optical network units (ONU) close to end users.

A passive optical network always works under the transmission between the OLT and the different ONT's through optical splitters, which multiplex or demultiplex signals based on their origin and destination. Therefore, they appear three distinct devices in the network: the OLT, the ONT, and the splitter, each of which has a necessary and priority function on the passive optical network. Below are the detailed functions and general characteristics of each of them.

2.1 Optical Line Terminal

The OLT is located in a central office and controls bidirectional flow of information across the ODN (Optical Distribution Network). An OLT must be able to support the transmission distances across the ODN of up to 20 km (currently could be more with EDFA). In the downstream direction, the function of an OLT is to take in voice, data, and video traffic from a long-haul network and then broadcast it to all the ONT modules on the ODN. In the reverse direction (upstream), OLT accepts and it also then distributes all the traffic from the network users.

For downstream transmissions, a PON uses 1490 nm wavelength for combined voice and data traffic and a 1550 nm wavelength for video distribution. Upstream voice and data traffic use a 1310 nm wavelength [4]. Each OLT is tasked to avoid interference between the contents of downlink and uplink channel, using two different wavelengths superimposed. For this, techniques for WDM (wavelength division multiplexing) are used, and are based on the use of optical filters.

2.2 Optical Network Terminal

An ONT is located directly at the customer's premises. There its purpose is to provide an optical connection to the PON on upstream side and to interface electrically to the customer equipment on the other side.

ONT are elements capable of filtering the information associated with a particular user from the OLT. They also have the function of encapsulating a user's information and send it toward the OLT header to redirect it to the appropriate network. [4]

Each ONT receives all the signals sent by its corresponding header ONT, like the rest of ONTs of the same stage. Information of OLT is transmitted by broadcast TDM, and reaches all ONT by alike. However, the ONT has the task of filtering the information that only goes directed himself (at a given time interval).

2.3 Splitter

Splitters are passive power dividers that allow communication between the OLT and their respective ONT who serve. However, not only are dedicated to multiplex or demultiplex signals, but also combine power: they are bidirectional optical distribution devices with one input and multiple outputs:

- The signal which enters from input port (downlink), it proceeds from the OLT and it is divided among multiple output ports.
- The signals which enter from the exits (uplink), they come from ONT and they are combined at the entrance.

The fact of being completely passive elements, it allows them to operate without external power, lowering their cost of deployment, operation and maintenance. They just introduce optical power loss on communication signals, which are inherent in nature [5].

III. PON TECHNOLOGIES

Full service access network (FSAN) working group's work on FTTH (Fibre to the home) architecture eventually led to the origin of Passive optical networks. International telecommunication union (ITU) did further work in this field and standardized various generations of PON. Below is an evolution of PON standards since its inception.

3.1 APON/BPON

ATM PON or Broadband PON has an ability to connect up to 32 subscribers to the PON. It gives a speed of 622 Mbps downstream and 155 Mbps upstream. Cell based ATM multiplexing is used of downstream transmissions of data while TDMA is used of upstream transmissions. ATM cells sent in both directions are known as APON packets.

As the data is sent over the network in the form of APON packets, the packets travel along different paths and arrive asynchronously. To avoid the collisions among the packets, equalization of connection distances between all ONU's and CO must be done. Guard times are left between the consecutive bursts so that the receiver gets sufficient time to recover the right clock for each burst [6].

3.2 EPON (Ethernet PON)

EPON works on point to multipoint (P2MP) topology. Subscribers can see the traffic from CO or OLT, but cannot see the traffic from other subscribers. Only one subscriber is allowed to transmit at a time, using TDMA. Multi point control protocol (MPCP) is used to control P2MP network. This protocol performs polling, bandwidth assignment, auto discovery and ranging. This protocol is implemented in MAC layer [6].

As transmission speeds are concerned, EPON establishes a symmetric speed line of 1 Gbps, both for downstream and upstream channels. This technology is also called GEPON (Gigabit Ethernet Passive Optical Network) due to its working speed in Gigabits [7].

3.3 GPON (Gigabit-capable Passive Optical Network)

It is standardized by ITU as ITUG.984. GPON has data packet cell size that varies from 53 bytes to 1518 bytes. The data rate of GPON is configurable from 1.2 Gbps to 2.5 Gbps for downstream transmissions and for upstream transmissions, different data rates of 155 Mbps, 622 Mbps, 1.25 Gbps or 2.5 Gbps can be used [10]. It uses ATM, Ethernet and TDM protocol. GPON offers more facilities but is more complex.[8]

3.4 10 G-EPON (10 Gigabit Ethernet PON)

10 G-EPON is the standard by IEEE. In this configuration, the data rate is kept as 1 and 10 Gbps for upstream and downstream respectively. It is also made companionable with EPON. The main characteristic of 10 GEPON is the utilization of same wavelength for downstream and upstream. These architectures are based upon TDMA technology. The various applications of GEPON are broadband services for internet, triple play services, online media streaming and gaming etc.

3.5 TDM PON

TDM PON works on the time multiplexing protocol and it is the most common PON architecture. In this configuration, the users can transmit and / or receive their data as per assigned time slots. The whole bandwidth is available to all the users. The circuits use power splitters for synchronization. ONUs recognizes their data through the specific packet headers attached with the signal. A TDM PON architecture using power splitter is shown in the Fig.2. Data transmission in TDM is not continuous, which results in less power consumption.

