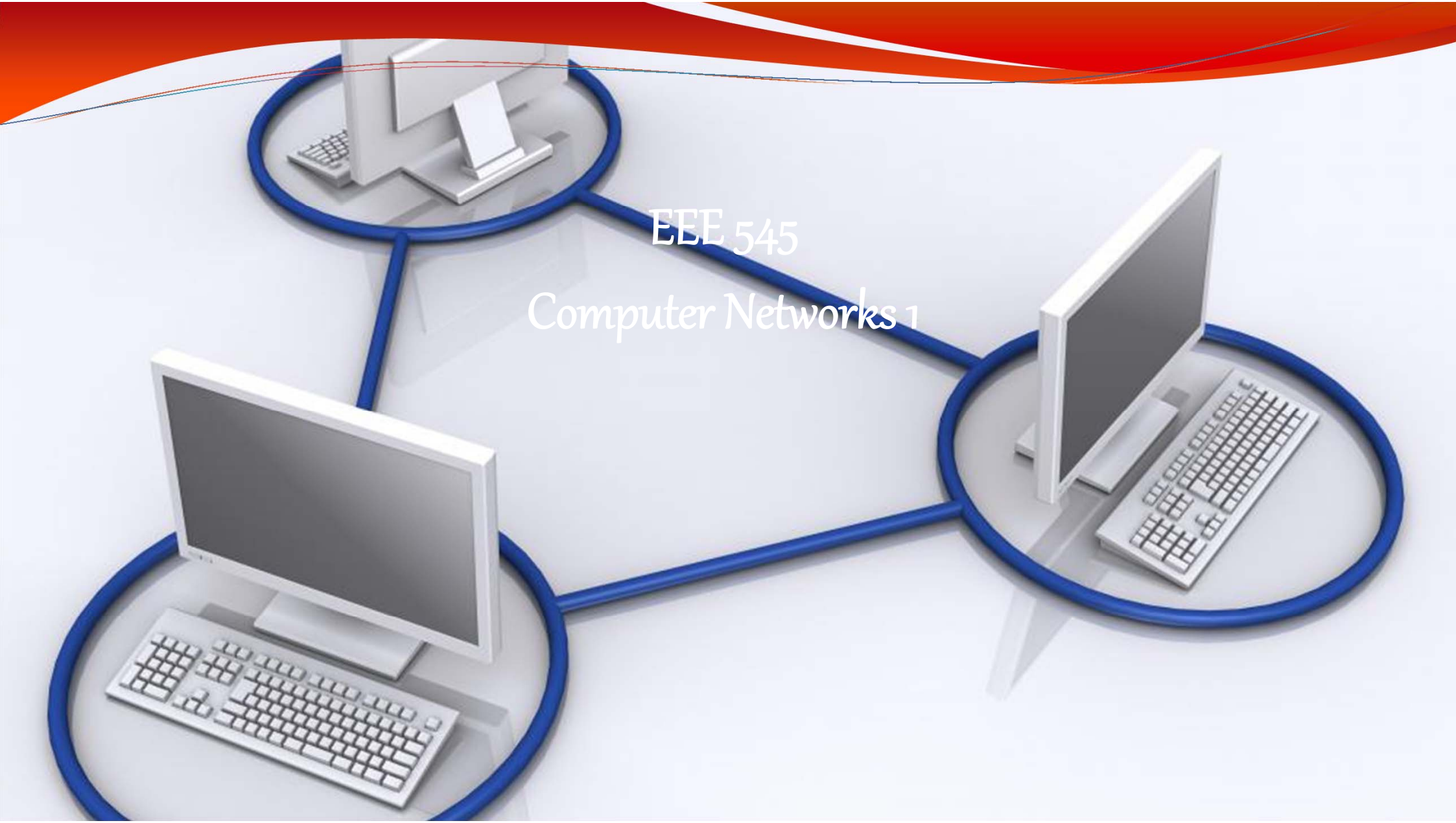
EEE 545

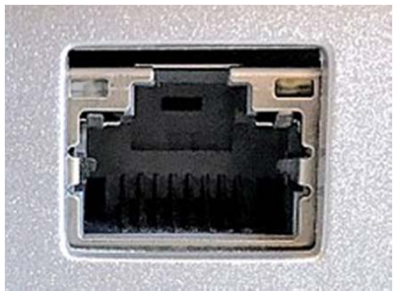
Computer Networks 1



CH2 – Ethernet

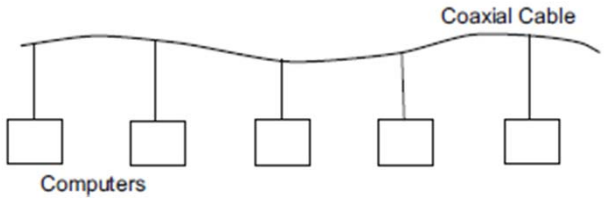
2.1 Introduction

- Ethernet is a family of wired computer networking technologies commonly used in local area networks (LAN), metropolitan area networks (MAN) and wide area networks (WAN).
- Ethernet has become the most popular wired local area network standard. While maintaining a low cost, it has gone through six versions, most ten times faster than the previous version (10 Mbps, 100 Mbps, 1 Gbps, 10Gbps, 40 Gbps, 100 Gbps, and in the works 400 Gbps).



2.2 – 10Mbps Ethernet

- Originally, Ethernet consisted of a long piece of cable (possibly spliced by repeaters). When a station transmitted, the data went everywhere along that cable(Figure). Such an arrangement is known as a broadcast bus; all packets were, at least at the physical layer, broadcast onto the shared medium and could be seen, theoretically, by all other nodes.
- Whenever two stations transmitted at the same time, the signals would collide, and interfere with one another; both transmissions would fail as a result. Proper handling of collisions was an essential part of the access-mediation strategy for the shared medium. In order to minimize collision loss, each station implemented the following:
