Communication Networks

Spring 2017/2018

Dr. Mohammad HAWA

By:

Mohammad
Abu Hashya.

* * *

Lecture 6: Example LAN: Ethernet

Dr. Mohammed Hawa
Electrical Engineering Department
University of Jordan

Network Types

- **Local Area Networks (LANs):** privately-owned networks within a single building or campus of up to few kilometers in size:
  - Ethernet, IBM Token Ring, FDDI and IEEE 802.11 Wi-Fi.
- **Metropolitan Area Networks (MANs):** spans a city or part of a city:
  - IEEE 802.16 WiMAX.
- **Wide Area Networks (WANs):** spans a large geographical area, often a country or continent:
  - ATM and Frame Relay.
- **Personal Area Networks (PANs):** spans a single room and connects personal devices:
  - Bluetooth, NFC and UWB.

FDDI ≡ Fiber Distributed Data Interface.

Asynchronous Transfer Mode.

NFC ≡ Near Field Communications.

UWB ≡ Ultra Wide Band.

- Example on Ring Topology: IBM Token Ring.
- SDH/SONET: is circuit switching, NOT LAN.
- Ethernat: => Was: Bus topology, New: Star topology.
- Wifi: => Popular: Star., Available: Bus

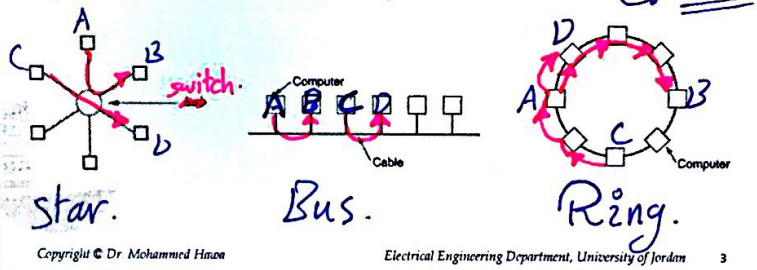
3/13/2018

this called infrastructure mode.

ad hoc.

LAN Network Topologies: Star vs. Bus vs. Ring

- Each LAN utilizes a single high-bandwidth shared medium (e.g., a cable), to which many computers are attached (*reduces cost*) & Increase utilization.
- Different computers take turns (coordinate) among each other to send frames on the shared medium. Handled by MAC (Medium Access Control) sublayer. Layer2



Star. Bus. Ring.

LANs: Ethernet & ALOHA

- Ethernet was inspired by the ALOHA protocol, which was the first LAN created.
- ALOHA, built at the University of Hawaii in early 1970s, ran at 9.6 kbps data rate and used a shared wireless medium.
- ALOHA allowed remote terminals at distant locations (different islands) to access a main computer in a central location.
- Ethernet was a variation of the ALOHA protocol, and inherited many of its features, but then *evolved significantly* over the years to support higher data rates and longer distances.

Ethernet

- Ethernet is a widely used LAN technology. It is also being expanded into MAN and WAN.
- Invented at Xerox Palo Alto Research Center in late 1970s .
- Operated at a rate of **10 Mbps** and was called DIX Ethernet (DEC, Intel and Xerox).
- IEEE now maintains the Ethernet standard, known as IEEE 802.3 (standardized in 1983).
- In its original 10 Mbps version, Ethernet used a single coaxial cable, called the **ether**, to which multiple computers connect through taps.
- Later versions of the 10 Mbps Ethernet used UTP cables with hubs and switches.
- A very popular version of Ethernet is Fast Ethernet, operating at **100 Mbps**, and uses UTP with switches.

DEC = Digital Equipment Cooperation.

⇒ (BUS Topology:)

Bus Topology.

Star Topology.

memorize: data rate = 10 Mbps.

↳ MOST POPULAR.

