A Review of Passive Optical Networks: Pros, Cons and Current Trends

Abstract

Passive Optical Networks (PONs) have become a popular fiber access network solution because of its service transparency, cost effectiveness, energy savings, and higher security over other access networks. This paper discusses about the evolution and basic structure of Passive Optical Networks. In this paper we discussed about the Access networks, their classifications and its types. How copper networks differs from optical network The Difference between active and passive optical networks and basic system of Passive Optical Networks. We show through analysis that Passive Optical Networks are very cheap and can provide better services as compare to copper access networks. PON is also better option for access networks because it is very cheaper than active optical networks.

Introduction

Passive Optical Networks (PONs) are a series of promising broadband access network technologies that offer enormous advantages when deployed in fiber to the home (FTTH) scenarios. The advantages include a point to multi-point architecture, high quality triple play service capabilities for data, voice and video, high speed internet access, and other services in a cost-effective manner [1]. Telecommunications today is perhaps the fastest evolving field of study. It is continuously offering new challenges and opportunities to telecommunications network planners [2]. The subscriber part of the telecommunications network or the network connecting the subscribers to the central office or the access network that has been traditionally simple twisted copper pair based, point to point, passive network is now becoming increasingly complex [3]. In the present scenario it becomes imperative for the access network planner to be familiar with both traditional and new technologies, structures and methods as their plans would have a profound long term impact on how the network shapes up and meets the desired objectives [4]. Over the past decade several PON architectures have been developed by the International Telecommunications Union (ITU) and the Institute of Electrical and Electronic Engineers (IEEE) [5]. The four main PON variations developed by the ITU and IEEE can be categorized into two groups. The first kind of architecture is based on Asynchronous Transfer Mode (ATM) and includes ATM PON (APON), Broadband PON (BPON) and Gigabit PON (GPON) and the second group consists of Ethernet PON (EPON). EPON and GPON are the most popular PON variations found in use today. The EPON and the GPON standards have the same general principle in terms of framework and applications but their operation is different due to the implementation of the physical and data link layers [6]. EPON is defined by IEEE 802.3 and it is widely deployed in Asia whilst GPON is deployed in a number of other regions. GPON's requirements

were defined by the Full Service Access Network (FSAN) group that was ratified as ITU-T G.984 and is implemented in North America, Europe, Middle East, and Austraia [7],[8].

Brief of Access Networks

It is that part of a telecommunications network which connects subscribers to their immediate service provider. The term access network refers to the network between the local exchange and the subscriber. In many countries this network is still predominantly made up of the copper cable based point to point connections [9]. The technology has not changed much during the last many decades even though considerable changes have been introduced in the field of switching and transport. With the advent of digital technology, the process of installation, maintenance has become less cumbersome and quality of services has improved [10]. It is therefore felt that the any cause for dissatisfaction, among customers about present services, is predominantly due to the frequent failures in the access network and the time taken for restoring them. most fundamental and remarkable of the driving technologies of today is the optical fibre. Without it the current telecommunications revolution would have been a non-event [11]. Supporting the high growth telecommunications demand with copper, radio and satellite alone would have stalled the information revolution [12]. These would not have made bandwidth and connectivity for all possible. Increasingly, therefore twisted pair copper cable is being replaced by optical fibre cable with new transmission technologies. The term access network has gained popularity after the advent of new technologies in the local loop [13]. Another change which is now becoming evident is change of character of the access network from passive to active.

Overview of Optical Networks

Fiber optics is a particularly popular technology for local-area networks. Telephone companies are steadily replacing traditional telephone lines with fiber optic cables. In the future, almost all communications will employ fiber optics [14]. Over metal cables, fiber optics provide a much greater bandwidth to carry more data, they are are less susceptible than metal cables to interference, they are thinner and lighter than metal wires, and most importantly data can be transmitted digitally (the natural form for computer data) through the use of fiber optics [15]. Optical networks are divided into two categories such as Active optical networks and Passive optical networks [16] [17]. 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 [18]. A Passive Optical Network is a single, shared optical fiber that uses inexpensive optical splitters to divide the single fiber into separate strands feeding individual subscribers [19] [20]. It is called passive optical network because it do not need any external energy for user splition [21] [22].

Passive Optical Networks

In the Figure 1, it can be seen that the PON architecture consists of an Optical Line Terminal (OLT), Optical Distribution Network (ODN), and Optical Network Units (ONU).

The OLT is placed at the Central Office (CO) and connected to the splitters by fiber [23] [24]. The optical splitters connect to customer premises making PON a point to multi-point architecture (P2MP). To control the P2MP fiber network, Passive Optical Network uses the Multi-Point Control Protocol (MPCP) [25]. MPCP performs bandwidth assignment, bandwidth polling, auto-discovery, and ranging [26] [27] [28]. It is implemented in the MAC Layer, introducing new 64-byte control messages: GATE and REPORT are used to assign and request bandwidth. REGISTER is used to control the auto-discovery process MPCP provides hooks for network resource optimization [29]. Ranging is performed to reduce slack, and bandwidth reporting satisfies requirements by ONUs for DBA. Optical parameters are negotiated to optimize performance [30] [31].

