Gigabit Ethernet – IEEE 802.3z
The Choice of a New Generation

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**Introduction**

In the last few years, the world of communications has seen a series of revolutions. The most noticeable of these was probably the Internet and the exponential increase in its usage. In fact, today, most American households own computers and are connected to the Internet. Furthermore, in countries where the economic situation does not allow private computer ownership and Internet access, cyber-cafés have flourished. With this increased usage, there has been a constant craving for more bandwidth and faster transmission. Both these needs have fostered the emergence of new technologies such as the Ethernet, the Fast Ethernet and the Gigabit Ethernet.

In general, the Ethernet brought many advantages with it, such as an increase in efficiency, larger capacity, lower cost, and simpler networks. The increase in usage of this new means created the need for standards for the convenience of both manufacturers and consumers. In order to fulfill this need, a task force was created by the Institute of Electrical and Electronics Engineers (IEEE) to put the 802 standard together. For the concerns of the project at hand, the part of the standard that we are concerned with is 802.3, which covers the physical layer of the Ethernet for Local Area Networks or LANs. Figure 1 shows a rough sketch of the first Ethernet system.

![Figure 1- Drawing of the First Ethernet System](image)

**Figure 1**- Drawing of the First Ethernet System [1].
From the simple structure illustrated in Figure 1 on the previous page, the Ethernet evolved to a much more complex entity and to a much faster means of transmission. In fact it has steadily evolved to reach speeds of transmission of 1 Mbps then 10, 100, and a 1000 Mbps as illustrated in Figure 2.

![Figure 2 – Evolution of the Ethernet [1].](image)

From this figure, it can be easily inferred why the terminology Gigabit Ethernet is in use instead of the name “Ethernet” by itself. The constant improvements of the Ethernet along with the many advantages it brought made it earn an ever-growing place in the market as illustrated in Figure 3 on the next page.
We can see in the above figure how the Ethernet market has evolved from 1999 to 2002. In an attempt to reach a better understanding of the Ethernet Technology, the Ethernet Standards will be discussed in the following section.

**The Ethernet Standards**

In doing research about the background of this project, there were four parts of the standard that were relevant: 802.3ab, 802.3u, 802.3ae and 802.3z. The 802.3ab standard describes the specifications for the 1000BASE-T (twisted-pair) Gigabit Ethernet system. The 1000BASE-T stands for the physical layer of the Ethernet. The physical layer is just the actual wiring that links the Ethernet network. The naming convention comprises 3 terms indicating the transmission; the method of transmission and the type of media and/or the way the signal is encoded. For 1000BASE-T, the speed of transmission is 1000 Megabits per second (1 Gigabit per second) and is done in baseband over twisted pair cables. The 802.3u represents the standard for the Fast Ethernet with a speed around 100 Mbps. In addition, 802.3ae sets the standard for the 10 Gigabit Ethernet while 802.3z is for the 1 Gigabit Ethernet with fiber optic cables [1].
The latter is the only standard that is needed for the accomplishment of the task assigned to our group.

The building of this standard made the IEEE constitute the 802.3z Task Force. This group put together a set of objectives that included the use of the 802.3 Ethernet format. In addition, the new standard would have to allow Full and Half Duplex operation. There would be the provision of wiring specifications that would support a minimum of 500 m on multimode fiber, 25 m on copper and 2 km on single mode fiber. From the initial set of objectives, the task force defined five final criteria for the standard. The first was the broad market potential (many applications, multiple vendors and users). The second criterion was the compatibility with IEEE Standard 802.3. The third criterion was the technical feasibility, i.e. the ability to make the model work. Another condition was the uniqueness of the standard, i.e. the difference between it and other standards. The last but not least of these norms was the economic feasibility meaning a reasonable cost for the performance expected [3]. The task force that was able to put out the standard in a timely manner successfully reached all these objectives. The reasons for this project being concerned with the 802.3z standard are multiple. One of the most important ones is the use of fiber, which has many advantages. Fiber is evolving towards being the only viable medium for high-speed, high-capacity data transmission. In using fiber for this project, two choices were available: single-mode fiber and multimode fiber. The next part of this report will make the comparison between these two alternatives and decide which one is better suited for this project.

