

Gigabit Passive Optical Network- A Review

Kulwinder Kaur¹, Ramandeep Kaur², Rajandeep Singh³

Department of Electronics and Communication Engineering, Punjabi University, Patiala^{1,2}

Department of Electronics and Communication Engg, GNDU Regional Campus, Fattu DHINGA, Sultanpur, Lodhi³

Abstract: A review on current advancement in gigabit passive optical network technologies to standardized economical system is investigated in this paper and also establishes cost-effective solutions and potential areas of application. The next-generation gigabit passive optical networks are required to provide flexible and various services to users in a cost-effective way. A GPON system is a bi-directional point-to-multipoint network architecture deploying optical access lines between a carrier's central office and customer sites. The GPON standard has more speed as compare to all other PON standards.

Keywords: Gigabit Passive Optical Network (GPON), PON standards, APON, BPON, EPON, GEPON.

I. INTRODUCTION

A PON is a point to multipoint, fiber to the building network design in which passive optical splitters are used to enable a single optical fiber to serve multiple services and users typically 32-128 [1]. Several fiber to the premises or fiber to the home networks have been proposed to offer broadband services to the customers [2]. However access networks have three great necessities they must meet high reliability, performances and be cost efficient. Passive optical networks meet the low cost and reliability requirements. Fiber to the home networks has employed passive optical components at the customer location [3]. The PON standard is shown as fig 1.

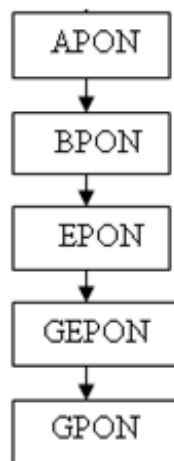


Fig. 1 Standards of PON

Passive optical network (PON) significantly decreases the network operation cost by employing passive optical devices along the optical line [4]. PON is widely known as artistic key for broadband capacity and transmission stability. PON is now widely accepted as optical access network solutions to distribute reasonably high bandwidth to the customers through an optical fiber network infrastructure [5]. PON system can carry various services such as plain old telephony service, voice over IP, data,

video and telemetry [6, 7].The convergence of voice, data, and video on a single WDM-PON is expected to reduce the cost and also promote the creation of new services. However, compared to APON, it may not be able to support (Quality of Services) QoS for application services as well as ATM, as APON has a more sophisticated QoS-supporting scheme inherited from the traditional ATM networks.

The ITU-TG.983.x standard, which is also known as APON (ATM PON) or BPON (Broadband PON) & the ITU-T G.984.x standard, which is known as GPON (Gigabit PON). APON/BPON gives downstream traffic at the rate of 622 Mb/s and upstream traffic at 155Mb/s. GPON allows the downstream rate of 2.488Gb/s and upstream rate of 1.244Gb/s. In 2004, IEEE 802.3 approved Ethernet PON (EPON/ GEPON) standard 802.3ah-2004. Ethernet passive optical networks (EPONs), which represent the convergence of low-cost Ethernet equipment and low-cost fiber infrastructure, appear to be the best candidate for the next-generation access network. Downstream signals are broadcast to all premises sharing a single fiber. Encryption can prevent eavesdropping. It has similar upstream and down stream rates of 1Gb/s. EPON is the attractive access solution and suitable for Fiber to the Home/ Building/ Business Applications with voice, video and data. After this 10Gb/s EPON or 10G-EPON was approved as an addition IEEE 802.3av to IEEE 802.3. After 2008 various companies installed GPON and advanced trial were made in Britain, Saudi Arabia, UAE and USA. Many advancements and developments were done on GPON. And anew generation G.987.x (XG PON) came into existence. It offers downstream traffic at a rate of 10Gb/s and upstream at a rate of 2.5Gb/s. And currently evolving standards work on Next Generation Passive Optical Networks (NGPON2s).

The XGPON and NGPON2 are providing high bandwidth and connecting millions of subscribers and premises worldwide. And now the service providers are looking

beyond this residential triple play services, pointing towards higher value business services.