Ethernet [2]

- Next version, getting more popular by the day, is Gigabit Ethernet (GigE or GbE) operating at 1 Gbps (1000 Mbps).
- The next, also popular but in Ethernet core switches, is 10 Gigabit Ethernet (10GigE or 10GbE) operating at 10 Gbps.
- The high data rate systems use hi-end switches with mostly optical fiber (but sometimes UTP as well). The 10GbE was finalized in 2002.
- The IEEE 802.3bm standard, released in 2015, defines 100G/40G Ethernet for optical fiber.
- The IEEE 802.3bs standard (December 2017) introduces 200GbE (200 Gbit/s) over single-mode fiber and 400GbE (400 Gbit/s) over optical physical media.
- IEEE 802.3av defines 10G-EPON (passive optical network).
- Ethernet Over SDH (EoS or EoSDH) & Ethernet over SONET.

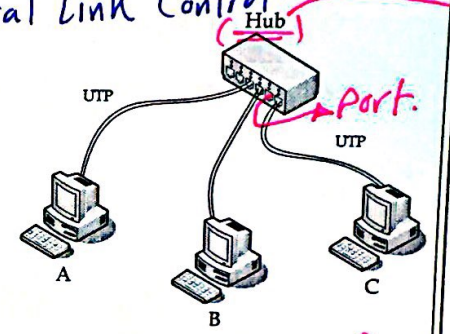
*Ethernet as BUS Topology:

classified under {layer 2 protocol}

Ethernet: IEEE 802.3 Standard

Logical Link Control:

802.2 LLC	LLC	
802.3	MAC	2
CSMA/CD	PHY	1



acts like ~~zero~~ length coaxial cable.

port.

This is a Half Duplex mode.

Ethernet MAC: CSMA/CD

- Ethernet MAC protocol is known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD).
- CSMA/CD coordinate access among different users to the shared bus. It is very similar to ALOHA but with improvements.
- If a station wants to send a frame, it first listens to the channel, called **carrier sense** or listen-before-talk (LBT). Carrier sense avoids interrupting an ongoing transmission.
- If the station senses a busy channel, it waits for the cable to become idle again then sends its frame after an "interframe gap time" (9.6 μs).
- If two stations sense an idle channel and start transmitting at the same time, the two signals will interfere with each other: called collision or contention.
- While a station is transmitting, it monitors the current flowing through the channel. If the current is higher than normal, then it detects a collision: **collision detect.** & stops transmitting immediatly.

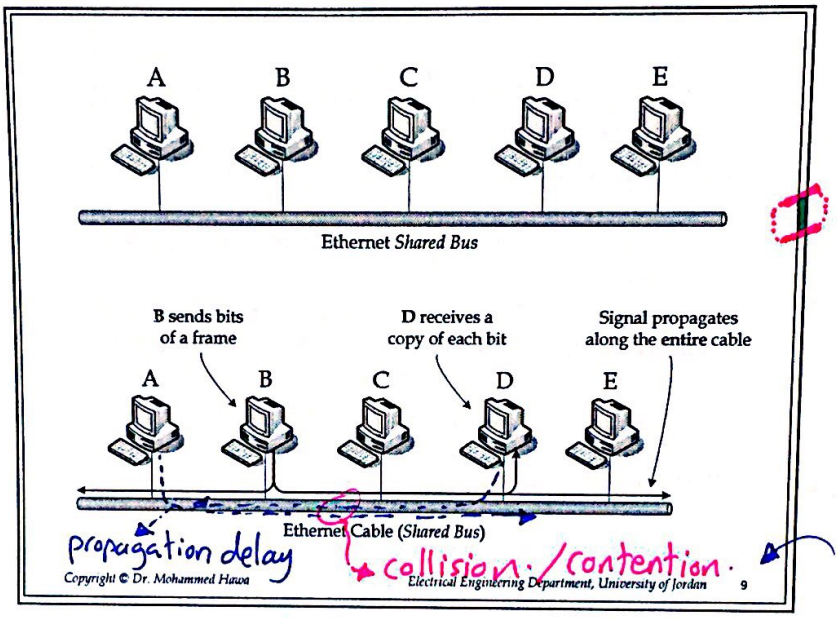
idle.
9.6μs for framing.

Wifi ⇒ CSMA/CA ≡ Carrier Sense Multiple Access with Colision Avoidance.

ALOHA → Bus.