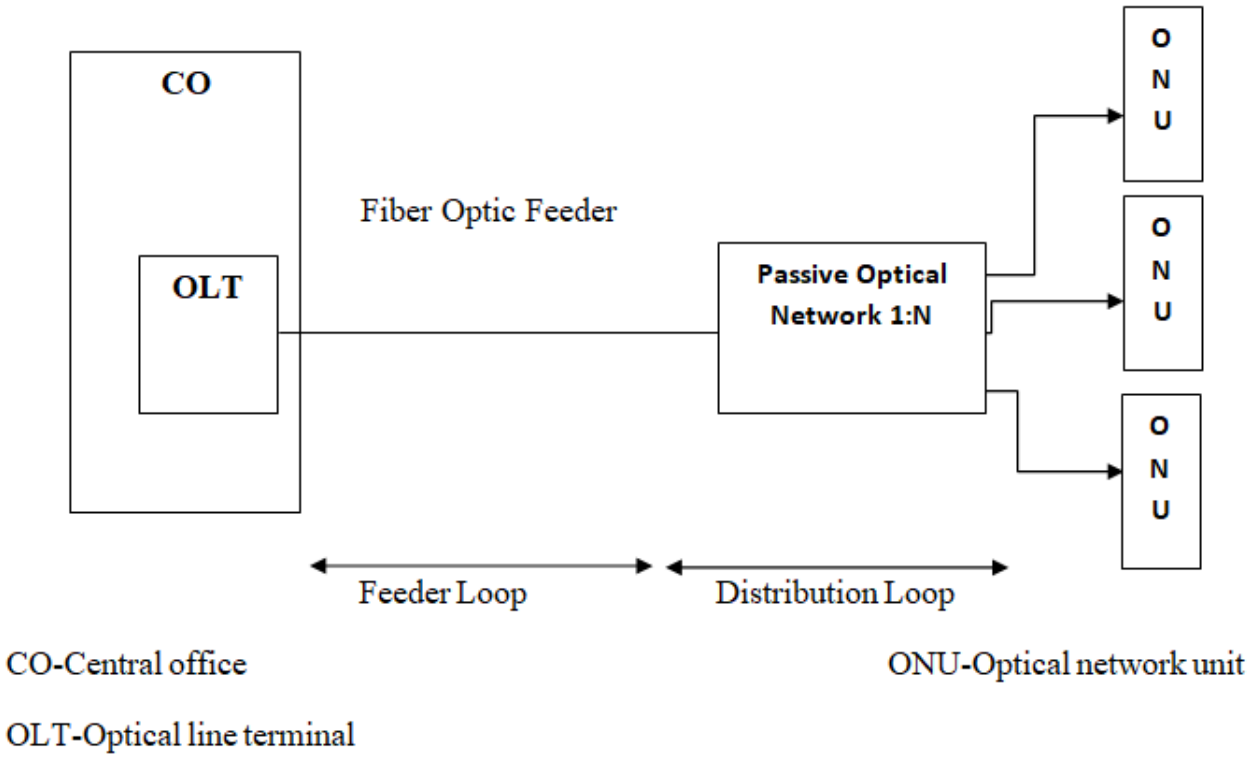

Figure 1 Passive Optical Networks

Types of Passive Optical Networks

BPON (Broadband PON)

BPON system is the first Passive optical network standard. This system is based upon Asynchronous Transfer Mode (ATM) protocol. Initially, the name was ATM PON and used primarily for business applications. The standard set by International Telecom Union for BPON

is ITUG.983. BPON data packet cell size contains 53 bytes of data. It has 1.2 Gbps data rate for downstream and 622 Mbps for upstream [32].

EPON or GEPON (Ethernet PON or Gigabit Ethernet PON)

The standard set for EPON is an IEEE standard 802.3ah which comes under the category of IEEE 802.3 standard. The purpose of EPON is to implement Ethernet technology in the PON systems to enhance the capabilities of the network with less number of components/ equipments at very low operation & maintenance cost [33]. EPON data packet cell size contains 1518 bytes of data. It supports P2MP subscriber access network topology.

GPON (Gigabit-capable Passive Optical Network)

It is standardized by ITU as ITUG.984. GPON has variable data packet cell size from 53 bytes to 1518 bytes. The data rate of GPON is configurable from 1.2 Gbps to 2.5 Gbps for downstream and for upstream different data rates of 155 Mbps, 622 Mbps, 1.25 Gbps or 2.5 Gbps can be used [34]. It uses ATM, Ethernet and TDM protocol. GPON offers more facilities but it is more complex. The next-generation GPON standard, which is classified as XG-PON1, has been released in 2010. A number of options have been considered for next generation broadband access standard (NG-PON2).

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 [35].

