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A review on Gigabit Passive Optical Network (GPON)

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Abstract: In this paper Gigabit passive optical network has been reviewed. In today scenario there is demand of High Speed Internet access (HSI), Video on demand (VoD) and live streaming which cannot be fulfilled by Asymmetric digital subscriber line (ADSL) technology (using copper media). Bringing optical fiber to every home is the definite response to such a demand of great bandwidth. One way of providing fiber to the home is through a GPON technology. GPON is point to multipoint mechanism and is regarded as one of the best choices for the broadband access network in the future.

Keywords: Asymmetric digital subscriber line (ADSL), Fiber-to-the-Home (FTTH), Gigabit Passive Optical Network (GPON), High Speed Internet Access (HSI), Video on demand (VoD).

I. INTRODUCTION

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 [1]. 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 (PON) architectures [2]. Gigabit-capable PONs (GPONs) are now standardized and commercially available [3]. Optical fiber based access technologies such as fiber-to-the-home, fiber-to-the-building, etc. (FTTX) have the well-known advantages of low loss, high bandwidth, long reach and is currently being deploying worldwide [4]. Gigabit Passive Optical Network (GPON) is defined by ITU-T recommendation series G.984.1 through G.984.4. G.984 standard series define general characteristics of GPON (G.984.1) as well as physical layer specification(G.984.2), transmission layer specification(G.984.3) and ONU (Optical Network Unit)management and control specification (G.984.4).GPON can transport not only Ethernet, but ATM and TDM (including PSTN, ISDN, E1 and E3) traffic by using GPON encapsulating method (GEM) [5].

A. PON Standards

First of all PON was, ATM PON (APON) which evolved in Broadband PON (BPON). BPON is backward compatible with APON. Ethernet PON (EPON and newer GePON) is alternate solution for PON networks. it is IEEE standard not compatible with A/BPON. It is PON exclusively for Ethernet and IP traffic. GPON (Gigabit PON) and EPON (Ethernet PON), standardized by the ITU-T and the IEEE [6].

The difference between APON and BPON are the extra overlay capabilities supported by BPON to use video and other Broadband services. The technology used in the BPON standard is called Asynchronous Transfer Mode (ATM). ATM is implemented now days in large interconnecting networks. The PON standard is shown as fig 1.

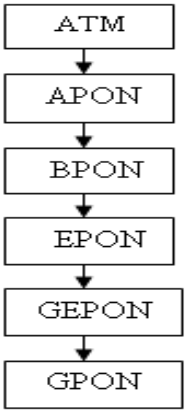

Fig 1. PON Standards

The timing requirement of GPON is much rigid than that of EPON [7].The performance of EPON systems frames are transmitted as a Control frame and Data frames. At the user level 1 Gb/s is available, on the lower level due to 8B/10B encoding the data rate at the fiber is 1.25 Gb/s. B-PON was developed as a PON system that uses ATM cells for transmission and has a maximum access speed of 155 Mbit/s upstream and 622 Mbit/s downstream. By using ATM cells, B-PON can accommodate various services, such as Internet or CATV services [8].

The differences between BPON, GPON and EPON can be found at different levels. A BPON system is a good system but more or less replaced by the GPON standard. All the user services provided by BPON can be found in the GPON system as well. GPON is more flexible since it provides not only an ATM service but also additional services like GEM with several possibilities for data encapsulation. Like ATM or GEM, Ethernet is capable of encapsulating other protocols.

Both BPON and GPON use the ATM protocol, where BPON actually uses it at the network level and GPON only provides a service point for ATM. The network layer of GPON uses its own frame format to transfer the data.