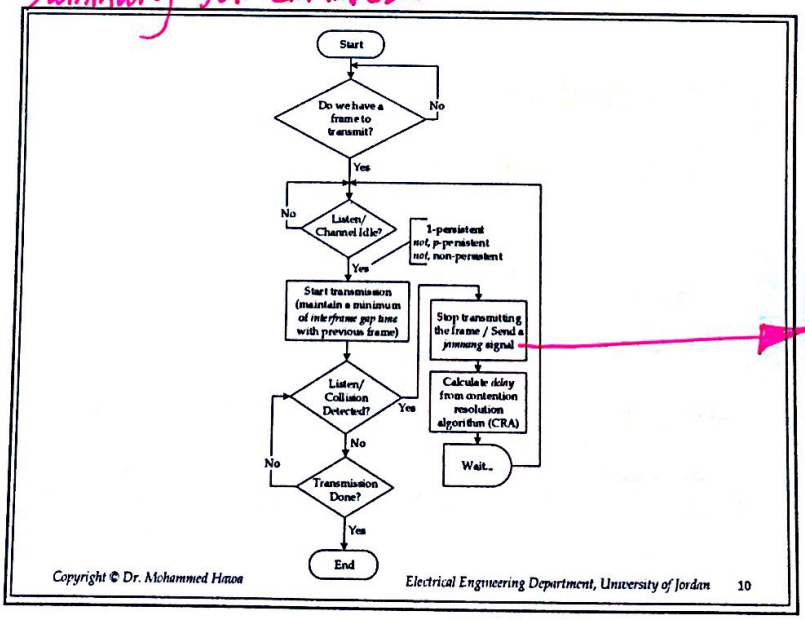
Ethernet → started (Bus).
now (star).

3/13/2018



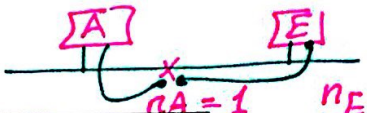
memorize the two words.

summary for CSMA/CD:



jamming signal:
32 to 48 randomly chosen bits sent once a collision is detected.

CRA used in CSMA/CD is



$n_A = 1$ $n_E = 1$

$m_A = 1$ $m_E = 1$

{0,1} {0,1}

wait for $0 \times 512 \times 10^{-7} = 0$ sec.

wait for $1 \times 512 \times 10^{-7} = 512 \times 10^{-7}$ sec.

for $n_A = 2$ $n_E = 2$

{0,1,2,3} {0,1,2,3}

prob of collision $= 4 \times (\frac{1}{4} \times \frac{1}{4}) = \frac{1}{4}$

for $n = 3$

prob of collision $= \frac{1}{8}$

{0,1,2,3,4,5,6,7}

Binary exponential backoff algorithm

counter for collisions.

- If a frame has collided n successive times (where $n < 16$) then the sending station must choose a **random number** K with equal probabilities from the set $\{0, 1, 2, 3, \ldots, (2^m) - 1\}$, where $m = \min(n, 10)$
- The station must wait for K **x 512 bit times** (at 10 Mbps, one bit time = 10^{-7} seconds) before starting another transmission attempt.
- Give up transmission attempt of the frame if it encounters 16 successive collisions, or reset counters (i.e., set $n = 0$) if the frame is successfully transmitted.

Copyright © Dr. Mohammed Hawa Electrical Engineering Department, University of Jordan 11

1 bit time $= \frac{1}{10\,\text{Mbps}} = 10^{-7}$ sec.

for $n_A = 1$, $n_E = 1$ $\Rightarrow$ prob. of collision = prob. of getting 0 & 0 + prob of getting 1 & 1

$= \frac{1}{2} \times \frac{1}{2} + \frac{1}{2} \times \frac{1}{2} = \frac{1}{2}$

Maximum Collision Detection Time = 2τ

time needed to detect a collision after starting to transmit (in the worst case).