- 1. Before transmission, wait for the line to become quiet
- 2. While transmitting, continually monitor the line for signs that a collision has occurred; if a collision is detected, cease transmitting
- 3. If a collision occurs, use a backoff-and-retransmit strategy



2.2 – 10Mbps Ethernet

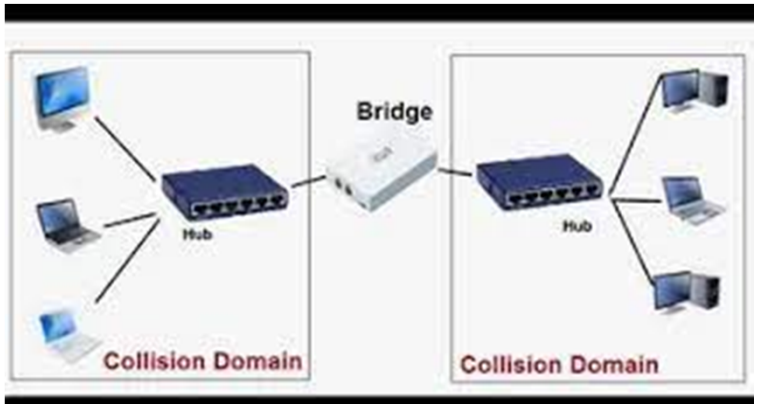
- Some Hardware Issues..
- **Repeater** operates at the physical layer. Its job is to regenerate the signal over the same network before the signal becomes too weak or corrupted so as to extend the length to which the signal can be transmitted over the same network.
- **Hub** is basically a multiport repeater. A hub connects multiple wires coming from different branches, for example, the connector in star topology which connects different stations.

Repeater

Hub

2.2 – 10Mbps Ethernet

- Some Hardware Issues..
- **Bridge** connects the devices which are present in the same network. It is mainly used to segment a network to allow a large network size. It has two types of port - incoming and outgoing. It uses the incoming port to receive the data frames and outgoing port to send the data frames to other devices. It is also used for interconnecting two LANs working on the same protocol.
- **Switch** is a multiport bridge with a buffer and a design that can boost its efficiency(a large number of ports imply less traffic) and performance.