There are TDM-PON areas which need more research, like Bandwidth sharing: The bandwidth per ONU is available for limited time [9] ; and Limited transmission range due to the power split losses associated with the optical splitter. The Security issue with TDM PON is that it requires algorithms to secure the information in downstream signals because the downstream information is shared by each ONU.

3.6 WDM PON

In the last two decades, the traffic demand in the Internet has increased rapidly. The rate of this escalation is expected more in the future. So, there is need to improve the existing system to meet the future requirements.

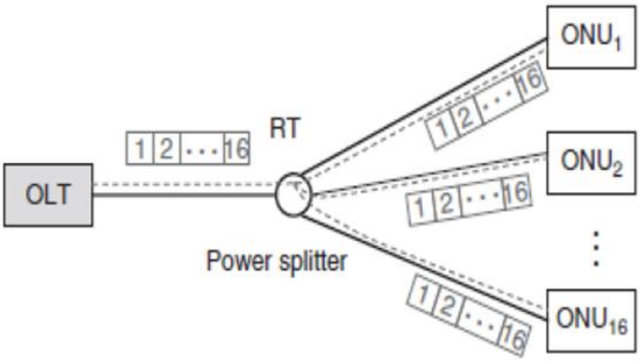

Figure 2- TDM PON [4]

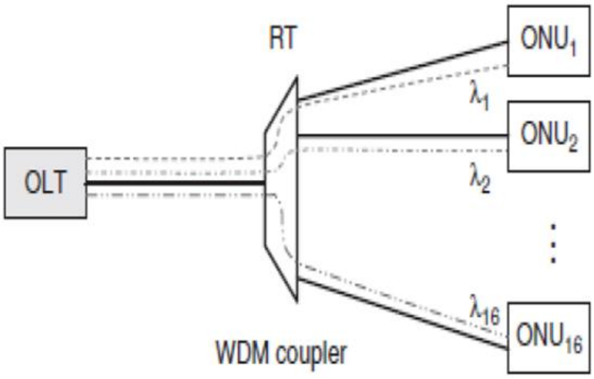

Figure 3- WDM PON [4]

The capacity of the networks can be increased by assigning the different wavelengths to the multiple users which share a single fibre. Also, the cost of installation will be very less due to reduction in cost per customer. This is the main reason that WDM will remain a promising solution to fulfil the requirement of more bandwidth in future [10].

WDM PON is the ultimate solution for fast, efficient and secure bandwidth allocation for passive optical networks.

3.7 WDM/ TDM or Hybrid PON

Hybrid (WDM/ TDM) PON is the system which uses both WDM and TDM techniques. The advantages of both multiplexing techniques are provided to the end users. Different wavelengths are used to realize communication between the Central Office (CO) and number of end subscribers. The communication is done in two phases. Firstly, numbers of wavelengths are assigned to the different groups of Optical Network Units (ONUs). Each wavelength will be shared on time basis by several ONUs of the same group. The entire wavelength is divided into number of wavelengths using WDM technique. Each wavelength is shared by a group of number of ONUs using TDM technique and so on [11].

IV. DISCUSSION

Many of the PON properties are given by the use of fibre, and of course, of the passive elements that compose the network, which, when 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.

A PON allows for longer distances between central offices and customer premises in comparison to DSL. While with the Digital Subscriber Line (DSL), maximum distance between the central office and the customer is only 18000 feet (approximately 5.5 km), the PON local loop can operate at distances of over 20 km. It adds to the reduced costs of network deployment in the outside plant. The use of passive elements in the network leads to the lower cost of implementation. On the one hand it reduces 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 with these elements is much more economic, and prevents operation and maintenance costs, such as the absence of falls or maintenance of the network feeds in case of other networks.

Finally, it is noteworthy 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 nowadays just another justification for the use of PON.

Passive optical networks have various related issues as well. EPON networks consist of a single OLT at the central office and multiple ONU's at the customer's premises. In the upstream data transmission, as OLT is a shared medium by ONU's, scheduling is required to prevent data from different ONU's to collide. Therefore, for better QOS, Dynamic bandwidth allocation (DBA) is required in EPON. Dynamic bandwidth allocation can be done on two basis : inter-ONU scheduling, and other one being , intra-ONU scheduling. Inter-ONU scheduling helps provide quality of service to different classes of packets in Ethernet passive optical network. Intra-ONU scheduling helps support efficiently the transmission of multimedia traffic and at the same time; it improves the performance of low priority traffic [3].

V. CONCLUSION

It is concluded that PON is an extremely high reliable, low cost and high bandwidth system. It is a competent solution for future access networks because of the high bandwidth that it offers and also the long distance of transmission. PON has an application in Broadband internet. In japan, fibre to the home started from simple application of IP/Ethernet and it is still leading. Simple indoor ONU provides Broadband access of 100 Mbps.

Triple play with RF video and IP triple play are other applications of Passive optical networks. PON is the most economical way of achieving large number of subscribers and high capacity which is very much in demand in the market. The network operators can better utilize their investment in triple service of voice, video and data to the home with the use of PON.

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