Lecture (04)
Data link layer

By:
Dr. Ahmed ElShafee

- Standards Overview
- CSMA/CD
- Ethernet standards
  - 10 base 5
  - 10 base 2
  - 10 base T
  - Fast Ethernet
  - Gigabit Ethernet

Standards Overview

- Like most protocols, Ethernet began life inside a corporation that was looking to solve a specific problem.
- Xerox needed an effective way to allow a new invention, called the personal computer network
- Eventually, Xerox teamed with Intel and Digital Equipment Corp (DEC) to further develop Ethernet, so the original Ethernet became known as *DIX Ethernet, meaning* DEC, Intel, and Xerox.er, to be connected in its offices

---

IEEE role

- The IEEE began creating a standardized version of Ethernet in February 1980, building on the work performed by DEC, Intel, and Xerox.
- The IEEE Ethernet specifications that match OSI Layer 2 were divided into two parts:
  1. the *Media Access Control (MAC) and*
  2. *Logical Link Control (LLC) sublayers.*
- *The IEEE formed a committee to work on each part—the*
  1. *802.3* committee to work on the MAC sublayer, and
 2. 802.2 committee to work on the LLC sublayer.

MAC and LLC Standards for Three Types of LANs

| Name	MAC Sublayer Spec	LLC Sublayer Spec
Ethernet Version 2 (DIX Ethernet)	Ethernet	—
IEEE Ethernet	IEEE 802.3	IEEE 802.2
IEEE Token Ring	IEEE 802.5	IEEE 802.2
ANSI FDDI	ANSI X3T9.5	IEEE 802.2

CSMA/CD

- early DIX Ethernet specifications called *10BASE5 and 10BASE2, which* differ in the cabling details
- Topology is a series of coaxial cables, connecting each device on the Ethernet network—there is no hub, switch, or wiring panel.
- The series of cables creates an electrical bus that is shared among all devices on the Ethernet.
- When a computer wants to send, all other computer receive it.
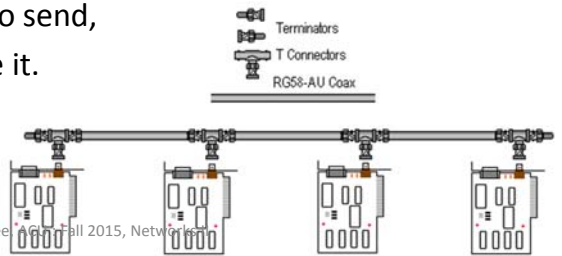
- Because it is a single bus, if two or more signals were sent at the same time, the two would overlap and collide
- So Ethernet defined a specification to ensure that only one device sends traffic on the Ethernet at one time
- The algorithm, known as the *carrier sense multiple access with collision detection (CSMA/CD) algorithm, defines how the* bus is accessed.

CSMA real life example:

- In a meeting room with many attendees. Some people talk much of the time. Some do not talk, but they listen. Others talk occasionally.
- Being humans, it's hard to understand what two people are saying at the same time, so generally, one person is talking and the rest are listening
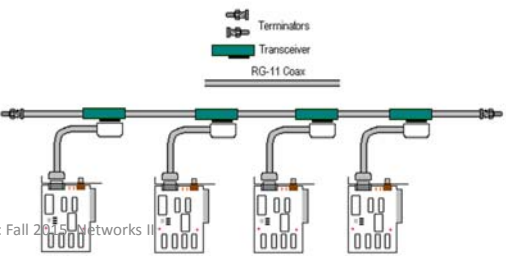
- Imagine that Bob and Larry both want to reply to the current speaker's comments.
- As soon as the speaker takes a breath, Bob and Larry might both try to speak.
1. If Larry hears Bob's voice before Larry actually makes a noise, Larry might stop and let Bob speak.
2. Or, maybe they both start at almost the same time, so they talk over each other and many others in the room can't hear what was said.
3. Or, in some cases, another person jumps in and talks while Larry and Bob are both backing off.

