Abstract— Gigabit Passive Optical Network (GPON), brings fiber to the home providing the capability of higher bandwidth to the consumer. With the high demand for HDTV channels, online gaming, and streaming services like Hulu and Netflix, the need for fiber and the bandwidth and capacity it provides becomes more apparent.

I. INTRODUCTION

The average American consumes 34 gigabytes worth of information each day [1]. The every growing need for faster speeds and bandwidth becomes more apparent with such services as Netflix, which takes around 3600 MB for a HD streaming movie and around 1500 MB for a 30 minute TV show [2], and Americans spending about 13 hours a week on the internet [3]. A solution to the consumers bandwidth and speed demands is the use of Passive Optical Networks, specifically a Gigabit Passive Optical Network.

A Passive Optical Network (PON) is a point-to-multipoint network architecture in which a single fiber is used to serve multiple premises. A PON consists of an optical line terminal (OLT) at the central office of the service provider and optical network units (ONUs) on the business or home of the end user [4]. There are several type of PONs such as: Ethernet PON (EPON), asynchronous transfer mode PON (APON), broadband PON (BPON), and gigabit PON (GPON).

Passive Optical Network architecture began in 1995 with the creation of the Full Service Access Network Initiative to provide business customers with multiservice broadband by combing ATM and PON into APON. In 1996, the name changed to BPON to avoid confusion with its close association with ATM. EPON, invented by IEEE, and GPON, invented by FSAN, both began development in 2001. By 2004, EPON was adapted as a full standard. Since GPON was an extension of BPON technology and reused most of its standard (G.983), FSAN decided to not make GPON backwards compatible. GPON became G.984 in 2003, but has yet to become a full standard. The focus of this paper is to discuss the PON architecture and operation, the benefits of adapting a GPON network architecture, and the applications of such architecture.

II. PON ARCHITECTURE AND OPERATION

In optical fiber communication the main architecture consists of the transmitter, the fiber, and the receiver. Pictured below is the standard Fiber-Optic Communication System:

![Figure 1: Fiber-Optic Communication System](image)

The transmitter component pictured in Figure 1 has two primary functions. First, it must be the source of the light into the fiber-optic cable. Secondly, the light must be modulated to represent the binary data it receives. Other important transmitter parameters include packaging, environmental, sensitivity, heat sinking, and reliability.

The receiver pictured in Figure 2, also serves two functions. It must detect light that is coupled out of the fiber-optic cable and convert the light into an electrical signal, and it must demodulate the light to identify the transmitted binary data. The receiver can also do other functions, such as clock recovery, synchronous signaling, decoding circuitry, and error
detection and recovery. The receiver has high sensitivity in order to detect low-level optical signals. The higher the sensitivity, the more attenuated signals can be detected [5].

**Figure 2: Schematic of Optical Receiver**

PON architecture utilizes this system and limits the amount of fiber that has to be run to the consumer by using an optical splitter and different end equipment. All types of PONS have similar architecture. The standard PON architecture consists of and optical line terminator, OLT, an optical splitter, and an optical network termination, ONT. Pictured below is a generic model of the PON architecture:

**Figure 3: PON architecture configuration**

In order to transmit downstream the OLT broadcasts traffic to every ONT connected through the action of the optical splitters. The ONT reads the data packet that are addressed to it. Each data packet is encrypted, so that there is no snooping on the downstream traffic during broadcasting. On the other hand, in the upstream direction the OLT manages and controls all data transactions using a certain protocol, in the case of GPONs this protocol is either asynchronous transfer mode (ATM), Ethernet, or TDM data transport [6]. GPON standard define different rates for downstream and upstream direction.

**Table 1. GPON Nominal bit rate**

<table>
<thead>
<tr>
<th>Transmission direction</th>
<th>Bit rate</th>
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<tbody>
<tr>
<td>Downstream</td>
<td>1244.16 Mbit/s</td>
</tr>
<tr>
<td></td>
<td>2488.32 Mbit/s</td>
</tr>
<tr>
<td>Upstream</td>
<td>155.52 Mbit/s</td>
</tr>
<tr>
<td></td>
<td>622.08 Mbit/s</td>
</tr>
<tr>
<td></td>
<td>1244.16 Mbit/s</td>
</tr>
<tr>
<td></td>
<td>2488.32 Mbit/s</td>
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</tbody>
</table>

Most vendors only offers 1.2 Gbit/s upstream and 2.2 downstream [6].

**III. GPON Features and Benefits**

There are advantages and disadvantages to every type of PON. Depending on the speed, protocol, and security the consumer desires ultimately determines which PON will be chosen.