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Table 1. GPON vs EPON

	GPON	EPON
Standrad organisation	ITU T	IEEE
Rate	2.488G/1.244G	1.25G/1.25G
Split Ratio	1:64-1:128	1:16-1:32
Carried Service	ATM, Ethernet, TDM	ETHERNET
Bandwidth Efficiency	92%	72%
QOS	Very Good Including Ethernet, TDM, ATM	Good Only Ethernet
Optical Budget	CLASS A/B/B+/C	Px10/Px20
DBA	Standard Format	Self defined
Communication With ONTs	ONT Management Control Interface	Not Supported
Operation And maintenance	ITU-T G.984(Strong)	Ethernet OAM (Weak)

II GPON Network Model

Gigabit passive optical networks (GPONs), which represent one optical solution for local access networks typically, provide distributed connectivity over a large geographic area [9]. A typical GPON model employs a tree-like topology consisting of one optical line termination OLT, ONT and ODN. The optical line terminal (OLT), optical network units/optical network terminals (ONUs/ONTs), and splitter/optical distribution network (ODN) are the major parts of a GPON system [10].The GPON network model is shown in fig.2.

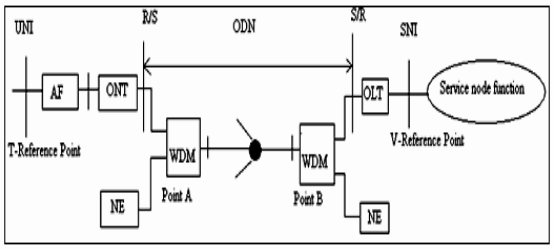

Fig 2. GPON Network Model

The OLT typically is located in the central office. An ONU is at the customer home or at the curb, outside the building. The splitter/ODN is between the OLT and ONU and divides the single fiber into separate strands and supplies individual subscribers [11].The GPON and EPON providing symmetrical (downstream and upstream) data rates of up to 2.488 Gbps (GPON) and 1 Gbps (EPON) while supporting tens of ONUs per OLT and providing a reach of up to 20 km (as opposed to the few kilometers of DSL and, most importantly, without significant signal degradation). WDM is an extremely efficient general-purpose and optical transport technology. Network element which uses the different wavelenght from optical line terminal and the optical distribution network. Fig. 3 shows logical network architecture with different FTTx (Fiber to the x, where x can stand for Curb, Building, or Home),

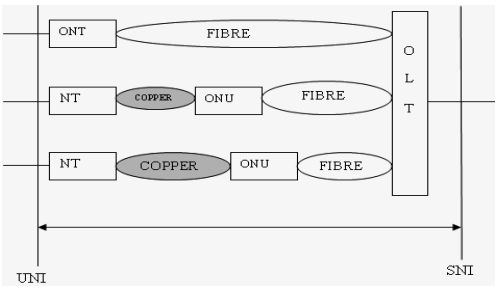

Fig 3. FTTx nework architecture

Options starting at the central office, only one single mode optical fiber strand runs to a passive optical power splitter near users locations (Fig 4). At this point the splitting device simply divides the optical power into N separate paths to the subscribers. The number of splitting paths can vary from 2 to 64. From the optical splitter, individual single-mode fiber strand run to each user (home, businesses, etc) The optical fiber transmission span from the central office to the each user can be up to 20 km. So, Increasing end-user demand for data-intensive services, such as high-definition internet protocol television and location-aware social networking, is additionally anticipated to continue motivating growth and expansion into the foreseeable future. New network solutions are, therefore, required for supporting continued growth of broadband access networks. The total number of fiber-to the- home (FTTH) subscribers has grown to about 38 million at the end of 2011 and is expected to reach about 90 million at the end of 2015[12].

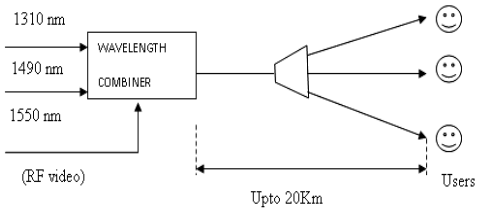

Fig 4.Typical GPON architecture

The wavelength range is 1480-1500 nm for the downstream direction and 1260-1360 nm for upstream direction.The wavelength range 1550-1560 nm can be used for downstream RF video distribution.GPON standard defines a lot of different line transmission rates for downstream and upstream direction. G-PON supports transmission line rates up to 2.448 Gb/s downstream and 1.244 Gb/s upstream [13].