CSMA, the whole story:
- As shown in figure, Larry message propagates to Archi, and Bob.
- If two stations send messages at the same time, a collision occurs.
- The collision first occurs on the wire, and then some time elapses before the sending stations hear the collision (due to propagation delay)—so technically, the stations send a few more bits before they actually notice the collision.

10BASE2, Single Bus
Larry
Archie
Bob
Solid Lines Represent Co-Ax Cable
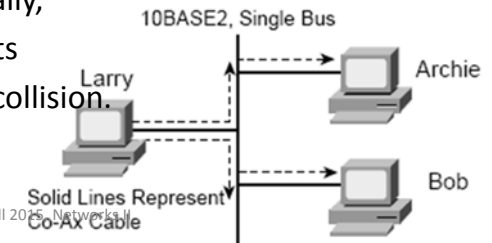
CSMA/CD algorithm:
1. A device with a frame to send listens until the Ethernet is not busy.
2. When the Ethernet is not busy, the sender begins sending the frame.
3. The sender listens to make sure that no collision occurred.

yap yap
1Va.c.   1Va.c.   yap yap
1+ Volts collision
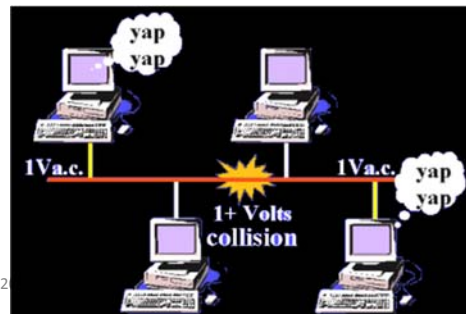
4. Once the senders hear the collision, they each send a jamming signal, to ensure that all stations recognize the collision.
5. After the jamming is complete, each sender randomizes a timer and waits a while.
6. When each timer expires, the process starts over with Step 1.

So, all devices on the Ethernet need to use CSMA/CD to avoid collisions and to recover when inadvertent collisions occur.

Ethernet standards

Repeaters

- 10BASE5 and 10BASE2 had limitations on the total length of a cable.
    1. 10BASE5, the limit was 500 m
    2. 10BASE2, it was 185 m.
- Interestingly, these two types of Ethernet get their name from the maximum segment lengths—
- if you think of 185 m as being close to 200 m, then the last digit of the names defines the multiple of 100 m that is the maximum length of a segment.
- That's really where the 5 and the 2 came from in the names.

Why repeater?

- One of the problems with using longer segment lengths was that the signal sent by one device could attenuate too much if the cable was longer that 500 m or 185 m, respectively.
- *Attenuation means that when electrical signals pass over a wire, the strength of the signal* gets smaller the farther along the cable it travels.
- It's the same concept behind why you can hear someone talking right next to you, but if that person speaks at the same volume and you are across the room, you might not hear her because the sound waves have attenuated.
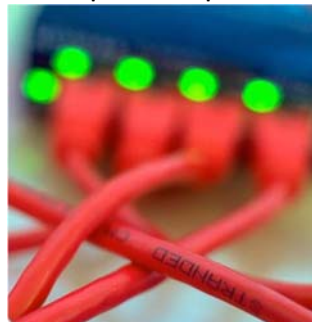
Segmentation using repeaters;

- Repeaters allow multiple segments to be connected by taking an incoming signal, interpreting the bits as 1s and 0s, and generating a brand new, clean signal.
- A repeater does not simply amplify the signal because amplifying the signal might also amplify any noise picked up along the way.

- 10BASE-T allowed the use of telephone cabling that was already installed, or simply allowed the use of cheaper, easier-to-install cabling when new cabling was required.
- 10BASE-T networks make use of devices called
    1. *Network card*
    2. *hub*
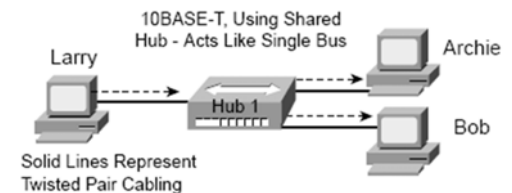
Hubs:

- The hubs used to create a 10BASE-T Ethernet are essentially multiport repeaters.
- That means that the hub simply regenerates the electrical signal that comes in one port and sends the same signal out every other port.
- By doing so, 10BASE-T creates an electrical bus, just like 10BASE2 and 10BASE5.
- Therefore, collisions can still occur, so CSMA/CD access rules continue to be used.

