Review: Passive optical networks current trends and future

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***Abstract*— In this paper, passive optical network has been reviewed in scenario of passive optical networks. In latest PON (passive optical networks) services there is a combination of data, video and audio signals. Passive optical network is point to multipoint architecture and is regarded as one of the best choices for the broadband access network in the future. By developing this network, larger transmission capacity at higher bit rate and longer transmission distance can be achieved.**

Index Terms*— Optical Line Termination (OLT), Optical Network Units (ONU), Passive Optical Networks (PON)

I. INTRODUCTION

With the advancement in the communication systems, there is a need for large bandwidth to send more data at higher speed. Residential subscribers demand high speed network for voice and media-rich services. Similarly, corporate subscribers demand broadband infrastructure so that they can extend their local-area networks to the Internet backbone. This demands the networks of higher capacities at lower costs. Our current "age of technology" is the result of many brilliant inventions and discoveries, but it is our ability to transmit information, and the media we use to do it, that is perhaps most responsible for its evolution [1]. Progressing from the copper wire of a century ago to today's fiber optic cable, our increasing ability to transmit more information, more quickly and over longer distances has expanded the boundaries of our technological development in all areas [2]. Optical communication technology gives the solution for higher bandwidth. By developing the optical networks, larger transmission capacity, higher bit rate and longer transmission distance can be achieved. PON uses a dedicated optical fiber, to provide virtually unlimited bandwidth, without using any active component within the network. It offers a true triple play service of voice, video and data on a network.

FTTH (Fiber To The Home)

The access network, also known as the "first-mile network," connects the service provider central offices (COs) to businesses and residential subscribers. This network is also referred to in the literature as the subscriber access network, or the local loop [3]. Demand for a new generation of bandwidth-hungry services and triple-play delivery to customers (voice, data, and video) ignited fierce competition among US service providers. These developments motivated service providers worldwide to invest in FTTx (Fiber To The x). FTTx is an acronym that embraces a number of optical access technologies, such as Fiber To The Node (FTTN), Fiber To The Curb (FTTC), Fiber To The Business–or Building–(FTTB), Fiber To The Home (FTTH), and Fiber To The Premises (FTTP)[4]. There are mainly two FTTH architectures that are of current interest, Active Optical Network (AON), and Passive Optical Network (PON)

Active optical network

An active optical system uses electrically powered switching equipment, such as a router or a switch aggregator, to manage signal distribution and direct signals to specific customers. This switch opens and closes in various ways to direct the incoming and outgoing signals to the proper place. In such a system, a customer may have a dedicated fiber running to his or her house [5].

Passive optical network

Passive optical network (PON) is a telecommunications network that uses point-to-multipoint fiber to the premises in which unpowered optical splitters are used to enable a single optical fiber to serve multiple premises by separating the signal towards each user. This network is called passive because within the central office and the subscribers, there is no power element used; hence the cost of the network and its installation is reduced. A PON reduces the amount of fiber and central office equipment required compared with point-to-point architectures. PON is a form of fiber-optic access network. It offers a true triple play service of voice, video and data on a network

PON ARCHITECTURE

The architecture consists of three main network elements as Optical Line Terminal (OLT), Passive Optical Splitter and Optical Network Unit (ONU). Optical line terminal (OLT) that locates at central office (CO) modulates the light wave and transmits it through fiber to optical network units (ONUs) that locates at end user. It is designed to provide virtually unlimited bandwidth to the subscriber. And we can define it as point to multipoint [p2mp] topology as it uses a single optical fiber to serve multiple users usually between 32 to 128. A PON is a single, shared optical fiber (shared feeder fiber) that uses a passive optical splitter to divide the signal towards individual subscribers as shown in figure 1.

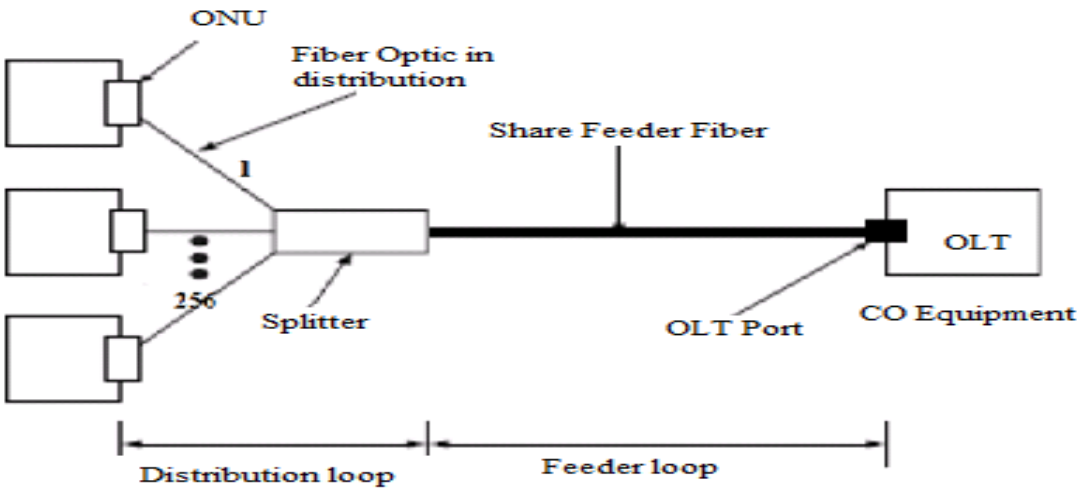

Figure 1 : Passive Optical Network (PON) [9]

