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Gigabit Passive Optical Networks (GPON) the Ultimate Solution for Large Bandwidth

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Abstract: ***The demand for bandwidth has increased drastically. So optical transmission has got more importance in access networks. The upcoming features like IPTV, High speed internet(HSI), Video on demand(VOD), online gaming are confronting large bandwidth at the customer end.The demand of bandwidth can be satisfied by XDSL, but the distance is restricted by using this type of technique. So we can use optical transmission for achieving large bandwidth by using passive optical networks(PON). One of the most advanced PON solution is Gigabit PON (GPON). This is the most widely used solution where there is a requirement of large bandwidth***

This paper provides an overview of GPONfeatures, transmission mechanism, optical splitting and power budget.

Keywords- IPTV, GPON, PON, HSI.

I. INTRODUCTION

The revolution in internet started by connecting million of people over copper wire and through dial-up modems at data rate of a few thousands of bits per second. Today, there is an increasing demand for high band width services in market around the world. However traditional technologies, like digital subscriber line (DSL)and cable modems technologies commonly used for broad band access , which have access speed to the order of mega bit per second ,with actual rates strongly depend on distance from the exchange and quality of copper infrastructure cannot fulfill today's customer's demand for bandwidth. Fortunately, the Ethernet technology with passive optical networks (PON) that revolutionized enterprise network promises to do the same for access to high speed applications. There are several flavor of PON technology, i.e. new access technology named BPON (Broadband passive optical networks), EPON (Ethernet passive optical network) and GPON (Gigabit passive optical networks).

GPON architecture offers converged voice and data services up to 2.5 gb/s GPON enables transport of multiple services in their native format, specifically TDM and data. In order to enable easy transmission from BPON to GPON, many functions of BPON are reused in GPON. In January 2003 the GPON standards are ratified by ITU-T and are known as ITU-T recommendation G.984.1, G.984.2 and G.984.3. GPON uses Generic Framing Procedure (GFP) protocol to provide support for both data and voice oriented services. A big advantage of GPON is over other schemes is that interfaces to all the min service are provided and GFP enables network packets belonging to different protocols can be transmitted in their native format.

GPON interfaces can transmit services over passive optical fibers at a symmetrical bit rate of 1.25 Gb/s or an asymmetrical bit rate of 2.5 Gb/s for downstream and 1.25 Gb/s for upstream for a distance of 20 Km. In downstream GPON optical line terminator transmit encrypted user traffic over the shared bandwidth. In upstream it uses Time Division Multiple Access (TDMA) technique.

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II. GPON FEATURES

A. Operating Wavelength

The operational wavelength for upstream is 1260-1360 nm. The operational wavelength for downstream is 1480-1500 nm. In addition to this a wavelength range of 1550-1560 nm is used for downstream RF video distribution.

B. Forward Error Correction

GPON uses FEC (Forward Error Correction) technique for error detection and correction. FEC is a mathematical signal processing technique that encodes data. With the help of FEC original information and redundant information are transmitted at the same time, as the redundant information is mall it doesn't require any lot of overhead. FEC increases the link budget which ultimately leads to increase in the bit rate therefore we can use more number of connections from one splitter.

C. Transmission containers

GPON uses T-CON (Transmission containers) for handling upstream bandwidth. T-CON enables quality of service for upstream. There are several types of T-CON that are offered to the user by the GPON.

D. Security

As GPON uses broadcast for transmission of data to all the ONU during the downstream so certain time is allocated for every ONU for having their data. During upstream GPON uses point to point connection so all the data is secured from eavesdropping. As per recommendation G.984.3 GPON allows user to have access to their intended data only.

Advanced Encryption standardized (AES) encrypting algorithm is used by GPON. AES allows 128, 192, and 256 byte keys which form a complex encryption for the data. The key in AES can be changed without disturbing the data flow for improving the encryption.

E. Protection

The protection of GPON systems is an administrator's duty. This enhances the reliability of the access networks. There are two types of protection schemes for switching. They are

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- Automatic switching: These are triggered by error detection like loss of signal, loss of frame, signal degradation and etc.
- Forced switching: These are triggered for administrative events like fiber replacing, components replacing and etc.

III. GPON TRANSMISSION

GPON uses GEM (GPON Encapsulation method) for encapsulation of the data. This model is based on ITU-T recommendation version G.7041.