10Base-T is more reliable than 10Base2/5

- The use of 10BASE-T hubs gives Ethernet much higher availability compared with 10BASE2 and 10BASE5
- because a single cable problem could, and probably did, take down those types of LANs.
- With 10BASE-T, a cable is run from each device to a hub, so a single cable problem affects only one device.

Topology:

- Physically hub creates star network (hub is the core of network), but logically it's still a bus network.
- we call this *shared Ethernet: All devices are sharing a single 10-Mbps bus.*

Ethernet 10BASE-T Cabling

Category 5 UTP cables with RJ-45 connectors

- the pair of wires on pins 1 and 2 is used to transmit data, and pins 3 and 6 are used for receiving data (network card /hub).
- The cable used to connect the PCs to the hub is called a *straight-through cable,*

Straight-Through Ethernet Cable with Exaggerated RJ-45 Connectors
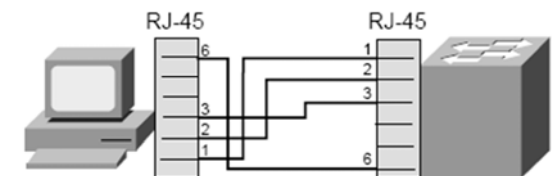
- you might want to create a small Ethernet between two PCs simply by cabling the two PCs together
- Use a special cable called a *crossover cable.*
- pin 1 on one end of the cable becomes pin 3 on the other end. Similarly, pin 2 is connected to pin 6 at the other end, pin 3 is connected to pin 1, and pin 6 is connected to pin 2.

Crossover Ethernet Cable
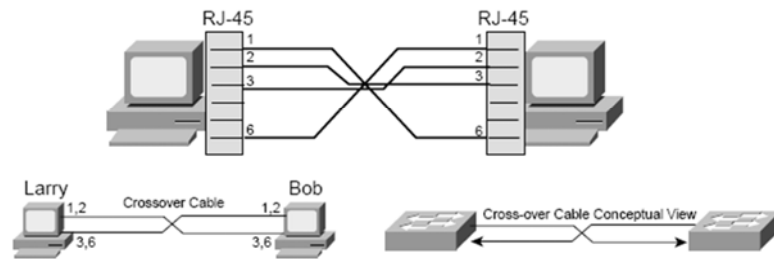
Expanding network:
- Most of the time, you will not actually connect two computers directly with an Ethernet cable.
- However, you typically will use crossover cables for connections between switches and hubs.
- An Ethernet cable between two hubs or switches often is called a *trunk.*