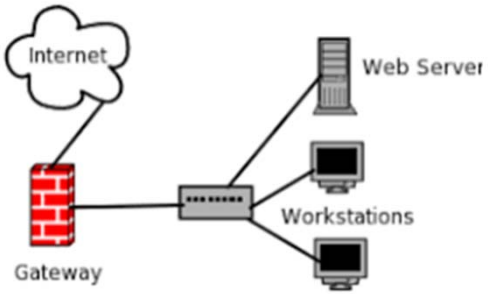
Bridge

Switch

2.2 – 10Mbps Ethernet

- Some Hardware Issues..
- **Router** is a device like a switch that routes data packets based on their IP or MAC addresses.
- **Gateway,** as the name suggests, is a passage to connect two networks together that may work upon different networking models.

Router



Gateway

2.2 – 10Mbps Ethernet

- These properties can be summarized with the CSMA/CD acronym: Carrier Sense, Multiple Access, Collision Detect.
- if the bit rate is 10Mbps, the actual useful information transport can be significantly less because of collisions (or occasional idleness).
- There were three physical formats for 10 Mbps Ethernet cable: thick coax (10BASE-5), thin coax (10BASE-2), and, last to arrive, twisted pair (10BASE-T). Thick coax was the original; economics drove the successive development of the later two. The cheaper twisted-pair cabling eventually almost entirely displaced coax, at least for host connections.

10Base-5, Thick net

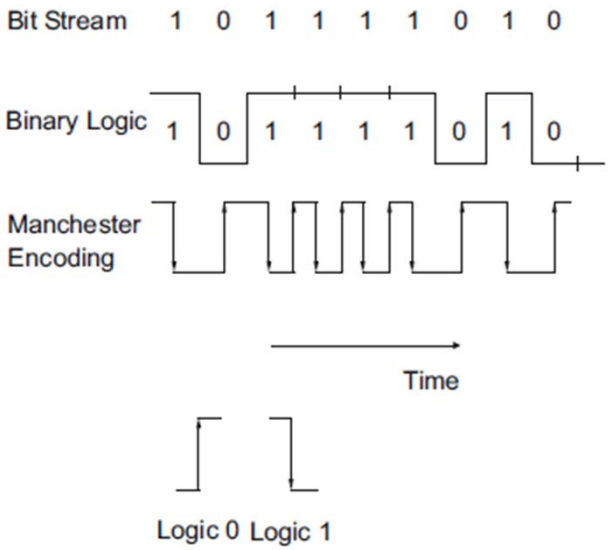
10Base-2, Thin net

10Base-T

2.2 – 10Mbps Ethernet

- Table above shows the fields in the 10Mbp Ethernet frame. A frame is the name for a packet at the data link layer.

Field	Length
Preamble	7 bytes
Frame delimiter	1 byte
Destination address	2 or 6 bytes
Source address	2 or 6 bytes
Data length	2 bytes
Data	up to 1500 bytes
Pad	variable
CRC Checksum	4 bytes



- To provide many transitions between logic levels, even if the data has a long run of one logic level, 10Mbps Ethernet uses Manchester encoding.

2.2 – 10Mbps Ethernet

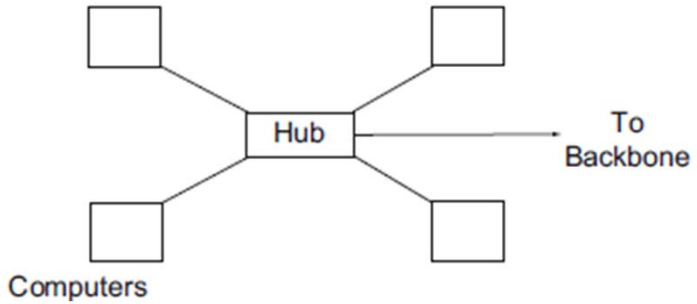
- About Ethernet wiring…
- In “10Base5”, the 10 stands for 10Mbps and the 5 for the 500m maximum size.
- Today, 10Base-T is the most common wiring solution for 10 Mbps Ethernet. Fiber optics, 10Base-F, was only intended for runs between buildings, but a higher data rate protocol would probably be used today for this purpose.