Table 2. GPON Nominal bit rate

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

III. GPON WORKING

GPON system uses the WDM technology to transmit data bi-directionally(upstream and downstream) over a single optical fiber. To seprate the Tx and Rx signals of different users over the same optical fiber, GPON uses the broadcast technology for downstream data transmission. The TDMA technology is used for upstream data transmission. 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. Although any type of data can be encapsulated, actual types depend on service situation. GEM provides connection-oriented communication. This

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method is based on slightly modified version of the ITU-T recommendation G.7041 Generic framing procedure (specification for sending IP packets over SDH networks)

A. GPON Transmission

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.

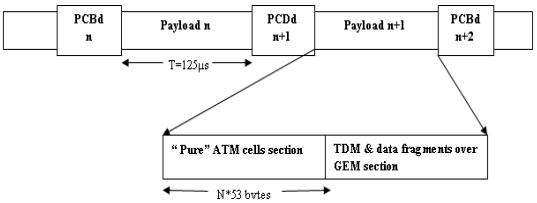

Fig 5. Downstream GPON frame

The downstream frame structure is shown in Fig 5. The frame is 125 µm 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 Overhead (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.

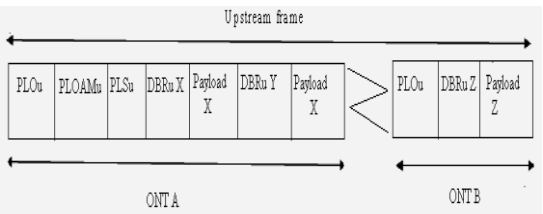

Fig 6. Upstream GPON frame

The upstream frame structure is shown in Fig 6. 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.

B. Dynamic Bandwidth Allocation (DBA)

A DBA profile defines GPON traffic parameters and can be bound to dynamically allocate bandwidth and improve the upstream bandwidth utilization. Dynamic bandwidth allocation can significantly improve network performance, provide a means of flexibly tailoring network responsiveness and enable a service provider to generate more revenue from their FTTH networks without boosting raw bandwidth by increasing the percentage of acceptable over subscription [16]. DBA is controlled by OLT, which allocates bandwidth volume to ONUs. This technique works only in upstream direction, in downstream direction traffic is broadcasted. The Dynamic bandwidth Allocation is shown as fig 7.

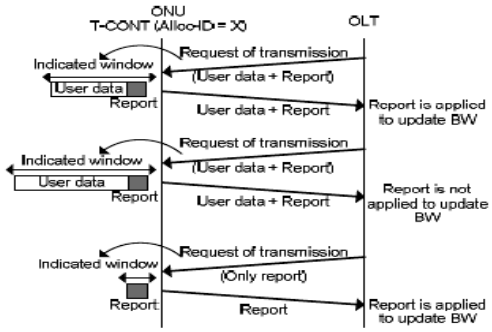

Fig 7. Dynamic bandwidth Allocation

To determine how much traffic to assign to an ONU, the OLT needs to know the traffic status of the T-CONT associated with the ONU. In status reporting method, as part of its traffic status a T-CONT indicates how many packets are waiting in its buffer. Once the OLT receive this information, it can share the allocation to various ONUs accordingly. When an ONU has no information waiting to be transported, upon receiving a grant it sends an idle cell upstream to indicate that its buffer is empty. This informs the OLT that the grants for that T-CONT can be assigned to other T-CONTs. If an ONU has a long queue waiting in its buffer, the OLT can assign multiple T-CONTs to that ONU. DBA algorithms can be divided into two categories: SR-DBA (Status Reporting Dynamic Bandwidth Assignment) provides bandwidth assignment according to report from ONU. NSR-DBA (Non-Status) give bandwidth assignment which does not need report from ONU. However, it provides dynamic assignment by using traffic monitoring by OLT.