WDM PON

In the last two decades, the traffic demand in the Internet is 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. The capacity of the networks can be increased by assigning the different wavelengths to the multiple users which share a single fiber. 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 fulfill the requirement of more bandwidth in future [36].

WDM/ TDM or Hybrid PON

In this architecture, 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 [37].

Requirements of PON Systems

Enhancement of Capacity of the Network: The existing WDM network with large spacing wavelengths can be converted into DWDM network by multiplexing these wavelengths with narrower spacing without disturbing the existing fiber.

Optimization of Existing Networks: The number of users can be increased by reducing the channel spacing but it also increases interference due to overlapping of the signals in the channel. So, there is requirement to optimize amplifiers and other components to utilize maximum bandwidth and receiver capability.

Scalability: The network should be able to scale in next generation networks for large bandwidths and capacity.

Compatible and Flexible: The network should be effective and flexible to fit to adopt new technology.

Integration: The integration of the network with smart traffic planning is required to achieve a good quality of service.

Immune to Interference: The network should be lossless network and immune to the interference produce by the same or different media.

Miscellaneous: The network should be secure and robust. Also, the overall cost of the network should be low.

Advantages of Passive Optical Networks

- Passive Optical LAN is a new application of a proven access network solution. It is a better way to structure a LAN, because:
- It flattens the Local Area Network
- It simplifies network moves, adds, and changes
- Is not limited by the distance and bandwidth constraints of twisted pair networks
- Is secure by design, based on optical fiber and built-in encryption
- Can eliminate wiring closets
- Eliminates the need for midspan electronics, power, and cooling infrastructure
- Uses smaller, lighter, less expensive cables to reduce pathway and space requirements
- Virtually eliminates the need to refresh cabling infrastructures
- As technology evolves, only the active endpoints need a refresh

A PON allows for longer distances between central offices and customer premises. While with the Digital Subscriber Line (DSL) the maximum distance between the central office and the customer is only 18000 feet (approximately 5.5 km), a PON local loop can operate at distances of over 20 km. 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. This is an essential support for services such as HD Video, services called "on demand".

Disadvantages of Passive Optical Networks

Despite the many advantages that have the PON to own intrinsic configuration, there are some disadvantages associated with it. However, there are not significant enough to avoid choosing PON as the best possible configuration.

One of the first disadvantages to be considered is that caused by distribution of information from the OLT to the different ONTs. The fact that a divisor distributes information from the OLT to all ONTs that are connected to the same stage or distribution tree, it causes a reduction in network efficiency.

The total capacity is divided into many ONT connected to the splitter, so that the efficiency of the channel is lower than in a point-to-multipoint link.

In addition, because PON has a preset speed, it is forced to work at that speed but providing different speeds to the customer service. For example, an ONT that provides 100 Mbps to the customer is required to work at higher speed rates: 1.25 Gbps or 2.5 Gbps.

Moreover, the fact that all information flow through the same physical channel increases the likelihood of sniffing on the network, losing security, and forcing to establish a high level of encryption.

Regarding security, PON architecture is sensitive to external sabotage. This problem is given by the nature of the transmission medium itself. Injection of constant light to a particular wavelength masks all communication and service tends to fall.

Another important aspect is the fact that a stage or distribution tree, depend exclusively on a single OLT. A fault in the OLT header supposes a high impact on the network, since all the ONT and splitters connected to it are affected. However, the installation of few OLT supposes a cost reduction of network deployment enough considerable.

Current Trends and Future of PONs

Researches besides WDM PON are also focussing on much more sophisticated passive optical networks like Orthogonal Frequency Division Multiplexing Passive Optical Network (OFDM PON) is another communication technique that is innovative and is used in passive optical

networks. OFDM forms the crux of the transmission technology used in next generation wireless systems including 3GPP LTE. OFDM PON dynamically allocates bandwidth, and has superior transmission quality. It can be extended upto 100km reach unlike TDM PON which can reach upto 20km in practise and 60 kms theoretically, WDM PON can reach upto 60 kms in practise. However, OFDMPON itself has merits and demerits. OFDM PON combined with WDM PON will become a competitive technology for NG-PON2. There are many other passive optical networks where communication between multiple subscribers and central office is possible, mainly on GPON which is a TDM PON system, and WDM PON network, because it a very much promising passive optical network which sustains high data rates, flexibility and interoperability. Also, since upgradation of GPON is not a viable technique and when the bandwidth requirements are high, upgrading to WDM PON from TDM PON by replacing the splitter with a thermal AWG mux/demux at remote node appears to be a satisfactory solution. And also, WDM PON provides more scalability, interoperability and most important security. If we can resolve the challenges associated with the cost, WDM PON would become the next generation access solution in fiber access passive networks.

Conclusion

Bandwidth demand for growth of existing services and introduction of new services will continue to increase day by day. Existing access method will not be able to meet the bandwidth requirement in near future. PON can offer sufficient bandwidth for providing true triple play services of voice, video and data. Among different PON technologies, GPON offers best solution that will address the access bandwidth growth in the foreseeable future.

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