Cable	Type	Maximum size
10Base5	Thick coax	500 m
10Base2	Thin coax	200 m
10Base-T	Twisted pair	100 m
10Base-F	Fiber optics	2 km

Ethernet wiring

2.3 Fast Ethernet

- In 1992, IEEE assigned the 802.3 committee the task of developing a faster local area network protocol.
- The committee agreed on a 100 Mbps protocol that would incorporate as much of the existing Ethernet protocol/technology as possible to gain acceptance and so that they could move quickly. The resulting protocol, IEEE 802.3u, was called Fast Ethernet.
- Fast Ethernet is only implemented with hubs, in a star topology. There are three major wiring options.



Ethernet wiring with hub in a star topology

2.3 Fast Ethernet

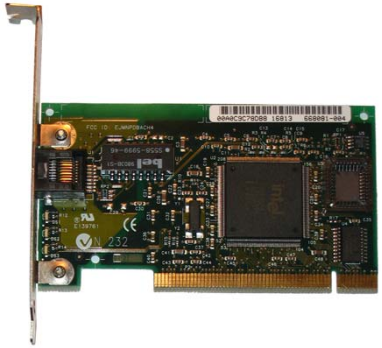
- Fast Ethernet 100 Base-T4 actually uses four twisted pairs per cable. Three twisted pairs carry signals from its hub to a PC.
- An alternative to 100Base-T4 is 100 Base-TX. This uses two twisted pairs, with 100 Mbps in each direction. However, 100 Base-T4 has a signaling rate of only 125 MHz. It accomplishes this using 4B5B (Four Bit Five Bit) encoding rather than Manchester encoding.
- 100 Base-FX uses two strands of the lower performing multi-mode fiber. It has 100 Mbps in both directions and is for runs (say between buildings) of up to 2 km.

4-bit	5-bit
0	0000 11110
1	0001 01001
2	0010 10100
3	0011 10101
4	0100 01010
5	0101 01011
6	0110 01110
7	0111 01111
8	1000 10010
9	1001 10011
A	1010 10110
B	1011 10111
C	1100 11010
D	1101 11011
E	1110 11100
F	1111 11101

4B/5B Coding

2.3 Fast Ethernet

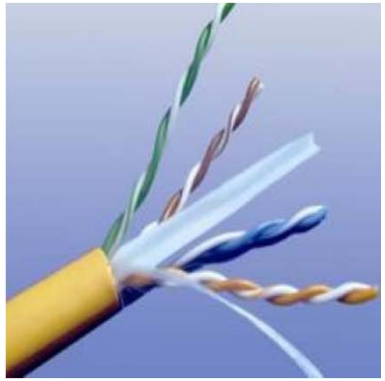
About the hardware and wiring..



Fast Ethernet Card

Cable	Type	Maximum Size
100Base-T4	Twisted pair	100 m
100Base-TX	Twisted pair	100 m
100Base-FX	Fiber optics	2 km

Fast Ethernet Wiring



100Base-T4

A device using 100Base- FX System

2.4 Gigabit Ethernet(GBE)

- The ever growing amount of network traffic brought on by the growth of applications and more powerful computers motivated a revised, faster version of Ethernet. Approved in 1998, the next version of Ethernet operates at 1000 Mbps or 1Gbps and is known as Gigabit Ethernet, or 802.3z.
- Gigabit Ethernet wiring is either between two computers directly or, as is more common, in a star topology with a hub or switch in the center of the star.

A Gigabit Ethernet Card

2.4 Gigabit Ethernet

- A shared medium hub uses the established CSMA/CD protocol so collisions can occur. At most, one attached station can successfully transmit through the hub at a time, as one would expect with CSMA/CD.
- A “switch,” on the other hand, does not use CSMA/CD. Rather, the use of buffers means multiple attached stations may send and receive distinct communications to/from the switch at the same time.
- In terms of wiring, Gigabit Ethernet has two fiber optic options (1000 Base-SX and 1000 Base-LX), a copper option (1000 Base-CX) and a twisted pair option (1000-Base T).
- ‘S’= Short Range (220m to 550m)
- ‘L’= Long Range (550m to 5km)
- ‘X’=4B/5B Coding for Fast, 8B/10B Gigabit Ethernet