Typical Uses for Straight-Through and Crossover Ethernet Cables
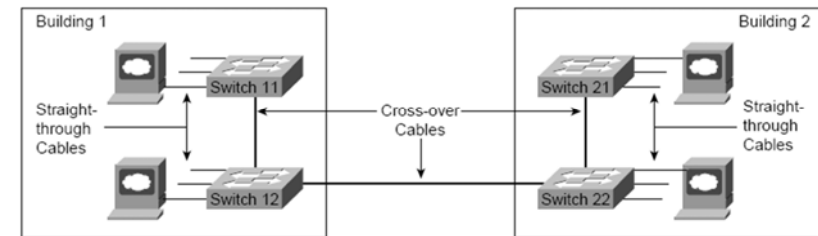
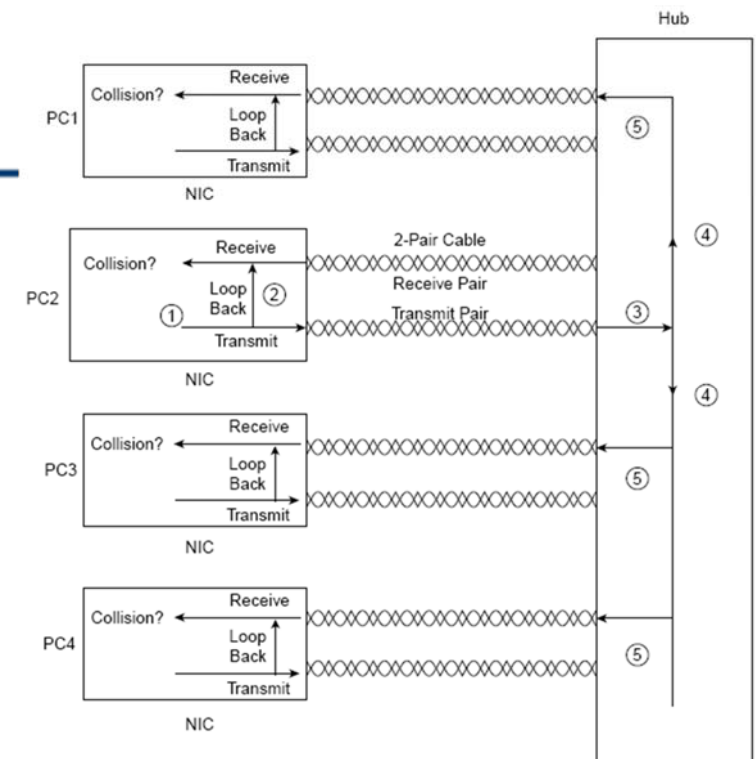**10Base-T & CSMA/CD**
- 10BASE-T still created a single electrical bus shared among all devices on the LAN.
- Ethernets that share a bus cannot reach 100 percent utilization because of collisions and the CSMA/CD arbitration algorithm.

Hub layout

Hub operation:

1. The network interface card (NIC) sends a frame.

2. The NIC loops the sent frame onto its receive pair internally on the card.

3. The hub receives the frame.

4. The hub's internal wiring propagates the signal to all other ports, but not back to the port that the signal was received upon.

5. The hub repeats the signal to each receive pair to all other devices.

Is there a need for CSMA/CD?

- If PC1 and PC2 sent a frame at the same time, a collision would occur.

- At Steps 4 and 5, the hub would forward both electrical signals, which would cause the overlapping signals to be sent to all the NICs.

- So, because collisions can occur, CSMA/CD logic still is needed to have PC1 and PC2 wait and try again.

Notes:

- NOTE PC2 would sense a collision because of its loopback circuitry on the NIC.

- The hub does not forward the signal that PC2 sent to the hub back to PC2.

- Instead, each NIC loops the frame that it sends back to its own receive pair on the NIC, as shown in Step 2 of the figure.

- Then, if PC2 is sending a frame and PC1 also sends a frame at the same time, the signal sent by PC1 is forwarded by the hub to PC2 on PC2's receive pair.

- The incoming signal from the hub, plus the looped signal on PC2's NIC, lets PC2 notice that there is a collision.

Performance Issues: Collisions and Duplex Settings

- 10BASE2, 10BASE5, and 10BASE-T Ethernet would not work without CSMA/CD.

- However, because of the CSMA/CD algorithm, Ethernet becomes more inefficient under higher loads.