**Single-Mode Fiber (SMF) vs. Multimode Fiber (MMF)**

The ever-emerging world of the telecommunication industry seeks more and more bandwidth to send information, albeit via wire or wireless communications. Not to long ago,
approximately 80 percent of all network traffic was contained within workgroups and departments; however, times have changed and this traffic now runs primarily through local-area network (LAN) backbones, wide-area networks (WAN), or the Internet [2]. This need for a greater amount of bandwidth has changed the type of transmission mediums used in transmitting raw bits. Traditionally, cooper wires have been used to transmit raw bits in the form of electrons; however, newer technology allows for transmission of bits in the form of photons (light) over fiber. Figure 4 shows a comparison between a line with multiple cooper wires and two fiber cables.

![Figure 4. Several copper wires (above) and two fiber cables (below).](image)

The two fibers above can transmit the same amount of information carried by several cooper wires put together on a line. There are two types of fibers used: single-mode fiber and multimode fiber.
**Single-Mode Fiber**

Since 1983, long distance service providers and CATV companies have extensively used single-mode fibers due to their excellent characteristics [4]. One of these characteristics includes maintaining signal integrity as shown in Figure 5c on the following page.

![Figure 5.](image)

In single-mode, pulses of light propagate parallel to the center axis. As a result, the signal’s integrity is maintained because all pulses arrive to their destination at the same time; therefore, eliminating any interference from trailing edges of pulses [4, 5]. All of these characteristics are inherited from the diameter size of the core, which is approximately 9 microns (or less).

**Multimode Fibers**

Multimode fibers, on the other hand, come in several different types and sizes. The first type, as shown in Figure 5a, is called a step-index multimode fiber. Step-index multimode fibers
measure roughly up to 100 microns in diameter. As a result, the light pulses zigzag across the fiber channel causing it to arrive at different times at the receiver. These different groupings of light pulses are referred to as modes. In order to eliminate cross talk between signals, a certain space must be maintained between pulses. This, in turn, limits the amount of bandwidth through the channel. This type of cable is primarily used for short distances [5].

The graded-index multimode fiber, as shown in Figure 2b, has a core size between 50-62.5 microns and contains a higher index of refraction at the center, which gradually diminishes as it moves towards the cladding. This results in helically shaped signals that travel much faster than those located near the center. In contrast to step-index fibers, these signals arrive to the receiver at the same time; therefore, causing less dispersion. This type of fiber is primarily found in LANs [5].

There are currently two categories of vertical cavity emitting lasers (VCSEL): long wave (1000BaseSX) and short wave (1000BaseLX). Long wave lasers have wavelengths measuring between 1270-1370 nm, while short wave lasers have wavelengths measuring between 770-860 nm. In addition, the 1000BaseSX can only be used with multimode fiber, while the 1000BaseLX can be used with either single-mode or multimode fiber [5].

**Comparison of SMF and MMF**

One of the main differences between SMF and MMF exists in the maximum allowable distance the signal travels before it begins to deteriorate. Table 1 lists these maximum distances based on the data rate.

<table>
<thead>
<tr>
<th></th>
<th>100Mbps</th>
<th>1000Mbps</th>
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<tbody>
<tr>
<td>SMF</td>
<td>5000m</td>
<td>5000m</td>
</tr>
<tr>
<td>MMF</td>
<td>2000m</td>
<td>550m</td>
</tr>
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*Table 1. SMF and MMF speed and distance table [2].*
At 100 Mbps or 1000 Mbps (1 Gbps), SMF can carry information without loss of signal integrity for approximately 5 km. This is one of the nicest features of SMF. On the other hand, this does not hold true for MMF. As the data rate increases by a factor of 10, the maximum allowable distance decreases by a factor of 4.