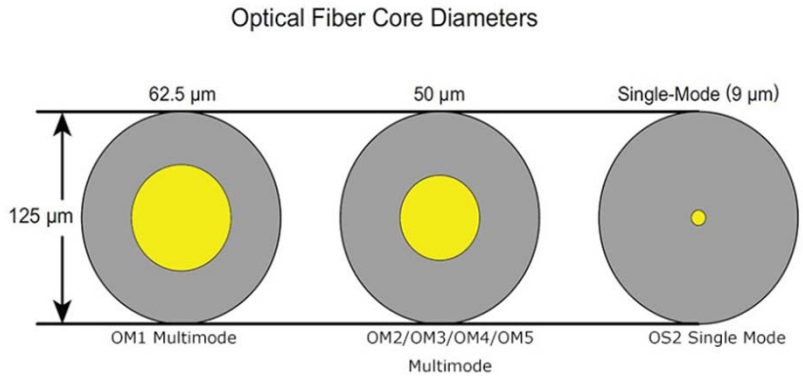
1000 Base-SX/LX

2.4 Gigabit Ethernet

- The Gigabit Ethernet fiber option deserves some comment. It makes use of 8B10B encoding, which is similar in its operation to Fast Ethernet's 4B5B. Under 8B/10B, eight bits (1 byte) are mapped into 10 bits. The extra redundancy this involves allows each 10 bits not to have an excessive number of bits of the same type in a row or too many bits of one type in each of 10 bits. Thus, there are sufficient transitions from 1 to 0 and 0 to 1 or the data stream even if the data has a long run of 1's and 0's.
- Gigabit Ethernet using twisted pair uses five logic levels on each wire. Four of the logic levels convey data and the fifth is for control signaling. With four data logic levels, two bits are communicated at once or eight bits over all four wires at a time. Thus the signaling rate is 1 Gbps/8 or 125 MHz.
- Gigabit Ethernet's range is at least 500m for most of the fiber options and about 200m for twisted pair

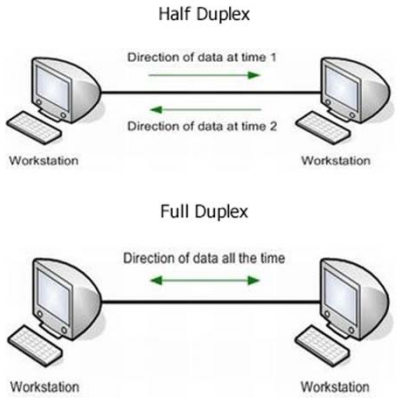
2.4 Gigabit Ethernet

- **Overview of Single Mode vs Multimode Fiber**
- Single mode means the fiber enables one type of light mode to be propagated at a time. While multimode means the fiber can propagate multiple modes. The differences between single mode and multimode fiber mainly lies in fiber core diameter, wavelength and light source, bandwidth, color sheath, distance and cost.
- Multimode fiber(MMF) is mostly used in data centers while single mode is used to provide internet connections for houses.



2.4 Gigabit Ethernet

- In a **full-duplex** system, both parties can communicate with each other simultaneously. An example of a full-duplex device is plain old telephone service; the parties at both ends of a call can speak and be heard by the other party simultaneously. The earphone reproduces the speech of the remote party as the microphone transmits the speech of the local party. There is a two-way communication channel between them, or more strictly speaking, there are two communication channels between them.
- In a **half-duplex** or **semiduplex** system, both parties can communicate with each other, but not simultaneously; the communication is one direction at a time. An example of a half-duplex device is a walkie-talkie, a two-way radio that has a push-to-talk button. When the local user wants to speak to the remote person, they push this button, which turns on the transmitter and turns off the receiver, preventing them from hearing the remote person while talking. To listen to the remote person, they release the button, which turns on the receiver and turns off the transmitter.



