Broadband Passive Optical Networks (BPON): A Review

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Abstract – Passive Optical Networks (PON) are significant research interest at present for both the industry and the academia considering its successful deployment in the metro networks. The research is focused on enhancing the performance of the access segment of the passive optical networks. One of the main purposes of any communication networks is to reach the end users who are situated far away. BPON (Broadband Passive Optical Networks) have been evaluated in both upstream and downstream for their capability to reach the end users. Various parameters as fiber length, the number of users, data rate, wavelength, coding techniques and Bit Error Rate (BER) are considered while evaluating the BPON networks. This paper provides an insight into the research that has already been done about the BPON networks. It includes a brief history of PON, its types, BPON, architecture, applications and much more. The paper will assist the researchers to review the work that has been done in this field.

Index Terms – Broadband passive optical networks, Optical Line Terminal, Optical Network Units, PON.

1. INTRODUCTION

Passive optical network abbreviated as PON is a system that helps to bring the optical fiber cabling as well as signals to the way to the users. PON architecture consists of different elements that include OLT (Optical Line Terminal), ONUs (Optical Network Units), etc. OLT is located at the office of the communication company. On the other hand, various ONUs are located near the end users [1]. Approximately 64 ONUs can be easily connected with one OLT PON port. The use of word "passive" describes that the optical network does not require any power and the active electronic part when signal start propagating through the network [3].

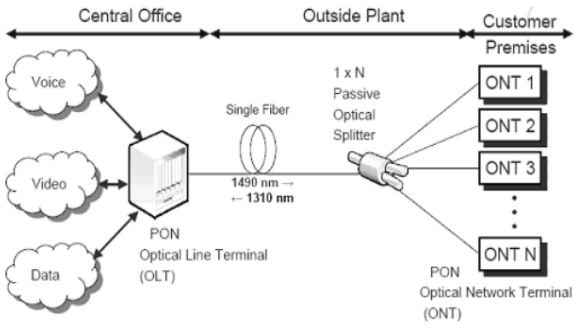

Figure 1: Schematic of PON

In simple words, it can be said that PON is a network of fibers that only uses the fiber and various passive components such as combiners and splitters instead of using active components such as shaping circuits, and repeaters in the network. But the main limitation of such network is the range of coverage which is limited by the signal strength [2].

Various telecommunication companies are using the PONs to provide numerous multimedia services such as Internet service, VoIP phone, and TV. Along with this, high data rate allows fast video streaming. The network is very simple because of the deployment of passive components that are small, cheaper and easy to replace. With the increase in demand for wide and faster internet service, the PONs are also in high demand [8].

2. TYPES OF PASSIVE OPTICAL NETWORKS

The Passive optical networks can be divided into different types according to the different generation. The PON types include the following:

A. Past generation PONs.

A PON and BPON are the types of passive optical network that was evolved in the 90s. APONs (Asynchronous Transfer Mode Optical networks) was the first system that accomplished huge deployment in the commercial areas. In this, an electronic layer is built on the ATM (Asynchronous Transfer Mode). On the other hand, BPON is the enhanced sequence of the APON. BPON offer high data rate as compared to APON. It provides speed up to 622 Mb/s. The meantime also increased the protection, dynamic bandwidth, and various other functions [9].

B. Current Generation PONs.

EPON and GPON are referred as the current generations PONs. EPON (Ethernet Passive Optical Network) support transmission rate of 1.25 Gbit/s in one direction while using the IEEE 802.3ah protocol. On the other hand, GPON (Gigabit Passive Optical Network) support 2.5 Gbit/s while using the protocol specified in the ITU-T G. Thus, both the EPON and GPON are based upon the IEEE 802. 3ah and ITU-T G.984.x standards respectively. Therefore, GPON and EPON are the PON types that are being used at present. We are trying to increase the data rate through the next generation PON types described in the upcoming section [4].

C. Next-generation PONs

Recently few recommendations were developed by the ITU-T standards development activity for providing definitions, service requirement, consent, and specifications of PON system that can transmit at the data rate of 10 Gigabit per second. Therefore, there are chances of the evolution of 10G PON, XG-PON 1 and XG-PON 2. There is the wide scope of communication in using the passive optical networks. WDM-PON (Wavelength Division Multiplexing-Passive Optical Networks) are also considered as the main base for the future PONs [12].

As this paper focus on the deployment of the broadband passive optical networks to serve a huge number of users, all the next sections would provide insight into the BOPN technology, its architecture, and applications.

3. BROADBAND PON

BPON was the first PON standards which were agreed by the ITU in 1999. The complete working of the BPON standards is based on the G.983 series given in the ITU-T recommendations. ATM is signaling and transference protocol as described by the G983 series of ITU-T recommendations. Previously, the access network that was based on the BPON standard were called APONs. The BPON standard was endorsed by various component sellers and network suppliers that collaborated in the FSAN group. Simply, the fact is that it was the FSAN group that suggested using the ATM protocol to carry subscriber data [10].