Gigabit-capable PON (GPON) and Ethernet PON (EPON) are being widely developed as an economical solution for attractive triple-play services. Gigabit PON is high capacity PON as compare to the APON and EPON.

GPON can transport Ethernet, as well as ATM and TDM traffic by GPON encapsulation method (GEM). GPON standard has defined different transmission rates for downstream and upstream. But most often vendors offer 1.2Gb/s upstream and 2.4Gb/s downstream [8]. And operating wavelength range for upstream is 1260-1360 and for downstream is 1480-1500. And the wavelength range 1550-1560nm can be used for video distribution. In GPON upstream bandwidth allocation is done with Transmission containers (T-CONT). T-CONTs are used to carry the data from ONU and maintain the quality of service as well as improve the bandwidth. OLT allocates the bandwidth to ONUs for the upstream operation. This method of quick adoption of the bandwidth by ONU is also called Dynamic Bandwidth Allocation (DBA) [9]. Downstream operation is just a broadcast of frames in TDM manner. Every ONU accepts only the frames which are intended. Each frame is encrypted and can only be accessed by the intended ONU. GPON has overcome EPON in many areas of services, line rate options and security [10-11]. GPON system is a bi-directional point-to-multi point network architecture deploying optical access lines between a carrier's central office and customer sites [12]. GPON is the most widely deployed in today's fiber-to-the home (FTTH) networks. Fiber-to-the-home (FTTH) networks are being installed in point-to-point (P2P) and point-to-multipoint (P2MP) time-multiplexed passive optical network architectures [13-14]. Gigabit-capable passive optical network (GPON) is the basic technology to support the structure of the next-generation fiber to the home (FTTH) system and supports multi-speed rates, full services, high efficiency and other advantages, and considers the suggestions of service providers at the same time [15-16].

II. STRUCTURAL DESIGN OF GPON

A typical GPON architecture consisting of one optical line termination (OLT) located at the Central Office (CO) and multiple optical network units (ONUs) at the user premises.

GPON solutions focus on how the OLT distributes slots of upstream frames among the queues of ONUs in a periodic basis. The architecture consists of three main network elements as:

- Optical Line Terminal (OLT)
- Passive Optical Splitter
- Optical Network Unit (ONU)

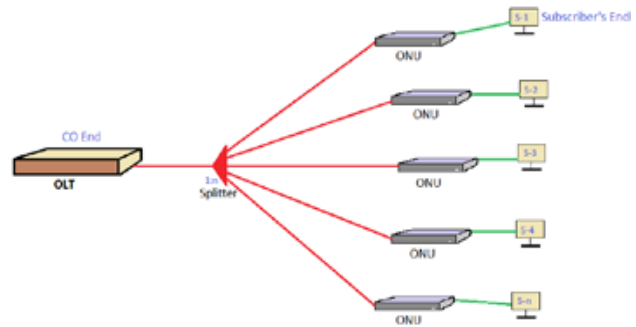


Fig. 2: Network elements of GPON

Optical Line Terminal is a network element consists of PON line card. It is usually placed in the central office or the Local Exchange. It works as an interface between PON network and core network. The transmitter comprises of data source, NRZ rectangular driver, laser source and optical amplitude modulator. Data source generates a binary data stream. Laser block shows simplified continuous wave Lorentzian (CW) laser. Optical Splitter is a passive device which splits the optical power. It consists of single input and multiple outputs. And the signal not only travels in one direction, but can also travel from output to input. Optical Splitter is used to connect an optical port of OLT with many subscribers. And it is present anywhere in between the Central Office and Subscriber Premises. Optical splitter component simulates an "Ideal" optical splitter.

Optical Network Unit is an interface to the network at the customer/subscriber end. At one side it connects to the OLT via Optical Splitter and on the other side to the subscriber directly, hence providing the subscriber a true triple play service of voice, video and data. At every subscriber's end an individual ONU is required. An ONU receiver consists of the PIN diode, Bessel filter. Photodiode works like a PIN photodiode. The photo detection method generates an output current depends on the input power and dark current.