C. Transmission Container (T-CONT)

The T-CONTs concept provides an adaptation between the PON transmission convergence and the ATM layer [17]. In the upstream direction, the bandwidth to be used by individual ONU not only depends on the traffic scenario at concerned ONU, but also on the traffic pattern at other ONUs in the network. As the medium is shared, any self-initiated transfer by any ONU in upstream direction would result in collision and retransmission causing degraded performance. Therefore, this shared media is made to behave as multiple point-to-point connections between an ONU and an OLT by use of TDMA. The OLT, being the

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central point, is told about the bandwidth demand at each ONU. Based on the traffic pattern at all the ONUs it grants access to the ONU at fixed slot with respect to downstream frame. For the upstream traffic, the frame can be considered to be divided into different container types. There are five types defined in GPON. Type-1 TCONT service is based on undesirable periodic permits granting fixed payload allocation or catering to fixed bandwidth requirements. This is a static T-CONT type and is not serviced by DBA. Type-2 T-CONT is intended for variable bit rate with bounded delay and jitter requirements like video and voice over IP. Type-3 T-CONT is intended for guaranteed delay.Type-4 T-CONT is for the best effort traffic.Type-5 T-CONT is combined for two or more of the other four types defined above and in this case the individual bandwidth reporting and assignment is done at the ONU. The T-CONT mapping and reporting is shown as fig 8.

Per T-CONT Upstream Map

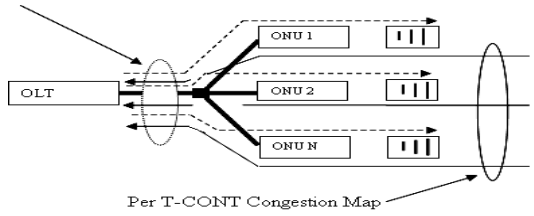

Fig 8. T-CONT mapping and reporting

D. T-CONT Bandwidth and DBA implmentation

T-CONT Type 1 is characterized by the fixed bandwidth only. The assured bandwidth equals the maximum bandwidth and has the highest priority. T-CONT Type 2 is characterized by Assured bandwidth only. The assured bandwidth is the provisioned maximum bandwidth. The T-CONT bandwidth type is shown as fig 9.

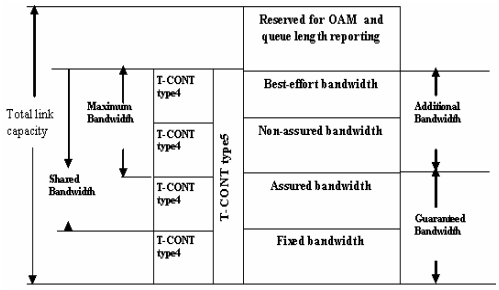

Fig 9. T-CONT bandwidth type

DBA Type 1 and DBA Type 2 do not participate in the bandwidth competition. If the assured bandwidth exceeds the maximum bandwidth, the extra will be discarded. DBA Type 2 has assured bandwidth and Non-assured bandwidth. DBA Type 3 will be allocated bandwidth equivalent to its Assured bandwidth, only when it has cells at a rate equivalent to Assured bandwidth or more than Assured bandwidth. Non-assured bandwidth shall be allocated across all T-CONTs with assured bandwidth that are requesting additional bandwidth in proportion to the assured bandwidth of the individual T-CONTs on the PON, e.g. Weighted Round Robin method. T-CONT Type 4 has Best-effort bandwidth only. T-CONT Type 4 shall only use bandwidth that has not been allocated as Fixed bandwidth, Assured bandwidth or Non-assured bandwidth to T-CONTs in the PON. Best effort bandwidth is allocated to each T-CONT Type 4 equally, e.g. based on the Round Robin method, up to the Maximum bandwidth. T-CONT Type 5 is the super set of all of DBA types. Fixed bandwidth is assigned first. If Fixed bandwidth is insufficient, check whether the assured bandwidth meets the requirement. If yes, the assured bandwidth is assigned. If not, the request for the additional bandwidth is tagged and competes with the DBA 3 tagged bandwidth, eg. based on the Round Robin method. If additional bandwidth is still requested, Best-effort bandwidth is assigned up to the Maximum bandwidth.