- In fact, during the years before LAN switches made these types of phenomena go away, the rule of thumb was that an Ethernet began to degrade when the load began to exceed 30 percent (**30%**) utilization.
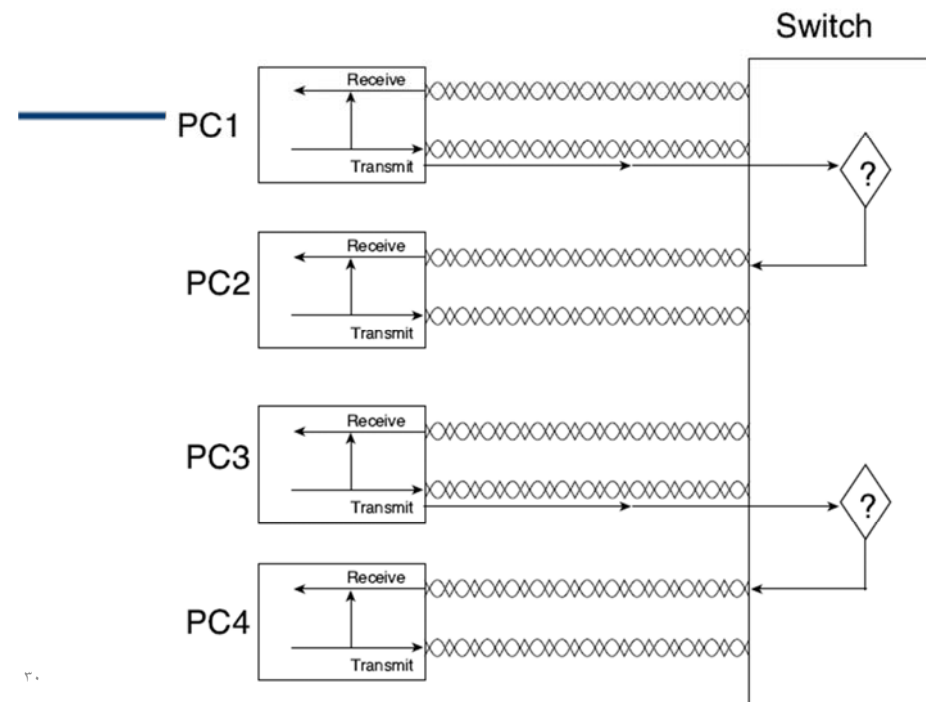
Reducing Collisions Through LAN Switching

- LAN switches overcome the problems created by collisions and the CSMA/CD algorithm by removing the possibility of a collision.

- switches do not create a single shared bus, like a hub; they treat each individual physical port as a separate bus.

- Switches use memory buffers to hold incoming frames as well, so when two attached devices send a frame at the same time, the switch can forward one frame while holding the other frame in a memory buffer, waiting to forward one frame until after the first one has been forwarded.

Basic Switch Operation

Switch

PC1 — Receive / Transmit — ?

PC2 — Receive / Transmit

PC3 — Receive / Transmit — ?

PC4 — Receive / Transmit

- both PC1 and PC3 are sending at the same time.

- The switch looks at the destination Ethernet address and sends the frame sent from PC1 to PC2 at the same instant as the frame is sent by PC3 to PC4.

- The big difference between the hub and the switch is that the switch interpreted the electrical signal as an Ethernet frame and processed the frame to make a decision.

Switching layer and Hub layer:

- A hub simply repeats the electrical signal and makes no attempt to interpret the electrical signal (Layer 1) as a LAN frame (Layer 2).

- So, a hub actually performs OSI Layer 1 functions, repeating an electrical signal, whereas a switch performs OSI Layer 2 functions, actually interpreting Ethernet header information, particularly addresses, to make forwarding decisions.

What if two PCs decide to send frames to same PC?

- Buffering also helps prevent collisions.
- Imagine that PC1 and PC3 both sent a frame to PC4 at the same time.
- The switch, knowing that forwarding both frames to PC4 would cause a collision, would buffer one frame until the first one has been completely sent to PC4.

Dr. Ahmed ElShafee, ACU : Fall 2015, Networks II

Summary of switch advantages:

- If only one device is cabled to each port of a switch, no collisions occur.
- If no collisions can occur, CSMA/CD can be disabled, solving the Ethernet performance problem.
- Each switch port does not share the bandwidth, but it has its own separate bandwidth, meaning that a switch with a 10-Mbps ports has 10 Mbps of bandwidth *per port.*

Dr. Ahmed ElShafee, ACU : Fall 2015, Networks II


Half duplex Ethernet

- The original Ethernet specifications used a shared bus, over which only one frame could be sent at any point in time.
- So, a single device could not be sending a frame and receiving a frame at the same time because it would mean that a collision was occurring.
- So, devices simply chose not to send a frame while receiving a frame.
- that logic is called *half-duplex* logic.