PON standards

There are several PON standards like APON, BPON, EPON or GEPON, according to the distance between OLT and ONU and data rates in downstream and upstream transmission.

APON (Asynchronous transfer mode PON)

These networks are referred as APON (ATM Passive Optical Network), and are standardized under ITU-T standard G.983.1 based on ATM cell transmission. It was the first network that was defined by FSAN (Full Service Access Network). APON offers maximum rate of 155 Mbps shared between the ONU numbers that are connected. Its initial problem was the limitation of 155 Mbps which later was increased to 622 Mbps. ATM PON connects up to 32 subscribers to the PON [6].

BPON (Broadband Passive Optical Network)

BPON (Broadband Passive Optical Network) is an ITU-T G.983.x standard. It emerges as evolution of APON, and has the speed limitation of the same. BPON networks are also based on ATM cell transmission, but they differ from APON as they support other broadband standards. BPON networks were first defined under a fixed rate of 155 Mbps transmission for both uplink and downlink. But later they were amended to introduce asymmetric channels:

Downlink: 622 Mbps
Uplink: 155 Mbps

For 1 fiber per ONU, sharing upstream and downstream:
Downstream channel: λ=1480-1500 nm
Upstream channel: λ=1260-1360 nm
Video: λ=1550-1560 nm

For 2 fibers for each ONU, one for upstream and one for downstream:
Downstream channel: λ=1260-1360 nm
Upstream channel: λ=1260-1360 nm
Video: λ=1550-1560 nm[6].

EPON (Ethernet passive optical network)

EPON is IEEE 802.3 standard, and is a category of networks based on the Ethernet technique. An EPON combines the low-cost Ethernet equipment and fiber infrastructure, and transmits Ethernet data frames directly. It can provide 1 Gbps capacity in both upstream and downstream directions. These features enable EPONs to transmit data, voice and video traffic. EPON also uses the 1310 nm window for upstream and 1490 nm window for downstream transmission. This standard allows transmission in downstream and upstream under only 1 single-mode fiber with a maximum range of 10 km between splitter and ONU, and there is provision for extending the distance to 20 km. The EPON standard establishes a dedicated wavelength for the broadcast of video from the OLT to the ONUs.

The wavelengths are:
Downstream channel: λ=1480-1500 nm
Upstream channel: λ=1260-1360 nm
Video: λ=1550-1560 nm[7]

GPON (Gigabit PON)

The more advanced standard which is still working is evolution of the BPON. To meet rapidly growing demand and to work better with changes in communication technologies a, ITU-T created the series of standards ITU-T G.984.x for Gigabit capacity PON, which are the basis of the standard GPON (Gigabit PON). Varied transmission rates are allowed by GPON in the range between 622 Mbps to 2,488 Gbps in the downstream channel. Like BPON, this standard allows data transmission both symmetric and asymmetric where rates of transmission for each one are:
Symmetric transmission: flow rates between 622 Mbps and 2,488 Gbps are offered both for downstream and upstream channel.
Asymmetric transmission: Different flow rates for downstream and upstream channel:

Downstream channel: up to 2,488 Gbps.
Upstream channel: up to 1,244 Gbps.

The wavelengths of work that sets the GPON standard vary depending on whether you use 1 or 2 fibers for each ONT, although for both sets a dedicated wavelength for video broadcast from the OLT to the ONTs, being this different from those used in the voice and data transmission. For 1 fiber per ONT, shared for transmission and reception:

Downstream channel: λ=1480-1500 nm
Upstream channel: λ=1260-1360 nm
Video: λ=1550 nm

For 2 fibers for each ONT, one for transmission and another one for reception:
Downstream channel: λ=1260-1360 nm
Upstream channel: λ=1260-1360 nm
Video: λ=1550 nm[8].

Table 1: Common PON standards

Technology	Standard	Distance (KM)	Down-stream (Mbps)	Up-stream (Mbps)
BPON	G.983	20	155,622, 1244	155,622
EPON	802.3	10	1244	1244
GPON	G.984	20	1244, 2488	155 to 2488

Implementation of Passive Optical Network system to reduce the system cost and increase data to per user

Feasible evolutionary path for FTTH PON was investigated, proposing a set of technical solutions that could potentially and remarkably reduce the individual cost, per user and per Mbps. Advanced FTTH access networks, based on new transmission concepts and advanced subsystems, were proposed and analyzed, being characterized by a higher density of users served per feeder fiber, extended distance reach to the metropolitan area, bidirectional single fiber, centralized control, guaranteed bandwidth per user of tens/hundreds of Mbps, passive protection and above all, low cost potentiality. With this aim, some novel devices like remote optical amplification in the passive network, hybrid WDM-TDM multiplexing, reflective ONU, bidirectional single fiber transmission, direct FSK/IM laser modulation and fast widely tunable lasers among others, were also implemented [8].