Some of the overall advantages of SMF include: greater bandwidth (up to 23.371 Gbps), and signal integrity over long distances. Even though SMF has excellent characteristics, it is very expensive to maintain. For beginners, SMF cards are often priced 200 to 300 percent higher than MMF cards, as well as require expensive equipment, specially trained personnel to attach connectors, and extensive infrastructure excavation [2]. For this reason, SMF has not been a big hit when it comes to computer networking.

MMF, on the other hand, is made up of less-expensive components such as light sources, detectors, optics, and standard mechanical tooling. This makes it a more economical choice. However, the 550-meter limit makes MMF somewhat impractical when considering that much of the fiber lying underneath streets and sidewalks exceed this limit. Companies like Blaze Network Products have devised ways to overcome this feat. By simply combining techniques like multi-level encoding and wave division multiplexing, MMF can deliver full gigabit speed at distances up to 2 km. Based on these observations, it was determined that a graded-index multimode fiber would be better suited for this project.

The specifics of the project

The goal of this project is to design, implement and test the transmitter part of the OE module, which is attached to a PC network card. Figure 6 illustrates the PC card as well as the OE module.
Figure 6a is a representation of the Intel Pro/1000F Gigabit Ethernet card, which will be used in the project. The features of this card include an Intel 82544El Gigabit controller for high performance and reliability. It has a 1000BaseSX Fiber Connection, which provides longer cable lengths and noise resistance for signal integrity at 1000Mbps. It also has Advanced Offloading to provide maximum scalability of servers; thus, minimizing CPU utilization. In addition, it is compatible with Fast Ethernet, so there is a reduction in training costs and quick ramp rollout. The Mixed Adapter Teaming offers greater flexibility and compatibility. Also, it allows the teaming of any combination of Intel PRO/100 S adapters. Furthermore, it can be coupled with Intel 10/100 Server Adapters (a cost-effective failover). Online serviceability is available through the PCI Hot Plug/Active PCI. It has Driver Backward Compatibility. One of its drivers works with all current Gigabit Ethernet products thereby reducing support costs. The module in Figure 6b is the actual opto-module, otherwise known as the transceiver. The first task in the project will be to get a thorough understanding of the transmitter part of the module,
which can be replaced by the Maxim Evaluation Board (MAX3287SW EV KIT). The MAX3287 kit typically requires a common-cathode configuration, which includes socket for laser insertion. It also works with an adjustable DC bias current. The board can be pre-biased at a current level compatible with the characteristics of the VCSEL that it is connected to. The board is configured for electrical operation, which allows an SMA cable to be directly connected to it. The outgoing SMA cable is then plugged into a pigtailed VCSEL. Also, it has an adjustable photodiode current and an adjustable modulation current. Once fully assembled, it will be tested using different methods. One of these methods is performed by comparing it to the eye mask provided by the IEEE Standard 802.3z as shown in Figure 7.

![Figure 7](image.png)

**Figure 7.** The eye mask used to test the transceiver

The significance of the eye mask is to differentiate between a logical zero and one. If the eye is not as specified then many errors may occur in data transmission or reception. In addition, the board can be tested using a bit error test set as well as signal analysis. Once the board is tested
and found to be working properly, it will be mounted on the Intel Network Card. The card will then be placed on a computer to verify proper communication through the computer network. Other parts of the project will involve the replication of the board using parts chosen and ordered by the group.

Conclusion

The assignment at hand is an engineering senior design project and it aims at making one earn some practical experience. An additional goal for the project is to reduce cost while maintaining the same quality as the original design. This will be achieved by comparing the present alternatives in the market, while trying to purchase the needed components at the lowest available price. In the process, we will acquire precious skills on how to build electronic components, how to solder and use testing equipment.

References