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Reach extendibility of passive optical network technologies

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ABSTRACT

Fiber to The Home (FTTH) Passive Optical Networks (PONs) are becoming popular because of their ability to accommodate the varying demands of the users regarding, voice, data and multimedia services. This paper compares, analyzes and proposes a method to extend the reach of various PON technologies like Ethernet Passive Optical Network (EPON), Gigabit Passive Optical Network (GPON) and XGPON. These technologies are analyzed and evaluated for the performance on the basis of parameters like Bit Error Rate (BER), Quality factor (*Q* factor), Signal to Noise Ratio (SNR) and input output powers at multiple distances. For the analysis of PON technologies, different split ratios like 1:8, 1:16, 1:32 and 1:64 are also considered. The results of this research reveal that the EPON performs better only up to a distance of 60 km with the maximum of 16 users. It has been observed that the GPON exhibits more reach extendibility than the EPON by using Erbium Doped Fiber Amplifier (EDFA) for the extended number of users, i.e. 32 users. It has also been observed that the XGPON supports reach extendibility up to 80 km by using EDFA. XGPON provides higher bandwidth efficiency per subscriber and with overall improved performance it can accommodates greater number of users i.e. 64 users.

1. Introduction

Due to the rising demands of customers for high data rate, the need for optical access technologies are increasing [1,2]. The local network between the user premises and the Central Office (CO) of the operator is called access network, which utilizes different broadband technologies including Digital Subscriber Line (DSL), Cable Modem, Hybrid Fiber Coaxial (HFC), Broadband over Power Line (BPL) and Fibers to The x (FTTx). The interim solutions like DSL, Cable Modem and HFC have reached to their limits like low data rates and short distance coverage. Therefore, the operators are moving towards ultimate solution of FTTH. The idea of FTTH was developed to satisfy the requirements of upcoming user applications. In contrast to the other broadband technologies, the PON technologies are the best feasible technologies to improve the bandwidth blockage and these are deployed as the primary infrastructure in the FTTH [2,3].

PON is a Point to Multipoint (P2MP) network. It consists of Optical Line Terminator (OLT) situated near the CO and a set of Optical Network Units (ONUs) situated near the end users. The link connecting the OLT with a set of ONUs is an optical fiber and consists of passive optical splitters as shown in Fig. 1 [4,5].

As the network between the OLT and the ONUs does not need any power supply, therefore, it is termed as a passive network. This property makes the network faults tolerant and reduces the operational and maintenance cost [5,6]. For all the downstream transmissions, PON uses a couple of

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1573-4277/

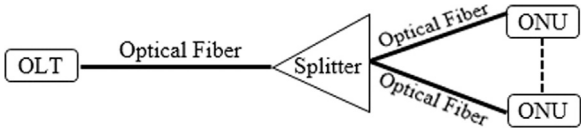

Fig. 1. Fundamental design of PON.

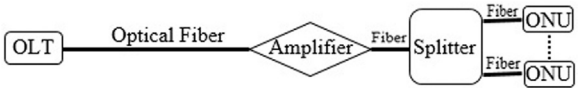

Fig. 2. Reach extended PON.

wavelength bands and a separate wavelength band for the upstream transmissions. For the EPON, 1490–1550 nm wavelength band is used for the downstream transmission whereas 1310 nm wavelength is used for the upstream transmissions with the symmetric data rate of 1.25 Gbps. For GPON, wavelength bands are same as EPON but with different data rate of 2.4 Gbps for the downstream and 1.2 Gbps for the upstream transmissions. In the XGPON, 1575–1580 nm wavelength band is used for the downstream transmissions, whereas 1260–1280 nm wavelength band is used for the upstream transmissions with data rate of 10 Gbps for the downstream and 2.5 Gbps for the upstream transmissions [1]. The block diagram of reach extended PON, by using the amplifier, i.e. EDFA is shown in Fig. 2.

In the reach extended PON, the OLT transmits optical signals towards the amplifier. EDFA amplifier is used for the reach extendibility of PON. This amplifier enhances the power of signals that have been degraded by increasing the length of fiber. These amplified signals are then fed into a passive optical splitter, which takes these signals, and divide them equally in all attached ONUs.

Three major standards based on PON as broadband access network are briefly described as follows:

1.1. EPON

EPON FTTH was adopted by the Institute of Electrical and Electronics Engineers (IEEE) standard, i.e. IEEE 802.3 ah in September 2004 [7]. Ethernet in the First Mile (EFM) introduced the concept of EPON in which a P2MP network topology was implemented with passive optical splitters [8,9].

The EPON is similar to the Asynchronous Transfer Mode Passive Optical Network (ATM PON) but transfers Ethernet frames/packets instead of ATM cells. It provides symmetric data rate of 1.25 Gbps for the upstream and downstream transmissions and covers a distance of 20 km with 32 users. These attributes enable the EPON to broadcast the triple play services like data, voice and video efficiently [4,5,10].

1.2. GPON

GPON standards were ratified by the ITU-T in January 2003 and are known as ITU-T Recommendations G984.1, G984.2, G984.3 and G984.4. Now G984.5 and G984.6 have also been defined. It interfaces to all services which are offered in the Generic Framing Procedure (GFP) and it is the major benefit of GPON [10–12].

Presently, the GPON standard has defined seven types of data rates, but the most popular and widely implemented is the data rate of 2.4 Gbps for the downstream transmission and 1.2 Gbps for the upstream transmissions. The logical reach of the GPON with 32 users is up to 60 km [8].

1.3. XGPON

It is the evolution of GPON, where the X specifies different data rates like 10–100 Gbps. It can co exists with the GPON and uses NRZ coding scheme same like GPON. The XGPON may be the symmetric or asymmetric. Asymmetric XGPON is termed as GPON1 with the data rate of 10 Gbps for the downstream and 2.5 Gbps for the upstream transmissions. Symmetric XGPON is termed as XGPON2 with the data rate of 10 Gbps for the both downstream and upstream transmissions but it needs expensive lasers at the ONUs.

In the XGPON, the wavelength band of 1575–1580 nm is used for the transmission of data/Voice over IP (VoIP) and wavelength band of 1490–1550 nm is used for the transmission of video in downstream, whereas, 1260–1280 nm wavelength band is used for the upstream transmissions [1,8,13].

In the GPON, if there are 32 users connected, then each user will get a bandwidth of about 80 Mbps for the downstream and 40 Mbps for the upstream transmission. While in the XGPON with the same 32 users, each user will get a bandwidth of about 320 Mbps for the downstream and 80 Mbps for the upstream transmissions. The XGPON standards were ratified by ITU-T and these are known as ITU-T Recommendations G987.1, G987.2, and G987.3 [11,14].

2. Comparison of PON technologies

The three PON technologies are compared in two ways:

2.1. General comparison

EPON, GPON and XGPON are assessed generally on the basis of parameters including data packet cell size, maximum upstream and downstream data rates, upstream and downstream wavelength, traffic modes, average bandwidth per user and are shown in Table 1.

2.2. Comparison through simulation

A simulation model has been developed which has included various scenarios of applications like triple play services, i.e. voice, data, and video services. The video is