Lab 4: Using IP and Ethernet

Assigned: Monday 10/23; Due **Monday 11/6** (midnight)

Instructor: James E. Stine, Jr.

1. Introduction

Ethernet was developed at Xerox PARC between 1970s as a method to allow Alto computers to communicate with each other. It was inspired by the ALOHAnet, which Robert Metcalfe had studied as part of his PhD dissertation and was originally called the Alto Aloha Network. Just like many engineering advancements, Robert Metcalfe and his colleagues were in the right place at the right time in addition to trying an idea that is practical and easy to implement. I guess the adage is the rest is history. A really great YouTube video documenting the ideas of Ethernet can be found here `https://youtu.be/g5MezxMcRmk?si=UomwAQHmMgY6cvh4`.

Personally, I think the idea is quite efficient and straight forward, but it is so vital to today's society that I firmly believe its something you should know about. This laboratory will be about using Ethernet from some pre-built Hardware Descriptive Language (HDL) or sometimes called Intellectual Property (IP). In many digital areas, IP is essential to many products both commercially and in research that you have to just add it to your design and try it. This laboratory will be about that very idea – that is, to use specific IP and understand how to use it.

1.1 Ethernet Packets

Ethernet is the most widely used LAN technology and is defined under the IEEE standards 802.3. The reason behind its wide usability is that Ethernet is easy to understand, implement, and maintain, and, most importantly, allows a low-cost network implementation. Also, Ethernet offers flexibility in terms of the topologies that are allowed. Ethernet generally uses a bus topology where each item connects to the Ether. Ethernet operates in two layers of the OSI model, the physical layer and the data link layer. For Ethernet, the protocol data unit is a frame since we mainly deal with DLLs. In order to handle collisions, the Access control mechanism used in Ethernet is CSMA/CD.

Although Ethernet has been largely replaced by wireless networks, wired networking still uses Ethernet more frequently. Wi-Fi eliminates the need for cables by enabling users to connect their smartphones or laptops to a network wirelessly. The 802.11ac Wi-Fi standard offers faster maximum data transfer rates when compared to Gigabit Ethernet. However, wired connections are more secure and less susceptible to interference than wireless networks. This is the main justification for why so many companies and organizations continue to use Ethernet.

The basic frame format which is required for all MAC implementation is defined in IEEE 802.3 standard. Though several optional formats are being used to extend the protocol's basic capability. Ethernet frame starts with Preamble and SFD, both work at the physical layer. Ethernet header contains both the Source and Destination MAC address, after which the payload of the frame is present. The last field is CRC which is used to detect the error. Now, let's study each field of basic frame format.

The size of an Ethernet frame by the IEEE 802.3 varies from 64 bytes to $1,518$ bytes including the data length (i.e., 46 to $1,500$ bytes). T

- PRE (preamble) – Ethernet frame starts with a 7-Bytes Preamble. This is a pattern of alternative 0's and 1's which indicates starting of the frame and allow sender and receiver to establish bit synchronization. Initially, the PRE (Preamble) was introduced to allow for the loss of a few bits due to signal delays. But today's high-speed Ethernet doesn't need the Preamble to protect the frame bits. PRE (Preamble) indicates the receiver that frame is coming and allow the receiver to lock onto the data stream before the actual frame begins.

- Start of frame delimiter (SFD) – This is a 1-Byte field that is always set to `1010_1011`. SFD indicates that upcoming bits are starting the frame, which is the destination address. Sometimes SFD is considered part of PRE, this is the reason Preamble is described as 8 Bytes in many places. The SFD warns station or stations that this is the last chance for synchronization.

- Destination Address – This is a 6-Byte field that contains the MAC address of the machine for which data is destined.
- Source Address – This is a 6-Byte field that contains the MAC address of the source machine. As Source Address is always an individual address (Unicast), the least significant bit of the first byte is always 0.
- Length – Length is a 2-Byte field, which indicates the length of the entire Ethernet frame. This 16-bit field can hold a length value between 0 to $65,534$, but length cannot be larger than $1,500$ Bytes because of some own limitations of Ethernet.
- Data – This is the place where actual data is inserted, also known as Payload. Both IP header and data will be inserted here if Internet Protocol is used over Ethernet. The maximum data present may be as long as $1,500$ Bytes. In case data length is less than minimum length (i.e., 46 bytes), then padding 0's is added to meet the minimum possible length.
- Cyclic Redundancy Check (CRC) – CRC is 4 Byte field. This field contains a 32-bits hash code of data, which is generated over the Destination Address, Source Address, Length, and Data field. If the checksum computed by destination is not the same as sent checksum value, data received is corrupted.
- VLAN Tagging – The Ethernet frame can also include a VLAN (Virtual Local Area Network) tag, which is a 4-byte field inserted after the source address and before the EtherType field. This tag allows network administrators to logically separate a physical network into multiple virtual networks, each with its own VLAN ID.
- Jumbo Frames – In addition to the standard Ethernet frame size of $1,518$ bytes, some network devices support Jumbo Frames, which are frames with a payload larger than $1,500$ bytes. Jumbo Frames can increase network throughput by reducing the overhead associated with transmitting a large number of small frames.
- Ether Type Field – The EtherType field in the Ethernet frame header identifies the protocol carried in the payload of the frame. For example, a value of `0x0800` indicates that the payload is an IP packet, while a value of `0x0806` indicates that the payload is an ARP (Address Resolution Protocol) packet.
- Multicast and Broadcast Frames – In addition to Unicast frames (which are sent to a specific destination MAC address), Ethernet also supports Multicast and Broadcast frames. Multicast frames are sent to a specific group of devices that have joined a multicast group, while Broadcast frames are sent to all devices on the network.
- Collision Detection – In half-duplex Ethernet networks, collisions can occur when two devices attempt to transmit data at the same time. To detect collisions, Ethernet uses a Carrier Sense Multiple Access with Collision Detection (CSMA/CD) protocol, which listens for activity on the network before transmitting data and backs off if a collision is detected.