2.5 10 Gigabit Ethernet

- 10Gbps (or 10,000 Mbps) Ethernet (IEEE 802.3ae-2002) is ten times faster than Gigabit Ethernet. Applications include backbones, campus size networks, and metropolitan and wide area networks.
- Unlike previous Ethernet standards, 10 Gigabit Ethernet defines only full-duplex point-to-point links which are generally connected by network switches; shared-medium CSMA/CD operation has not been carried over from the previous generations Ethernet standards so half-duplex operation and repeater hubs do not exist in 10GbE.
- There are eight implementations of 10 Gbps Ethernet. It can use four transceiver types (one four wavelength parallel system and three serial systems with a number of multi-mode and single mode fiber options). Like earlier versions of Ethernet, it uses CRC error coding. It operates in full duplex non-CSMA/CD mode. It can go more than 40 km via single mode fiber.
- Transceiver=Transmitter+ Receiver

10 Gigabit Ethernet Transceiver

2.6 40/100 Gigabit Ethernet

- Over the years Ethernet has been attractive to users because of its relatively low cost, robustness, and its ability to provide an interoperable network service. Users have also liked the wide vendor availability of Ethernet related products. However, even with the release of gigabit and 10 Gbps Ethernet demand for bandwidth continued to grow. Network equipment shipments can grow at a 17% a year rate. Internet traffic grows at 75–125% a year. Computer performance doubles every 24 months. A 2008 projection was that within 4 years 40Gbps would be needed.
- One of the applications driving this growth is the increasing use of data centers These facilities house server farms for hosting web services and cloud computing services. Projections indicate a need for 100 Gbps of data transfer capacity from switch to switch. Also 100 Gbps will have applications between buildings, within campuses, and for metropolitan area networks (MAN) and wide area networks (WAN).

2.6 40/100 Gigabit Ethernet

- In implementing 40 and 100 gigabit Ethernet some of the objectives are:
- • MAC (medium access control) data rates of 40 and 100 gigabit per second.
- • Full duplex is only supported (i.e., two way communication).
- • Maintain the existing minimum and maximum frame length.
- • Use the current frame format and MAC layer.
- • Optical transport network (OTN) support.

40 Gbps	100 Gbps
≥ 10 km single mode fiber	≥ 40 km single mode fiber
≥ 100 m multi-mode fiber	≥ 10 km single mode fiber
≥ 10 m copper cable	≥ 100 m multi-mode fiber
≥ 1 m backplane	≥ 10 m copper cable

Cabling

2.7 Higher Ethernet Speeds

- In 2012 the IEEE 802.3 Ethernet committee did a data rate growth assessment and came to the following conclusions:
- • The need for increased data rates was increasing more rapidly for "network aggregation nodes," than for end-station applications. Network aggregation nodes combine traffic from very many end users. Perhaps the most important example of this is data centers.
- • The compound annual growth rate (CAGR) that should be supported is 58%. The biggest growth rates were in data intensive science and in the financial industry.
- • In 2012 the 802.3 committee projected a need in data rate capacities of 1 Tbps (i.e., 1012 bps) by 2015 and 10 Tbps by 2020.
- In fact there is a cyclic action where enabling higher data rates enables applications which creates a need for increased data rates leading to enabling higher data rates and on and on. . .

2.7 Higher Ethernet Speeds

- As of 2016 there were a number of parallel efforts going on under the aegis of IEEE standards bodies. These include a 200 Gbps version of Ethernet as well as a 400 Gbps version. Moreover higher data rates are built out of parallel lanes or channels. In this light, to be started is work on a 50Gbps version of Ethernet which can be used as a building block for higher rates.
- In terms of goals for higher rates, one has :
- • Full duplex operation only (as has been true since 10 Gbps Ethernet).
- • MAC data rates of 200 and 400 Gbps.
- • Use existing Ethernet frame format using the Ethernet MAC.
- • Keep the minimum and maximum frame size of the existing standard.
- • The bit error rate should be 10^-13 or the frame loss equivalent. Note that for 10, 40 and 100 Gbps Ethernet versions the bit error rate was 10^-12.
- • OTN (optical transport network for Ethernet) should be supported. Energy- Efficient Ethernet (EEE) is optionally supported.

2.7 Higher Ethernet Speeds

- • Optional 400 GBps attachment unit interfaces for chip-to-chip and chip-to module applications.
- • The physical layer supports link distances in Table.
- While the implementation details need to be filled in, the trend for Ethernet is a march to higher and higher data rates.

200 Gbps	400 Gbps
≥500 m single mode fiber	≥ 100 m multi-mode fiber
≥2 km single mode fiber	≥ 500 m single mode fiber
≥10 km single mode fiber	≥ 2 km single mode fiber
	≥10 km single mode fiber