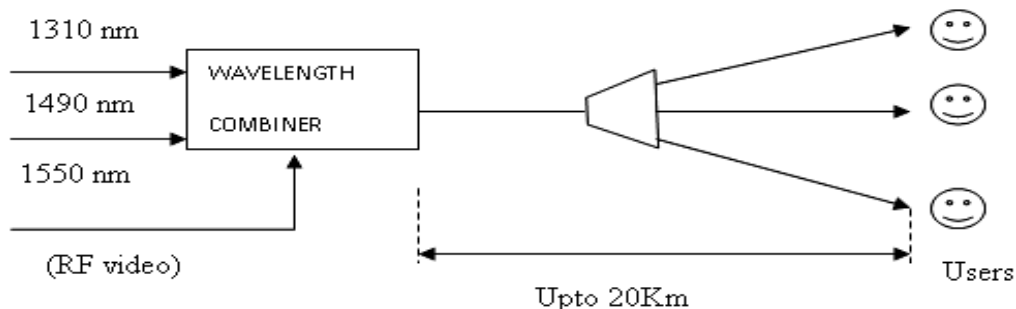


Fig 3. Typical GPON architecture

In Fig. 1, the downstream wavelengths destined for ONU 1, ONU 2 and ONU n are denoted $\lambda_1, \lambda_2, \lambda_3 \dots \dots \dots$, and λ_n respectively. Likewise, upstream wavelengths from ONU 1, ONU 2, and ONU n that are destined for the CO are

denoted $\lambda_1', \lambda_2' \dots \dots \dots$ and λ_n' respectively. In atypical WDM PON, wavelength channels are spaced 100 GHz (0.8 nm) apart.

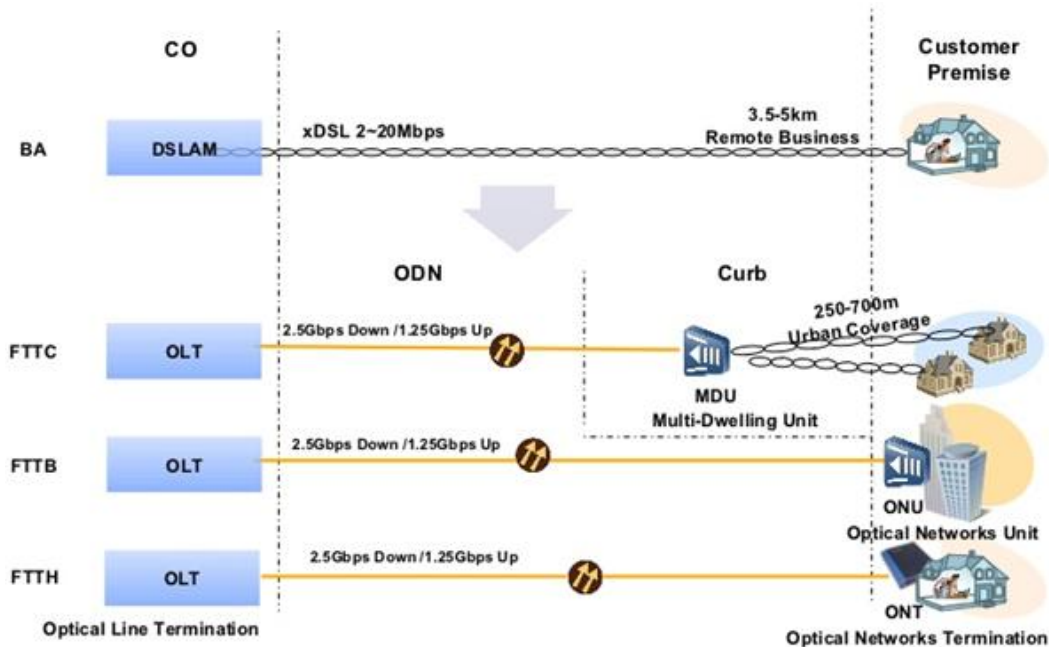


Fig.4 Architecture of GPON

ONU receives down-stream signals on λ_n and transmits upstream signals on λ_n . The capacity on these wavelengths is solely dedicated to that ONU. Commonly cited benefits of WDM-GPON resulting from this unique feature include protocol and bit-rate transparency, security and privacy, and ease of upgradeability and network management. GPON resulting from this unique feature include protocol and bit-rate transparency, security and privacy, and ease of upgradeability and network management [17].