Dr. Ahmed ElShafee, ACU : Fall 2015, Networks II

Full duplex Ethernet

- Ethernet switches allow multiple frames to be sent over different ports at the same time.
- Additionally, if only one device is connected to a switch port, there is never a possibility that a collision could occur.
- So, LAN switches with only one device cabled to each port of the switch allow the use of *full-duplex operation.*
- *Full duplex means that an Ethernet card can* send and receive concurrently.

10BASE-T Full-Duplex Operation Using a Switch
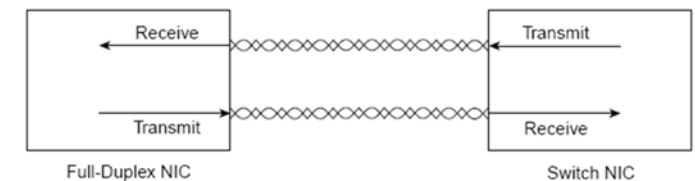
- For this to work, the NIC must disable its loopback circuitry

Summary of Some Basic Ethernet Features

Ethernet Environment	Description
10BASE2, 10BASE5	Single bus cabled serially between devices using coaxial cable. Neither is used much today.
10BASE-T with a Hub	One electrical bus shared among all devices creating a single collision domain, cabled in a star topology using twisted-pair cabling.
10BASE-T with a Switch	One electrical bus per switch port creating multiple collision domains, cabled in a star physical topology but a logical bus topology using twisted-pair cabling.
Half Duplex	Logic that requires a card to only send or receive at a single point in time. Used to avoid collisions.
Full Duplex	Logic that enables concurrent sending and receiving, allowed when one device is attached to a switch port, ensuring that no collisions can occur.

Recent Ethernet Standards

- More recently created alternatives, areFast Ethernet and Gigabit Ethernet
- Fast Ethernet most likely being used on the desktop and Gigabit Ethernet being used between networking devices or on servers.
- Additionally, 10 Gb provides yet another improvement in speed and performance

Fast Ethernet

- Fast Ethernet, as defined in IEEE 802.3u, retains many familiar features of 10-Mbps IEEE 802.3 Ethernet variants.
- The age-old CSMA/CD logic still exists, but it can be disabled for full-duplex point-to-point topologies in which no collisions can occur.
- The 802.3u specification calls for the use of the same old IEEE 802.3 MAC and 802.2 LLC framing for the LAN headers and trailers.
- A variety of cabling options is allowed—unshielded and shielded copper cabling as well as multimode and single-mode fiber.

Fast Ethernet (2)

Key features
1. higher bandwidth
2. auto negotiation, allows an Ethernet card or switch to negotiate dynamically to discover whether it should use either 10 or 100 Mbps
- many Ethernet cards and switch ports are called 10/100 cards or ports today because they can autonegotiate the speed.
- The endpoints autonegotiate whether to use half duplex or full duplex as well.
- If autonegotiation fails, it settles for half-duplex operation at 10 Mbps.

Fast Ethernet (3)

Recommendations

- for devices that rerely move, such as servers and switches, you should configure the LAN switch and the device to use the identical desired setting instead of depending of autonegotiation
- using autonegotiation for switch ports connected to end-user devices because these devices are moved frequently relative to servers or other network devices, such as routers.

Gigabit Ethernet

- The IEEE defines Gigabit Ethernet in standards 802.3z for optical cabling and 802.3ab for electrical cabling.
- Gigabit Ethernet retains many familiar features of slower Ethernet variants.
- CSMA/CD still is used and can be disabled for full-duplex support.
- uses of the same old IEEE 802.3 MAC and 802.2 LLC framing for the LAN headers and trailers
- The most likely place to use Gigabit is between switches, between switches and a router, and between a switch and a server.

Gigabit Ethernet (2)

- Gigabit Ethernet differs from the slower Ethernet specifications in how it encodes the signals onto the cable.
- Gigabit Ethernet is obviously faster, at 1000 Mbps, or 1 Gbps.

Thanks,..

See you next week (ISA),…