τ = Maximum end-to-end propagation delay in the cable τ is:

- τ = maximum end-to-end distance (m) / propagation speed in coax (m/s) $= 2500 / 2.3 \times 10^8 = 10.9 \times 10^{-6}$ s. $= 10.9\,\mu$sec. $\rightarrow 0.1\,\mu$sec.
- At 10 Mbps, one bit time = 10^{-7} seconds, which means τ = 109 bit times.
- To allow for some delay in the repeaters, the specifications of Ethernet allow for a maximum end-to-end propagation time of τ = 225 bit times.

Copyright © Dr. Mohammed Hawa Electrical Engineering Department, University of Jordan 12

memorize: 2.5Km = 2500m.

500m R 500m R ....

τ = PROP. = 225 bit times $= 225 \times 10^{-7}$ sec.

Ex.

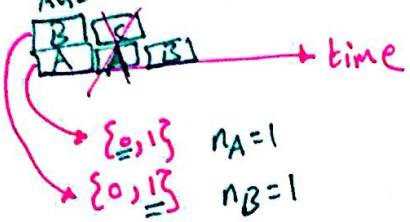
n=1 [A] $\rightarrow$ {0,1}

n=3 [C] $\rightarrow$ {0,1,2,3,4,5,6,7}

prob. of collision $= \frac{1}{2} \times \frac{1}{8} + \frac{1}{2} \times \frac{1}{8} = \frac{1}{8}$

• Note: probability of No collision $\Rightarrow$ Take the complement of the prob. of collision.

A&B collision.



$\{0,1\}$ $n_A = 1$

$\{0,1\}$ $n_B = 1$

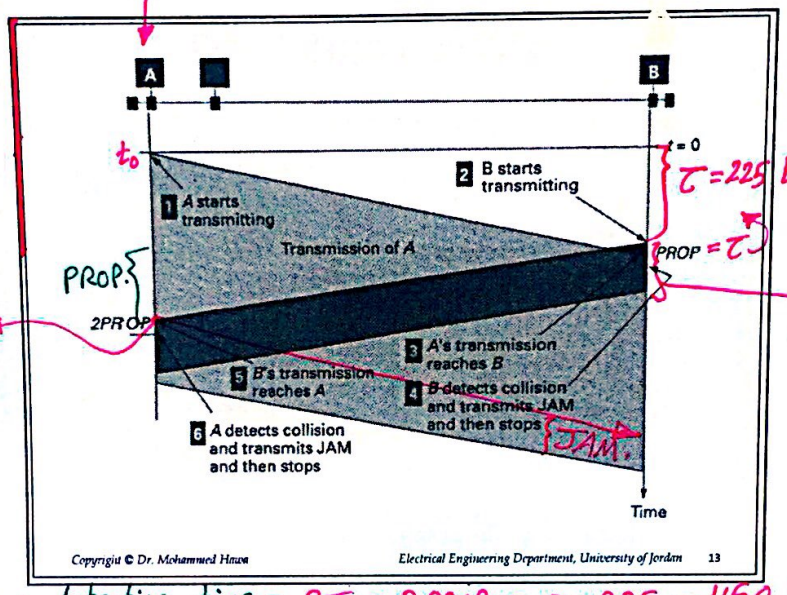
* Min frame Length in Ethernet:
= 512 bits = 64 bytes.

512 bit / 8 bit

* Max frame length in Ethernet = 1500 Bytes + 18 Bytes (header & trailer)
= 1518 Bytes
to limit memory.

3/13/2018

wasting time seen By A: 2PROP. + JAM.



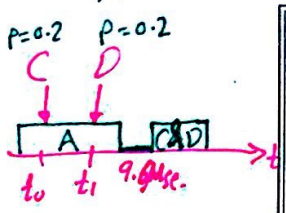
τ = 225 bit times.

32-48 bits (jamming signal).

A detection of collision.

Max collision detection time = 2τ = 2PROP = 2 × 225 = 450 bit time.