A. Upstream frame format of GPON

GPON uses TDMA technique for trafficking under the control of the OLT (optical line terminator) situated in the exchange. It assigns variable time slots to each ONU for synchronized transmission of the data burst.

The upstream frame of GPON consists of several transmission burst. Each transmission burst consists of Physical Layer Overhead upstream (PLOu). Moreover the payload it may also contain Physical Layer Operations, Administration and Management upstream (PLOAMu), Power Leveling Sequence upstream (PLSu) and Dynamic Bandwidth Report upstream (DBRu) sections

PLO	PLOAM	PLS	DBR x	Payload x	DBR y	Payload y

Fig 1

The structure of upstream frame is given in the fig 1. Each frame consists of variable transmission from one or more ONUs. The BW map dictates the alignment of these transmissions.

B. Downstream frame format of GPON

GPON uses TDM technique for broadcasting the traffic from OLTs to all ONUs. Every ONU must receive the frames which are intended to it that are assured by encryption.

The downstream frame of GPON consists of Physical Control Block downstream (PCBd), the ATM partition and the GEM partition. The downstream frame provides common time reference and common control signaling for PON and upstream respectively.

PCBd n	Payload n	PCB n+1	Payload n+2

Fig 2 (UPSTREM FRAME)

"Pure" ATM cells section	TDM & data fragments over GEM section

Fig 3 (PAYLOAD)

The structure of the upstream frame and its payload are given in fig 2 & 3 respectively. Each frame is of 125µs. If there is no data to transfer also the downstream frames are transferred to maintain the synchronization.

IV. OPTICAL SPLITTERS

In general PON uses only one fiber to connect Optical Line Terminator (OLT) to various Optical Network Units (ONU). The point-to-multipoint connectivity between OLT and multiple ONUs can be achieved by using various passive branching optical devices.

The passive optical splitter is the heart of the PON architecture. This device is used for splitting one optical signal input into multiple optical signals. Basically the optical output is of 2^n. The optical power is equally split among the outputs. According to rule of thumb, the every output is reduced relatively to the input by a factor of n x 3.5 (i.e. $10\log2^n$). There will be optical splitting losses so we add a 0.5db.

Basically splitters are bidirectional devices so they are also called coupler. But the splitting ratio and the losses are same in both directions. Mostly there are two techniques in the manufacture of the splitters they are Planar Lightwave Circuit (PLC) and Fused Biconical Taper (FBT). A PLC splitter consists of microscopic optical circuit that is typically etched in silicon. In order to manufacture 1x2 FBT splitter two fibers are fused together. In order to achieve higher order splitter we connect various low order splitters in a cascade.

The optical signal in this architecture is attenuated by various components like splices, connectors, transmission fiber and also by optical splitters. Typically the loss ata 1x32 optical splitter is in between 16 to 18 db.

V. LINK BUDGET

Typically PON consists of OLTs, ONUs and Optical Distribution Network (ODN), the transmission media for connecting OLTs to ONUs. Normally the ODN contains passive optical elements, optical fiber, optical connectors, passive branching components, attenuator, and splicer. The losses pertaining to these components should be considered while designing optical networks. Here are some ranges of attenuations in GPON

Item	Unit	Path loss
Min optical loss 1310 nm	dB	13
Max optical loss 1310 nm	dB	28
Min optical loss 1490 nm	dB	13
Max optical loss 1490 nm	dB	28

A. Power Budget

The factors which define the possible reach of access network are transmitter power and receiver sensitivity. The following table gives us the parameters of the commercially available burst transceivers capable of supporting up to 1.25 Gbps.

ONUs	L	Λ	FCA	SL	Penalty	Req. power budget
16	10 km	1310 nm	0.4 dB/m	14.5dB	2.5 dB	21 dB
16	20 km	1550 nm	0.3 dB/m	14.5 dB	2.5 dB	23 dB
32	10 km	1310 nm	0.4 dB/m	17 dB	2.5 dB	23.5 dB
32	20 km	1550 nm	0.3 dB/m	17 dB	2.5 dB	25.5 dB

For getting the power budget of worst case scenario we subtract minimum receiver sensitivity from the minimum transmitter power.

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In optical devices the available power budget is in between 22 and 23 dB. The maximum reach of the access network can be known from the following formulae.

P = FCL x L + SL +Penalties

Where P = Power Budget

FCL = Fiber cable attenuation

L = Distance

SL = Splitter loss

Penalties = Losses at splices and connectors

As we know the ranges of all these components we can design the access network we need.

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