Broadband PON which is one of the past generation types of PON has the capability to support high data rate, high-speed voice, and video services to the end users at small businesses as well as residential homes. Gigabit PON and Ethernet PON which are two other types of PONs also offer high data rate. But the most beneficial factor about using the Broadband PON is the reduced cost. The cost of the maintenance between the users and the central office is affordable [6].

There are numerous telecommunication services that are using the BPON to increase the FTTP (Fiber-to-the-premises) networks. It is because of the wide embedded switching structure of the carriers. The major benefits of using the ATM networks include the flexible and scalable traffic management along with robust QoS (quality of services) features [13].

4. BPON ARCHITECTURE

The Fig. 2. Represent the generic architecture of the Broadband Passive Optical Network. It is apparent from the figure that a typical BPO architecture comprises maximum 20 km distance between the Optical Network Unit (ONU) and Optical Line Terminal (OLT). An architecture might consist of symmetric or asymmetric PON with a maximum of 622 Mb/s and 1.244 Mb/s for upstream and downstream respectively to the customers [1].

As shown in Figure 1, a passive optical splitter is used between the central office and the user sites. Due to the deployment of the passive optical filter in the BPON the maintenance free operation is feasible. It is one the most cost effective way of communication among different PON types.

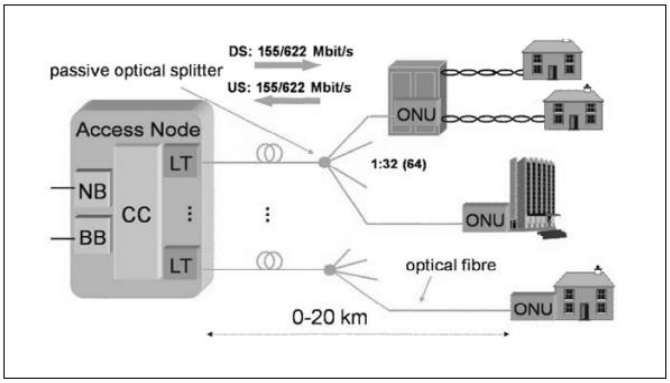

Figure 2: Broadband PON Architecture [1].

5. OPERATIONAL FEATURES OF BPON

There are three major factors used in the BPON to accomplish service performance of high quality. These three essential factors include the organization of the buffer content, proper synchronization of the upstream traffic and effective bandwidth utilization. These three are the unique operational features of BPON.

A. Video Traffic

The transmission of the video relies on one component called as a head-end transmitter. The main function of the head-end transmitter is to receive content from different digital as well as analog sources [5]. The transmission system uses the same standard that CATV utilize for distributing the video traffic to the subscribers. The voice traffic can be easily transmitted using the same 1490 nm fiber as it uses different wavelength. As a consequence, we can use any coding technique for the video. It could be quadrature phase shift keying (QPSK), 64-point quadrature amplitude modulation (QAM 64), 256-point quadrature amplitude modulation (QAM 256), and others [11].

B. Data and Voice Traffic

The optical line terminal which is situated in the central office is accountable for the complete interface between the users and the exchange carrier network. The information is transmitted to all ONTs by the optical line terminal in the form of ATM cells utilizing the TDM (Time Division Multiplexing) structure. The information which is transmitted by the OLT to the ONUs is in the form of data or voice which was received from the carrier network. There are total three options in the downstream

direction of the BPON networks which include 155.52, 622.08 and 1244.16 Mb/s.

6. LITERATURE REVIEW

S.F. Shaukat, U. Ibrahim and S. Nazir [1] presented the analysis of the Broadband Passive Optical Networks. BPONs are used in industry and academia after the successful development of the optical fiber in the metro networks because these types of the network have the capability to access network. The main motive of the research was to improve the access segment performance and to provide the highly scalable solutions to the service providers so that fiber reaches to the end user. They also evaluate the Broadband Passive Optical Network (BPON) for upstream and downstream traffic so that they can achieve their target. They analyzed the system by wavelengths, the number of users, coding technique, fiber length, and data rates. The research also analyzed their effect on the key performance parameter Bit Error Rate (BER) with the help of OptiSystem Simulator version 7. The most important parameters including the number of user, performance, system, and scalability have been optimized with the help of OptiSystem version 7. From the result, it is concluded that the number of users is doubled in the downstream direction when the lower data rate is switched so that they can maintain the identical effects of Bit error rate over the optical fiber length. The higher data rate degrades the performance of the system over the different length of the fiber, and the number of users is constant in the downstream direction. It is also observed from the result that data rate is decreased by increasing the length of the fiber, so that same value of bit error rate is achieved and on changing the length of the fiber, an inverse exponential relation is developed when the fiber split ratio is increased. The Research also develop the relation between accommodated users and the data rates by testing the relation using the coding techniques such as Non-Return-to-zero (NRZ) and Return-to-Zero (RZ). From the test of the relation, it is concluded that the relation between accommodating users and data rate was unaffected by the coding formats which are used in it. Use of the different data rates affects the performance of the network when the length of the fiber is changed [1].