Max collision & clearing of the channel = 2τ + JAM. = 450 + 48 = 498 bit time.
≃ 512 bit time.



prob.
= 0.2 × 0.2
= 0.04

Persistance

- **1-persistent:** If the transmitting node senses an idle channel, it immediately starts transmitting its frame. If the channel is sensed busy, the node continues listening until the channel is idle again, then starts transmitting its frame after a small interframe gap.
- **p-persistent:** If the transmitting node senses an idle channel, it starts transmitting its frame with probability p (i.e., it might not transmit with probability 1-p). If the channel is sensed busy, the node continues listening until the channel is idle again, then starts transmitting with probability p. If the node decides not to transmit (with probability 1-p), it defers transmission by one time slot (which is typically τ), and at the start of the next time slot, …

Copyright © Dr. Mohammed Hawa
Electrical Engineering Department, University of Jordan
14

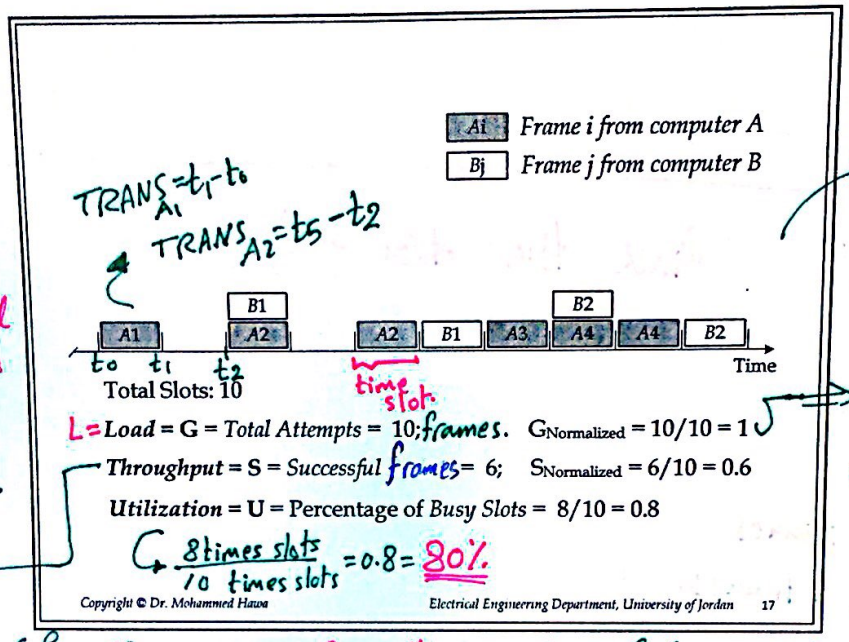
Persistance (*Cont.*)

- …, the nodes checks the channel again and transmits with probability p if the channel is idle (or defers again with probability 1-p). This process is repeated until either the frame is transmitted or the channel becomes busy again. When the channel becomes busy, the station acts as though there had been a collision and waits for a random amount of time before the next attempt.
- **non-persistent:** If the transmitting node senses an idle channel, it starts transmitting its frame immediately. If the channel is sensed busy, the node does not continue listening until the channel is idle again; rather it waits a random amount of time and re-senses the channel again after that delay.

Performance Parameters vs. Load

- **Throughput (S):** average rate of successful frame delivery. Calculated as the number of successful bits sent in a period of time divided by that time period (bit/s).
- **Delay (D):** the time period the frame needs to successfully reach the destination. Usually average delay is calculated.
- **Utilization (U):** proportion of the channel time which is used by the traffic which arrives at it.
- **Frame drop probability (P):** proportion of total frames sent by the source that are not received by the destination.

* for this Example:
  - min frame Length = 64 bytes
  - max " " = 1518 bytes.