The path going from OLT to ONU is called downstream. And its reverse path i.e. from ONU to OLT is referred to as Upstream. A single fiber is used to carry both sided signals. The downstream signal transmitted by the OLT when arrives at the Passive splitter, the same signal is sent towards every subscriber. But while on the upstream, all subscribers send different signals, which when reach the splitter, they get superimposed. This superimposed signal is received at the OLT. To multiplex the signal on to the same fiber, we use different access schemes. Coarse Wavelength Division Multiple Access (CWDM) is used in PON. The CWDM performs two functions. One is to ensure that only the desired wavelengths are used by filtering the light. And other is to multiplex or demultiplex the wavelengths. The 1310-band and 1490-band are used which are further divided into smaller bands of 20 nm width. A Coarse Wavelength Division Multiplexer is used at every end of the network to insert and extract the signal from the fiber. In downstream transmission same signal reaches at every subscriber. Each subscriber extracts its

relevant signal from the fiber. While, during upstream operation, in addition to CWDM, another multiplexing method TDMA is used to prevent superimposition of the signals at Passive Optical Switch.

III. GPON FUNCTIONING

GPON system uses the Wavelength division multiplexing technology to transmit data bi-directionally (upstream and downstream) over a single optical fiber. To separate the Tx and Rx signals of different users over the same optical fiber, GPON uses the broadcast technology for downstream data transmission. The Time Division Multiplexing Access technology is used for upstream data transmission [18]. GPON is the best choice for the triple play service Such as high-speed Internet, IP telephony, and broadcasting video [14]. GPON uses GEM (GPON Encapsulation Method) as a method which encapsulates data over GPON.

Table 2 GPON bit rate

Transmission Direction	Bit Rate
Downstream	1244.16 Mbit/s
	2488.32 Mbit/s
Upstream	155.52 Mbit/s
	622.08mMbit/s
	2488.32 Mbit/s

Although any type of data can be encapsulated, actual types depend on service situation. GEM provides connection-oriented communication [11].

1. Downstream GPON Frame format:

Downstream traffic is broadcasted from the OLT to all ONUs in TDM manner. Every ONU must take into account only frames intended for him what is assured by encryption. The downstream frame consists of the physical control block downstream (PCBd), the ATM partition and the GEM partition. The downstream frame provides the common time reference for the PON and provides the common control signaling for the upstream. The frame is 125 μ m for both downstream data rates. The downstream GPON frame consists of a header and a payload section. The header is called the Physical Control Block downstream (PCBd). A payload section contains the actual data which has to be transferred. The PCBd length range is the same for both speeds and depends on the number of allocation structures per frame. If there is no data for sending, downstream frame is still transmitted and used for time synchronization.

2. Upstream GPON Frame format:

In the upstream direction, each ONU has its own optical transmitter to communicate with the OLT. Since there is only one optical receiver at the OLT, ONUs need to take turns to send their data to the OLT [15]. Upstream traffic uses TDMA, under control on the OLT located at the CO, which assigns variable time length slots to each ONU for transmission of its data bursts. The upstream frame consists of multiple transmission bursts. Each upstream burst contains at a minimum the Physical Layer Over head (PLOu). Besides the payload, it may also contain the PLOAMu (Physical Layer Operations, Administration and Management upstream), PLSu (Power Leveling Sequence upstream) and DBRu (Dynamic Bandwidth Report upstream) sections. The frame length is the same as in the downstream for all rates. Each frame contains a number of transmissions from one or more ONUs. The bandwidth map dictates the arrangement of these transmissions. During each allocation period according to the OLT control, the ONU can send from one to four types of PON overheads and user data.