S. Chi, C. H. Yeh and C. W. Chow [2] demonstrated about broadband access technology which is used for the passive optical network. For describing the passive optical network, they used four different fiber access network technologies. They firstly designed the power signal power equalizer with the help of FP-LD in optical line terminal which is applied to the TDM-PON and a dynamic upstream power of 2 dB having the range from -5 to -25dBm which retrieved the maximum power variation of 1.7dB. For the passive optical network, the main issue is related to the fiber fault protection. They also investigated about TDM/PON/WDM systems which are simple and cost-effective with the self-protected function. After that, the research focus on describing RSOS-based Colorless WDM-PON. For this, the study proposed the cost-effective CW light source into the RSOA for 25 GB/s for the upstream in both WDM-PON and self-healing mechanism against the fault of the fiber. At last, it was investigated about both downstream and upstream traffic of 4 GB/s OFDM-QAM in the long-reach of TDM PON/WDM systems which are under the transmission of 100km without the dispersion compensation. From the result, it was concluded that the key access technologies are useful for next generation FTTH broadband networks [2].

*F. Effenberger, H. Ichibangase, and H. Yamashita [*3] presented the advances in the broadband passive optical network technologies. The new technological advancements extend the capabilities of the basic Broadband Passive Optical Network (B-PON) which are described in ITU-T. They also describe the new three technologies such as survivable networking, dynamic bandwidth division multiplexing, and wavelength division multiplexing. The addition of these new technologies in the Broadband Passive Optical Network family of solutions results in increasing their utility by enhancing their reliability, efficiency, and capacity [3].

C. Chen, et al. [4] experimentally verified and theoretically analyzed the reconfigurable and scalable generation of the flat optical comb with the help of TCG (Tunable comb generator). For the scalable and reconfigurable generation of the flat optical comb, a tunable comb generator is cascaded with a single-phase modulator with the help of two identical intensity modulators. To determine the optimized condition for flat optical comb generation, theoretical analysis is performed with the help of TCG and scalability of the optical comb is also analyzed under the optimized conditions. The result of the experiment proves the theoretical prediction of scalability and flatness of the obtained optical comb. They also described stability and reconfigurability of the obtained optical comb in the verification of the experiment. The feasibility of the flat comb as WDM optical source for the system of WDM-RoF and hybrid WDM-OFDMA-PON are successfully proved in the demonstrations of the performed experiments. The average Rx sensitivity for 17 WDM channels is 18.5 dBm at the 10^{-9} in the WDM-RoF system after 25 km SSMF. In the result, the power penalty has been observed of about 1.3 DB for the wireless and wired access in the system of hybrid WDM-OFDMA-PON [4].

H. S. Abbas and M. A. Gregory [5] provides the survey of the research in the next generation of the passive optical networks. The modifications of each standard require the physical layer. They also highlight the multiplexing techniques and the requirements for the NG-PON2 and then determines its advantages and disadvantages. Hybrid technologies are used to fulfill the requirements of the NG-PON2. Passive optical networks have the popular fiber access network solution due to its transparency, energy savings, cost effectiveness, and higher security in comparison to the other network access. Passive

optical network removes the requirement for the power-feeding in the fiber distribution network by utilizing the passive low-power components. They also presented the three different generations of passive optical networks which are based on the Gigabit PON and Ethernet PON standard. The first generation PON is described regarding physical and data link layer. The main objective of their research was to review the technologies which are proposed for the next generation PON (NG-PON2). The hybrid method combines the multiple technologies and introduces a solution, which helps in removing the limitations so that the overall performance of the system will be improved [5].

N. Ghazisaidi, M. Scheutzow, and M. Maier [6] presented the survivability analysis of the next-generation passive optical networks and the fiber-wireless access networks. The passive optical networks are evolving into the next generation PON so that they can achieve the wavelength channel counts, higher data rates, extended coverage, and a number of optical network units. NG-PONs face many issues or challenges due to the increasing number of stages in order to provide the survivability same as conventional PONs without increasing the constraints of the budget of the cost-sensitive access networks. Partial optical protection with the interconnecting subset of ONU with the help of wireless mesh network front end provides the best solutions to solve the problem of NG-PONs survivable in respect of cost-effectiveness. The research also presented the analysis of survivability of NG-PONs and hybrid fiber-wireless access network with the help of optical and wireless protection. They also proposed various schemes for wirelessly upgrading the subset of ONUs so that they can investigate the performance for wide range failure of fiber link scenarios and various topologies of NG-PON [6].