we need: S↑ U_{max} = 100% U↑ D↓ P↓

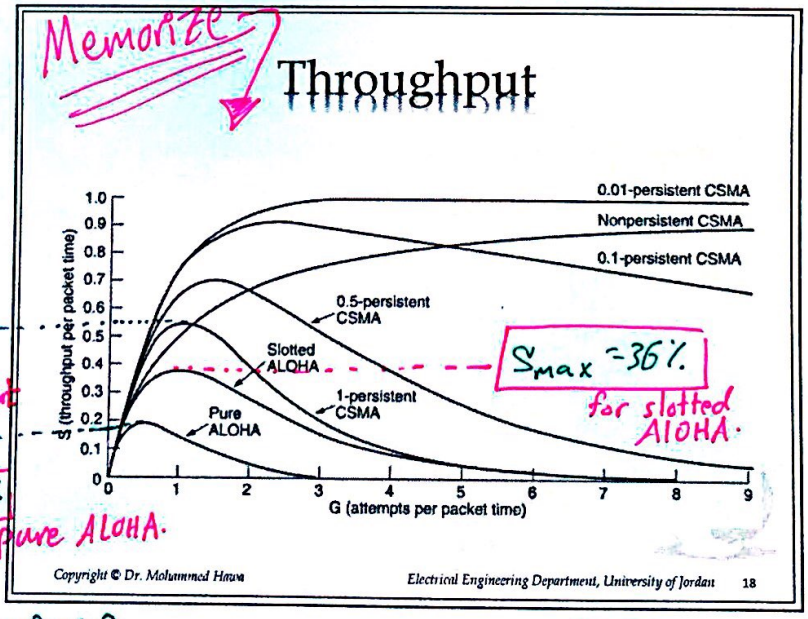
slotted ALOHA

.Ethernet works better than this.

10 frames / 10 times slots = 1 frame / time slot. ≡ 100% of the Capacity of channel.

6 Frames / 10 times slots = 0.6 frame/time slot. ≡ 60 % of the Capacity of channel.

Memorize



S_{max} = 54% Max of 1-persistent

S_{max} = 18% for pure ALOHA.

S_{max} = 36% for slotted ALOHA.

Continue ... Behind the Page.

for Ex: P = 0.2

B C → P = 0.2

A | B&C → t

prob. of collision = 0.2 x 0.2 = 0.04.

* if P↓ ⇒ prob of collision ↓

S↑ D↑ U↓ good Bad Bad.

* Now for the delay:

$delay_{frame1}$ = PROP + TRANS + QUEUE + PROC.

+ $delay_{frame2}$ =

+ $delay_{frame3}$ =

$\div N$ (find the Average).

sent M frames.
received M-2 frames.
$P = 2/M$.

Communication Networks

Spring 2017/2018

Dr. Mohammad HAWA

By:

Mohammad
Abu Hashya.

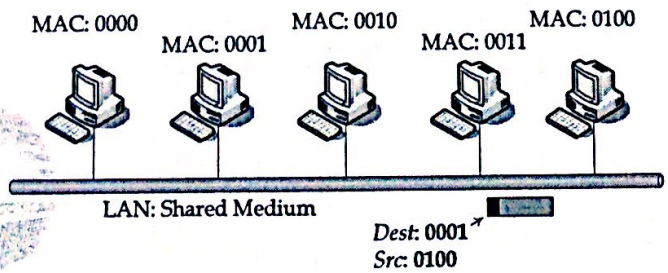
* * *

Lecture 7: Ethernet Hardware Addressing and Frame Format

Dr. Mohammed Hawa
Electrical Engineering Department
University of Jordan

MAC Addresses

- The shared medium in a LAN connects a large number of stations.
- However, typically communications involve only one source and one destination.
- MAC Addresses allow a frame to reach its destination.



- HW_1: find the MAC address for your Ethernet card using 3 different methods?
- HW_2: find Wifi MAC address?
- HW_3: find MAC address for Wifi on your cell & Bluetooth MAC address?

3/14/2018

NIC ≡ Network Interface Card.

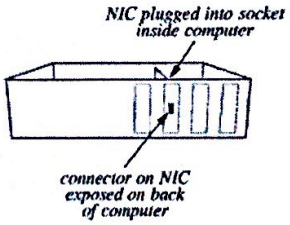
Ethernet MAC Address

memorize →

- Ethernet uses a unique 48 bit (6 byte) (MAC address) (Physical address) (Hardware address)
- Example: ① ② ③ ④ ⑤ ⑥ bytes.
  - 08-00-07-A9-B2-FC or 00:00:94:BA:0E:CC → these are in Hexa Decimal.