IV. ADVANTAGES OF GPON

GPON reduces the reliance on and cost of physical equipment in the fiber distribution network. No physical switches are necessary, because a single fiber can be dividing into many dissimilar signals, less fiber is required in the network. A GPON network is thus cheaper and quicker to construct. As an illustration, the cabling and splitters of a typical GPON costs 40-50% less than copper access lines. GPON offers higher bandwidth delivery – it has a 2.4 Gbps downstream capacity and a 1.2 Gbps upstream capacity. It uses larger, variable length packets to transmit data and employs frame segmentation to give higher quality for voice and video traffic. The GPON

standard is more than speed all other PON standards. In the GPON distance between OLT and ONU/ONT can be up to 20km. GPON provides optical split ratio 1:32 or 1:64. That means each fiber can serve up to 32 or 64 subscribers. Split ratios up to 1:128 are possible in some systems. GPON is highly secure due to the elimination of EMI radiation associated with traditional copper wired facilities. Enhanced security for GPON at the physical layer, data layer and the end user port.

GPON network is less susceptible to physical equipment maintenance. The design specifications of GPON were ease of troubleshooting. Because of the number of passive components, it tends itself more easily to centralized management, compared to an Ethernet network. It is also easier to make high volume moves, changes and additions, with less field technician support required. GPON offers less costly connections than a standard Ethernet. By using a single fiber cable to serve upto 32 users, the need for hardware decreases. This reduces cost and space necessary to host larger amounts of hardware to support the network. The technology has fewer electrical and moving parts than in the standard network, which lowers the risk of downtime.

V. RELATED WORK

Ki-Man Choi et.al [19] proposed an efficient evolution method from a time-division multiplexing passive optical network and demonstrated for a next-generation PON. Each user on the TDM-PON has a dedicated data rate of 40Mb/s equal to only 1/N of the total downstream data rate of 1.25 GB/s. The proposed evolution scenario does not interfere with both the existing PON infrastructure and the wavelength band. In addition, user-by-user evolution is feasible. Thus, it is possible to provide a smooth evolution from the TDM-PON to the next-generation PON.

Lingbin Kong et.al [20] demonstrated a novel dense wavelength division multiplexing passive optical network system which provided bidirectional transmission of simultaneous download, upload and video select cast services using single light source in central office. The experiment results showed that for 10 Gbps DL, 2.5 Gbps VS and 1.25 Gbps UL services over 20 km transmission, the system had good performance with power penalties less than 0.5 dB.

McDonna [21] gives a brief overview of the type of optical components that are required for Local Loop transmission network architectures such as Fiber to the Home (FTTH). It discusses some of the technology issues and presents a number of recent technology developments which should help enable commercial feasibility of lower cost optical components.

Jong-Won Kim [22] describes an optimized ATM-PON based FTTH access network to provide residential subscribers with full services. Upto now, a major obstacle

to the deployment of FTTH has been the expensive cost of the optical module and fiber. The PON (passive optical network) architecture provides a common platform towards achieving a cost effective optical access network including FTTH. We propose an optimized architecture of an ATM-PON based FTTH access network to provide residential subscribers with full services economically.

Frank Effenberger [23] did a review of PON including G-PON, E-PON and advanced PON. They outlined current and next generation of PON technologies. They mention that deployment of PON grows into many millions of home served. Ten year old copper network carrying end of PON has begun.

Ken-ichi Kitayama [24] studies about data transfer up and down link using gigabit symmetric system. It introduced the architecture using WDM inter channel. Basically discuss about OCDMA (optical code division multiple access) and provide the powerful alternative of TDMA and WDM in FTTH system.

Jensen, M. Nielsen [25] presented concerning the coverage of households for a variety of xDSL technologies. Cost estimation has been made when expanding the current copper infrastructure to provide VDSL connections to all households in a municipality. This is compared to the price of providing fiber to the home (FTTH) in the same area. Furthermore, the prices of providing FTTH to the coverage areas of those comparable with VDSL are estimated.