M. D. Andrade, et al. [7] demonstrate about the passive optical network (PON) that support the networking. They firstly described all the issues on the passive optical network which support the networking. After that, they described the optical networking in all the segments of the global communication network and also described the importance of the passive optical network to access the network and for supporting the communication network technologies. The issues of the optical switching and networking help in proving the snapshot of the state-of-the-art in the passive optical network supported networking [7].

A. Kokangul and A. Ari [8] described the optimization of the passive optical network planning. The problem of network planning involves the large capital investment which can be formulated as the organization problem in order to decrease the first installed cost. They also described the passive optical network planning problem which is based on the residential area in Adana situated in Turkey in which four there are four primary node locations, twenty-eight customers, and twenty secondary node locations. For optimizing the position of primary and secondary nodes and their split levels, they use the techniques of mathematical modeling and genetic algorithm. They also assign the customers to secondary nodes and from secondary nodes to primary nodes using some constraints like technical characteristics and system attenuations of all the equipment [8].

D. K. Mynbaev [9] presented the broadband optical access components for the passive optical networks. The requirement for the broadband access is appreciated by the telecommunication industry and by various broadband access networks. The wired optical networks solved all the problems related to the access of broadband network. They described the passive optical networks because it is the major technology which we are using today. They also described the components of the passive optical networks and then give a brief survey on the passive optical network protocols, standards, topologies, operations, and architecture. At last, they analyzed the different elements and structure of the passive optical network components to describe its technical characteristics [9].

E. Wong [10] present the survivable architecture for time and wavelength division multiplexing passive optical networks. The increased network reaches to the next-generation wavelength division and time multiplexing PON which are used for the fault detection and for the restoration of the services for its users. The direct applications, which are using in the conventional PON to TWDM-PONs are unsuitable as they lose the signal in the upstream transmission to trigger the protection switching. TWDM-PONs are used for loss of upstream transmission, sleep mode optical network units and for trigger the protection switching. They require the monitoring modules for the most sensitive detection of the fault. Three survivable architectures are used to eliminate this issue from the TWDMPON specifications. These architectures detect and protect the switching from multipoint failure, and they do not rely on the upstream transmission for LOS activation [10].

7. RESULT AND DISCUSSION

Table 1 provides insight into the research findings. It is an overview of the different methods used and associated results in different researches.

Table 1: Research Findings

Year	Researchers	Algorithm/ Method	Results/ Solution
2001	F. Effenberger, H. Ichibangase, and H. Yamashita [3].	The research focussed on deliberating the three technologies associated with BPON that	Apart from describing the three technologies in BPON, the research suggested different

		includes dynamic band-Width assignment, wavelength division multiplexing, and survivable networking.	innovations to enhance the performance of the BPON.
2009	S. Chi, C. H. Yeh and C. W. Chow [2].	Reviewed different technologies for FFTH in fiber communication. These include RSOA-based Colorless WDM-PON, fiber access network along with self-healing function, upstream equalization technique and OFDM-QAM WDM/TDM PON.	The research demonstrates the potential capabilities and limitation of all the reviewed technologies.
2011	S.F. Shaukat, U. Ibrahim and S. Nazir [1].	Evaluated the BPON for both upstream and downstream to achieve the target to provide of covering the maximum number of users.	The result of the study represents that doubling the number of users make it necessary to decrease the data rate to maintain the similar BER.
2014	M. D. Andrade, M. Maier, M. P. Mcgarry, and M. Reisslein [7]	Describes the optical networking and significance of PON in the access networks.	They provided several suggestions and reviews for the future of the PON networks.
2015	C. Chen, C. Zhang, W. Zhang, W. Jin, and K. Qiu [4].	Verified the feasibility of the tunable generator for increasing the scalability and reconfigurability of optical comb.	The results of the experiment showed the similarity with the theoretical prediction.
2016	H. S. Abbas and M. A. Gregory [5].	Reviewed three different technologies of PON. Along with this, reviewed the pros and cons of next generation PON-2.	The areas where NG-PON-2 needs improvement includes the cost, power consumption, reach and capacity.

8. CONCLUSION

Presently, Passive optical networks are completely supported by the commercially available standards and technologies. Still, there are some glitches for the appropriate adaptation of passive optical networks in the broadband services. This paper provides great insight about the PON and BPON. The literature review has the potential to help the researchers who are seeking to investigate on the passive optical networks or any related technology. The research review delivers information about the evolution of PON and how the emerging technologies are better than the previous regarding date rate, bit error rate, and bandwidth utilization. The literature review will help us to explore further about the Broadband passive optical networks.

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