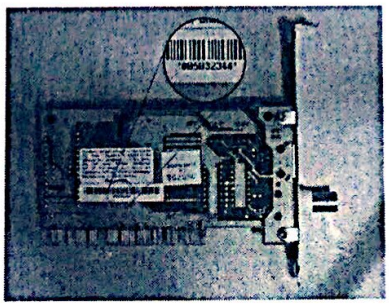
(hex)

one byte.



Does RA matche hardware?

Bytes	8	1	6	6	2	0-1500	0-46	4
	Preamble	SOF	Destination Address	Source Address	Length	Data	Pad	CRC



Memorize:

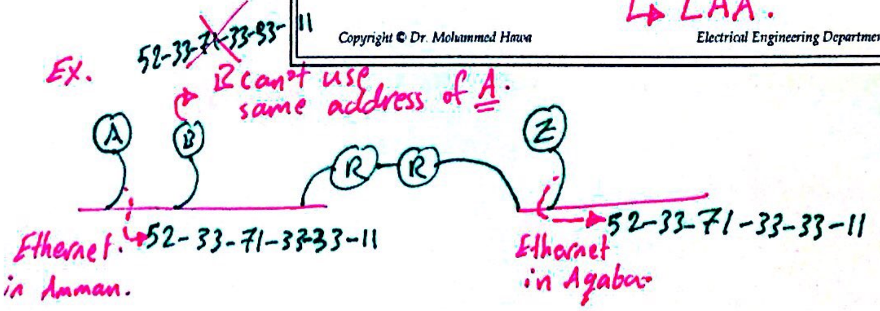
Types of Ethernet MAC Addresses

- Ethernet
  - Unicast Address
    - **Global Address (Static Address)**
    - **Local Address (Configurable Address) (LAA)**
  - Multicast Address — *Group Address*
  - Broadcast Address — *Group Address*

Types of Ethernet MAC Addresses

- Group Address: LSB of the destination address is a 1. (→ used when one source sends one frame that needs to be read by multiple destination.)
  - **Broadcast Address**: FF-FF-FF-FF-FF-FF. (special case: 1 to everybody)
  - **Multicast Address**: Other addresses with a LSB of 1. (1 to many)
- Unicast Address: LSB of the destination address is a 0.
- There are two types of **Unicast addresses** used by Ethernet:
  - **Global MAC Address** (also called Static MAC Address)
  - **Local MAC Address** (also called Configurable MAC Address, or Locally Administered Address). (→ LAA.)

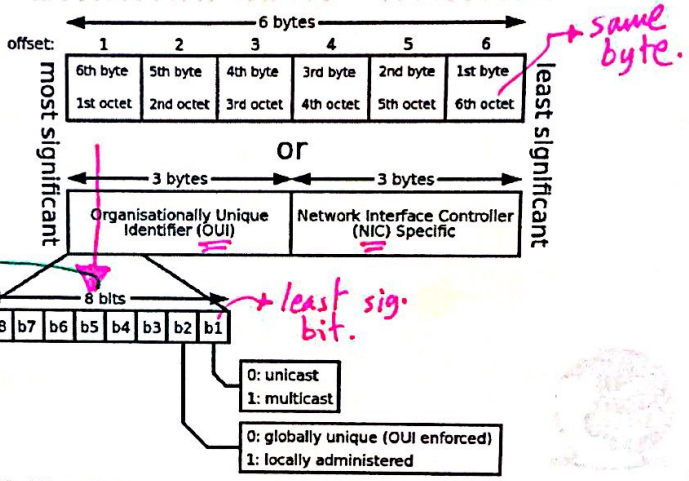
Ex.



* MAC: has to be Unique Locally.

• HW4: Who built your Ethernet card, Wifi card, Bluetooth card, WiMAX card?

Ethernet MAC Address



same byte.

Most significant Byte.

least sig. bit.

*How many global unicast MAC addresses Available

2^{46} addresses.

3Com
02-60-8C 00-00-00
00-00-01
00-00-02

AMD: 08-00-20 00-00-00

Rules for Reading Frames

- An Ethernet card passes the Ethernet frame to the upper layer if the destination address (DA) is equal to:
  - Broadcast address: FF-FF-FF-FF-FF-FF.
  - Multicast address of a multicast group to which the station belongs.
  - Global unicast address of the card when LAA is not setup.
  - LAA unicast address of the card when LAA is setup.
  - Any address if the card is in promiscuous mode.