Benyuan Zhu et al. [26] described a 1: n 10G PON and GPON system using 1: n splitter and an optical amplifier. An n=8 10G PON overlay of GPON link with 20 km feeder fiber and 1:32 way splitter using a bidirectional discrete Raman amplifier.

Derek Nettet et al. [27] presented an experimental demonstration of GPON system with reach extension up to 50 km for 1:64PON split using Raman amplification of the upstream signal with wavelength stabilized pump laser.

Benyuan Zhu et al. [28] described 10G ON and GPON compatible reach extender using Raman amplifications. The author demonstrated operation of coexisting 10 G-PON and GPON over 50 km fiber using 96 way splitter.

Naresh Kumar [29] designed a GPON system for 60 km transmission distance at data rate of 2.5 Gbps with and without square root module. It has been observed that square root module leads to an efficient improvement in quality factor which further helps in increasing the transmission distance of GPON system.

VI. CONCLUSION

In this paper, we presented a comprehensive review on technologies for the GPON. We focused on various

aspects of device technologies, network architectures, working and services for the WDM-GPON. We observed that Gigabit Passive Optical Networks are very cheap and can provide better services as compare to copper access networks. GPON is also better option for access networks because it is very cheaper than active optical networks.

REFERENCES

1. Rajneesh Kaler, Pradeep Teotia, R.S. Kaler, "Simulation of FTTH at 10 Gbit/s for 8 OUT by GE-PON Architecture" *Optik*122, pp. 1985-1989,2011.
2. Hui Yang, Juhao Li, Bangjiang Lin, Yangsha Wan, et.al, "DSP-Based Evolution From Conventional TDM-PON to TDM-OFDM PON Journal of Lightwave Technology, vol.31, no.16, pp. 2735-2741, 15 August 2013.
3. Deeksha Kocher, R.S. Kaler, Rajneesh Randhawa, "Simulation of fiber to the home triple play services at 2Gbit/s using GE-PON architecture for 56 ONUs" *Optik* 2013.
4. R.S. Kaler, T.S. Kamal, A.K. Sharma, "Approximate and exact small signal analysis for single mode fiber near zero dispersion wavelengths with higher order dispersion" *Fiber and Integrated Optics* 21 (5), pp. 391-415, 2002.
5. Yejun Liu, Lei Guo, Cunqian Yu, Yinpeng Yu, et.al, "Planning of survivable long-reach passive Optical network (LR-PON) against single shared-risk link group (SRLG) failure" *Optical Switching and Networking* 2013.
6. Huda Saleh Abbas n, Mark A. Gregory, "The next generation of passive optical networks: A review" *Journal of Network and Computer Applications*, pp.1-22, 2016.
7. Fady I. El-Nahal, Abdel Hakeim M. Husein, "Bidirectional WDM-PON architecture using a reflective filter and cyclic AWG" *Optic* 122,pp.1776-1778, 2011.
8. Elaine Wong, "Next-Generation Broadband Access Networks and Technologies" *JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 30, NO. 4, FEBRUARY 15, 2012.*
9. M.F. Huang, D.Qian, and N. Cvijetic, "A novel symmetric light wave centralized WDM-OFDM PON architecture with OFDM remodulated ONUs and a coherent receiver OLT," in *Proc. Eur. Conf. Opt. Commun.*, 2011, paper Tu.5.C.1
10. Fröhlich B, Dynes JF, Lucamarini M, Sharpe AW, Tam SW, Yuan Z, Shields AJ. Quantum secured gigabit passive optical networks. *Opt. Fiber Commun. Conf.* 2015.
11. N. Cvijetic, M.F. Huang, E. Ip, Y.K. Huang, D.Qian and T.Wang, "1.2 Tb/s symmetric WDM OFDMA- PON over 90 km straight SSMF and 1:32 passive split with digitally-selective ONUs and coherent receiver OLT," in *Proc. Opt. Fiber Commun. Conf. Nat. Fiber Optic Eng. Conf.*, Mar. 2011, paper PDPD7.
12. N. Cvijetic, D. Qian, and J. Hu, "100 Gb/s optical access based on optical orthogonal frequency-division multiplexing," *IEEE Commun. Mag.*, vol. 48, no. 7, pp. 70-77, Jul. 2010.
13. Tashiro T, Kuwano S, Terada J, Kawamura T, Tanaka N, Shigematsu S, Yoshimoto N. A novel DBA scheme for TDM-PON based mobile front haul. *Opt. Fiber Commun. Conf.* 2014.
14. N. Kataoka, G. Cincotti, N. Wada, and K. Kitayama, "Demonstration of asynchronous, 40 Gbps 4-user DPSK-OCDMA transmission using a multi-port encoder/decoder," in *Proc. Eur. Conf. Opt. Commun.*, 2011, paper Tu.C.4.
15. S. Smolorz, E. Gottwald, H. Rohde, D. Smith, and A. Poustie, "Demonstration of a coherent DWDM-PON with real-time processing," in *Proc. Opt. Fiber Commun. Conf. Nat. Fiber Optic Eng. Conf.*, Mar. 2011, paper PDPD4.
16. H.G. Bach, R. Kunkel, G. G. Mekonnen, R. Zhang, and D. Schmidt, "100 Gb/s photoreceivers for coherent and direct detection," in *Proc. Opt. Fiber Commun. Conf. Nat. Fiber Opt. Eng. Conf.*, Mar. 2011, paper OML1.
17. Chow C, Sung J, Yeh C. A convergent wireline and wireless time-and-wavelength- division-multiplexed passive optical network. *IEEE, Photonics*, pp. 1-7, 2015.
18. Sumanpreet, Mr. Sanjeev Dewra, "A review on Gigabit Passive Optical Network (GPON)" *International Journal of Advanced*