**Figure 4: PON comparisons [7]**

As shown in Figure 4, compared to EPON and its predecessor BPON, GPON offers not only the fast down/upstream in Mbit/s, 2488.36/1244.16 to EPON's 1250/1250, but also offers an improved downstream security. GPON uses the GEM, Generic Encapsulation Method, as its native protocol for its transport layer. GEM supports ATM, Ethernet, and TDM data transport,
making GPON the most versatile PON. GPON has several operational details that set it apart from other PON types such as: forward error correction, transmission containers, dynamic bandwidth allocation, and security.

Forward Error Correction (FEC) encodes data so that errors can be detected and corrected using signal-processing techniques. With FEC, redundant information is transmitted simultaneously with the original information so that a lot of overhead is not introduced. FEC increases the link budget, therefore allowing a higher bit rate and longer distance between the OLT and the ONU and allows for a more splits on a single PON tree [7].

Transmission Containers (T-CONT) manage upstream bandwidth allocation in the GPON. T-CONTs enable Quality of Service (QoS) implementation in the upstream direction. There are five T-CONT types which can be used by the user. T-CONT 1 guarantees fixed bandwidth allocation for time-sensitive application like voice over IP; T-CONT 2 is for non time-sensitive applications. T-CONT 3 is a mix of minimum bandwidth and non-guaranteed. T-CONT 4 is best effort with no guaranteed bandwidth. Finally, T-CONT 5 is a mix of all [7]. Figure 5 below shows the different T-CONT types.

Another feature that is important to GPON is Dynamic Bandwidth Assignment (DBA). DBA not only enhances the uplink bandwidth utilization of PON ports and the number of users that can be added on a port, but also user will have higher-bandwidth services as a whole [7]. DBA is controlled by the OLT, which allocates bandwidth volume to the ONUs. DBA is only used in the upstream; the downstream broadcasts direction traffic [6]. Figure 6 demonstrates how the DBA process works.

In GPON there are two forms of DBA, status-reporting (SR) and non-status-reporting (NSR). SR DBA requires the OLT to poll the ONUs for their backlogs. The ONU reports each T-CONT separately to the OLT; this report contains a logarithmic measure of the backlog. By knowing T-CONT type across the entire PON, as well as the size of the backlog, the OLT can optimize allocation of the spare bandwidth on the PON. Adversely, NSR DBA, the OLT tries to continuously allocate a small amount of extra bandwidth to each ONU connected. If the ONU has no traffic then idle frames are transmitted during allocation. On the other hand, if the ONU is sending traffic then bandwidth allocation is increased to that individual unit [4].

GPON broadcasts downstream data to all ONUs and every ONU has an allocated time when data belongs to that user. Due to this design, a user can program their ONU to capture all downstream data connected to the OLT leading to security issues. However, in the upstream direction GPON uses point-to-point connection so the traffic is secure from snooping. GPON recommendation. G.984.3 uses a security mechanism that will only allow them to access data addressed to them. GPON utilizes the encryption algorithm called the Advanced Encryption Standard (AES). Since AES has the ability to accept 128, 192, and 256 byte keys, the encryption is extremely difficult to compromise [5].
GPON has four different network protection modes, fiber backup and OLT interface backup.

The fourth type of network protection is a Mixed backup, shown in Figure 10.

![Figure 7: Type A Fiber Backup](image)

Fiber backup does not store any backup on the ONUs. If the primary fiber fails, all services transfer to the secondary fiber. The protected area is from the OLT to the optical splitter. On the other hand, OLT interface backup, pictured below in Figure 8, the OLT provides two GPON interfaces. The primary fiber is protected and if the primary fiber fails the services will transfer to the secondary fiber.

![Figure 8: OLT interface backup](image)

The third type of protection is All-backup. In this protection mode, shown in Figure 9, both the OLT and the ONT provide two GPON interfaces which work in 1:1 mode. This will provide protection to the entire network allowing the network to recover from various faults between the OLT and the ONU. No service outage will occur due to when a line fails, services are automatically transferred to the secondary line on both the ONU and the OLT.

![Figure 9: All Backup](image)

IV. Applications of GPON

The major application will be its ability to compete with cable companies by offering the Triple Play service through a single fiber connection. Triple Play service is a marketing term for the provisioning of bandwidth-intensive services, such as high-speed internet, television, and telephone [11]. With further implementation of GPON, consumers will be able to have a direct fiber line run to their home or business, resulting in not only better and faster connectivity, but also providing competition to cable companies. With the ability to maintain 48 users on a single port, GPON offers the opportunity for a more connected world.

References