Effect of number of users on system in Passive Optical Network at high Data rates

Evaluation on WDM-PON access network architecture accommodating 32 users was done successfully. Results affirmed that network performance degrades more linearly over increasing secondary SMF lengths when Avalanche photo diodes (APDs) were used compared to exponential decay in signal quality which was found to be the case using PIN photo receivers. Simulation work revealed that performance gains of around 15km in terms of system reach and up to 5 Gbps in terms of data carrying capacity per user can be attained if APDs are used at the receiver side in downstream direction [9].

Use of Bidirectional fiber in the Passive Optical network for upstream and downstream Data

An extensive research had been carried out to evaluate a Broadband Passive Optical Network (BPON) for both downstream and upstream traffic to highly scalable solutions to service providers to make fiber reach the end user. The system was analyzed on the basis of Data Rate, Fiber length, Coding technique, number of users, wavelengths and their effects on Bit Error rate (BER) as the key performance parameter . Remarkable results had been achieved and a novel relation had been developed between the data rate and accommodated users. It had been revealed that, in downstream direction, doubling the number of users only requires switching to the lower data rate in order to maintain identical BER effects over the same fiber length. Additionally, the relation had also been tested on Return-to-Zero (RZ) and Non-Return-to-zero (NRZ) coding and was found to be unaffected by coding formats used [10].

Fiber to the home triple play services using GE-PON(gigabit ethernet PON) architecture

Evaluation and comparison of Fiber to the home, FTTH, GEPON (gigabit Ethernet passive optical network) link design for 56 subscribers at 20 km reach at 2 Gbps bit rate was carried out to provide residential subscribers with triple play services. A 1:56 splitter was used as a PON element which creates communication between a Central Office to different users and a boosting amplifier is employed before fiber length which tends to decrease BER and allows more users to accommodate. This architecture was investigated for different values of data rate from a CO (Central Office) to the PON in terms of BER (Bit Error Rate). BER was considered as the major technical issue to realize the GEPON based FTTH access network. The simulation work reports for the case of 56 users at 2 Gbps and by further increasing the data rate of system say 5 Gbps, and then there was a sharp increase in BER. Similarly in the variation of BER with respect to transmission distance, BER shows an increase in its value as transmission distance increases [11].

High capacity long reach 32 channel FTTH downstream link employing triple play services

Performance of high capacity, long reach, 32 channel FTTH downstream link employing triple play services had been investigated. DWDM has been employed for bandwidth optimization. The triple-play service was realized as a combination of data, voice, and video signals. The Internet component is represented by a data link with a high-speed of 2.5 Gb/s downstream. The voice component was represented as VOIP and then combined with data component. The video component was represented as a RF video signal. The reach of the WDM-PON system can be severely limited by chromatic dispersion. Therefore, by employing 80 km of non-linear fiber in combination with 20 km of reverse dispersion fiber to negate the accumulated chromatic dispersion which ensured long reach of the modeled FTTH system. Investigations revealed the effective bandwidth optimization using DWDM. High quality factor and low BER results confirmed the feasibility of proposed high capacity, long reach FTTH link. The investigations further revealed that the system reach can be extended up to 100 km with efficient chromatic dispersion management[12].

Bi-directional passive optical networks in the scenario of triple play service

Performance of bi-directional passive optical network (BPON) had been evaluated and compared at different bit rates in the scenario of triple play service. The triple-play service is realized as a combination of data, voice and video signals. This architecture was investigated for symmetrical data traffic for uplink and downlink transmission and its performance was also evaluated in terms of Q-factor and eye height at different transmission distance. The Q-factor results show the acceptable performance at 10 Gbps data rate for downstream and upstream transmission, as it accommodates 128 optical network units (ONUs) covering the transmission distance of 40 km[13].

CONCLUSION

PON is point to multipoint mechanism and is one of the best choices for the broadband access network to achieve higher data rates and longer transmission distances. NG-PON and GPON are the most advanced PON protocol and offers higher bandwidth and longer transmission distance when compare to ATM and Ethernet based PON technologies. Use of amplifiers increase the link length and system performance but it add cost and noise to the system. Therefore correct amplifier design is required to amplify the signal in the Gigabit Passive Optical Network. Bidirectional Passive Optical Networks are more useful, But with the increase of No. of users, Data rate, link length and non linear effects system performance degraded. Work has to be done on these parameters for better Bidirectional-GPON systems.

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