- Research in Computer and Communication Engineering, Vol. 3, Issue 3, March 2014
19. Ki-Man Choi, Sang-Mook Lee, Min-Hwan Kim, Chang-Heel Lee, "An Efficient Evolution Method from TDM-PON to Next-Generation PON" IEEE Photonics Technology Letters, Vol. 19, No. 9, May 1, 2007.
 20. J. Li, G.X. Shen, "Cost minimization planning for green field passive optical networks", Journal of Optical Communications and Networking 1, pp. 17–29, 2009.
 21. McDonna, A.P. MacDonald, B.M. "Optical component technologies for FTTH applications" IEEE Conference Publications, pp.1087 – 1091, 1995.
 22. Jong-Won Kim Information, Communications and Signal Processing, ICICS, IEEE Conference Publications, pp. 1800 – 1804, 1997.
 23. Frank Effenberger "Next generation PON: lessons learned from G-PON" 35th European Conference on Publication, pp. 1 – 3, 2009.
 24. Ken-ichi Kitayama, "OCDMA over WDM PON—Solution Path to Gigabit-Symmetric FttH" Journal of Light wave Technology, Vol. 24, No. 4, April 2006.
 25. Jensen, M. Nielsen, R.H. Madsen, O.B. "Comparison of Cost for Different Coverage Scenarios between Copper and Fiber Access Network", IEEE Conference Publications, pp. 2015 – 2018, 2006.
 26. B. Zhu, D. Au, F. Khan, Y. Li, "1:n 10G-PON Overlay of GPON link using Bidirectional Raman Amplifier," In Proceedings of IEEE Optical Communications, 38th European Conference and Exhibition, 2012.
 27. Nettet, K. Farrow, P. Wright, "Bidirectional, Raman Extended GPON with 50 km Reach and 1:64 Split Using Wavelength Stabilized Pumps," In Proceedings of IEEE Optical Communications, 37th European Conference and Exhibition, 2011.
 28. B. Zhu, D. Au, F. Khan, Y. Li, "Coexistence of 10G-PON and GPON Reach Extension to 50-km with Entirely Passive Fiber Plant," In Proceedings of IEEE Optical Communications, 37th European Conference and Exhibition, 2011.
 29. N. Kumar, "Improved performance analysis of Gigabit passive optical networks," Optik 125, pp. 1837– 1840, 2014.