Table 3.T-CONT type

	Delay Sensitive	Allocation Mode	T-CONT type				
			Type 1	Type 2	Type 3	Type 4	Type 5
Fixed	Yes	Provisioned	X				X
Assured	No	Provisioned		X	X		X
Non-Assured	No	Dynamic			X		X
Best-Effort	No	Dynamic				X	X

E. GPON Encapsulation Method Segment

GPON supports two methods of encapsulation: the ATM and GPON encapsulation method (GEM). With GEM, all traffic is mapped across the GPON network using a variant of SONET/SDH Generic Framing Procedure (GFP). A GEM port is the smallest service unit in the GPON system.Every GEM port can carry one or more types of service stream.The GEM port,after carrying service stream,must be mapped to a T-CONT upstream service scheduling.Every ONU supports multiple T-CONTs can be configured with different service type. A T-CONT can be bound with one or more GEM ports,depending on the user's configuration. A GEM port is used to carry service between the OLT and ONU. GEM supports a native transport of voice, video, and data without an added ATM or IP encapsulation layer. GPON supports downstream rates as high as 2.5 Gbits/sec and upstream rates from 155 Mbits/sec to 2.5 Gbits/sec. The GPON encapsulation method header is shown as fig 10.

PLI	Port ID	PTI	HEC	Freament Payload
12-Bits	12-Bits	3-Bits	13-Bits	L Bytes

Fig 10. GPON encapsulation method header

The Payload Length Indicator (PLI) indicates Payload Length L and also synchronizes and detects the next frame. The PLI is a 12-bits field, as a result 4095 bytes is the maximum fragment size. The second field Port ID provides a unique traffic identifier on the PON. Payload Type Indicator (PTI) field is used to identify the contents of the Payload. The Header Error Control (HEC) field is used to protect the header for errors.

F. Optical Splitter

The typical PON connects a single fiber from an Optical Line Terminal (OLT) to multiple Optical Network Units (ONUs). The point to multipoint connectivity between OLT and multiple ONUs is obtained using one or more

passive branching devices in the fiber path. This device has a single input and multiple outputs. An optical splitter is a bi-directional device. There are two techniques for manufacturing splitters: Fused Biconical Taper (FBT) and Planar Lightwave Circuit (PLC). The FBT splitter is made by precisely fusing two fibers together. The PLC splitter consists of a microscopic optical circuit that is typically etched in silicon. Optical splitter is not a part of the GPON i.e without splitter we can use GPON, but if optical splitter is used it increases the capacity of the GPON.

IV. ADVANTAGES OF GPON

The GPON bandwidth downstream 2.5 Gbit/s and upstream 1.25 Gbit/s for each subscriber**.** 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.

V. CONCLUSION

GPON recognized the need to evolve PON to being a Gigabit capable solution for transporting Ethernet and IP traffic. GPON is the most advanced PON protocol in the market place today. it offers far higher efficiency when compare to ATM and Ethernet based PON technologies. GPON provide the longer transmission and higher bandwidth. GPON is point to multipoint mechanism and is one of the best choices for the broadband access network. The GPON speed is more than other PON standards.

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BIOGRAPHIES

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Sanjeev Dewra was born in Panagarh (West Bengal), India, on October 22,1971.He received a B.E(Electronics & Telecomm.) degree from Mahatma Gandhi Missions College of engineering & technology, Marathwada University, Aurangabad (M.S) in 1993 and a M.E. degree from GNDEC, Ludhiana in 2002.He is currently working toward his Ph.D. degree at Thapar University, Patiala (Punjab). His field of interest is optical add drop multiplexer & optical cross connect for optical communication systems. He has published various research papers in international journals & conferences. Mr. Dewra is a life member of the Indian Society for Technical Education, Institution of Engineers (India). He has over 20 years of Education Experience. He served as lecturer in Saint Kabir Institute of Pharmaceutical & Technical Education, Fazilka from 1994 to 1998. He then joined Lala Lajpat Rai Institute of Engineering & Technology, Moga as a lecturer in 1999. In 2000, he joined Giani Zail Singh College of Engineering & *Technology*, Bathinda (Punjab), as Lecturer in the Department of Electronics and Communication Engineering and continued till 2003. In 2003, he joined as a Lecturer in the Electronics and Communication Engineering Department in Shaheed Bhagat Singh College of Engineering and Technology, Ferozepur (Punjab) & became a senior Lecturer in 2005. Presently he is working as an Assistant Professor & Head of ECE Department in the same college.