• HW5: Download wire shark. /find youtube tutorial.

Layer 2 PDU: Frame.

Ethernet Headers & Frame Format Type II vs. IEEE 802.3

Type II Ethernet Frame: (DIX Ethernet).

6+6+2 | +0 | +4 = 18 headers.

Bytes	7	1	6	6	2	0 - 1500	0 - 46	4
	Preamble	SOF	Destination Address	Source Address	Type	Data	Pad	CRC

Header. | L3 PDU: Packet (payload). | Trailer. | >1500 dec.

memorize the form.

This is a physical layer.

IEEE 802.3 Ethernet Frame:

Bytes	7	1	6	6	2	0 - 1500	0 - 46	4
	Preamble	SOF	Destination Address	Source Address	Length	Data	Pad	CRC

data never start @ 0. | never reaches 46.

LLC header | L3 data — Data

 Electrical Engineering Department, University of Jordan 9

Ex. length=1500
=> 8 LLC
=> 1492 L3 PDU.
, This is IEEE 802.3.

Ex. length = 0800h = 2048 decimal.
Type => IPv.4

Ex. Length = 8
=> means length NOT Type (≤1500)
=> means 8 Bytes LLC header
so 0 Bytes L3 PDU.

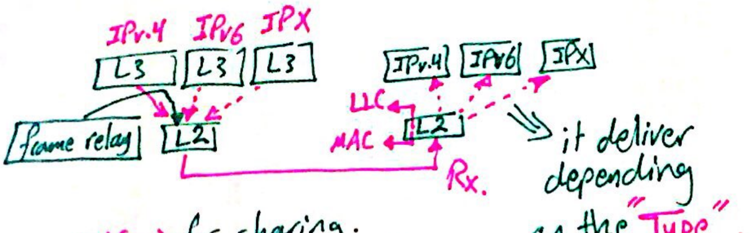
Ethernet Frame Fields [1]

- **Preamble:** Consists of 7 bytes, each byte containing the bit pattern **10101010**. It helps synchronize the receiver clock. No part of the preamble ever enters the Ethernet adapter's memory buffer since it is a physical layer header.
- **Start of Frame (SOF) delimiter:** One byte with the bit pattern **10101011** used for framing. It is compatible with other IEEE 802.x standards.
- **Destination Address (DA)** and **Source Address (SA)**: Contain Ethernet MAC addresses of the source and destination (each of 6 bytes).

 Electrical Engineering Department, University of Jordan 10

MTU = 1492 Bytes. 802.3

MTU ≡ MAX. Transfer Unit
Type II Ethernet. = 1500 Bytes.



MAC => for sharing.
LLC => do the demultiplexing & decide where to send.

* In Ethernet:
Max. frame length = 1500+18=1518 Bytes.
Because of memory limitations.

* Type II Ethernet:
6 Bytes DA.
6 Bytes SA.
2 Bytes Type.
0 Bytes Data from L3
46 Bytes for Pad.
4 Bytes CRC
Total = 64 Bytes.

* Type II Ethernet:
6 Bytes
6 Bytes
2 Bytes.
1500 Bytes for data.
0 Bytes for Pad.
4 Bytes for CRC.
Total = 1518 Bytes > 64.

* 802.3 frame format:
0 Bytes for L3 PDU.
find Pad = ?
6 Bytes DA
6 " SA
2 " Length.
8 " LLC header inside data. } 8.
0 Bytes L3 PDU
? 38 Pad
4 CRC
Total = 64 Bytes.

3/14/2018

Type field

Protocol	Type field
IPv4 packet	0800h
IPv6 packet	86DD
CCITT X.25 packet	0805h
Frame Relay	6559h
Reverse ARP	8035h
Novel Corporation IPX	8137h – 8138h
Reserved	FFFFh

→ memorize.

All type values > 0SDCh. = 1500 decimal

Ethernet Frame Fields [2]

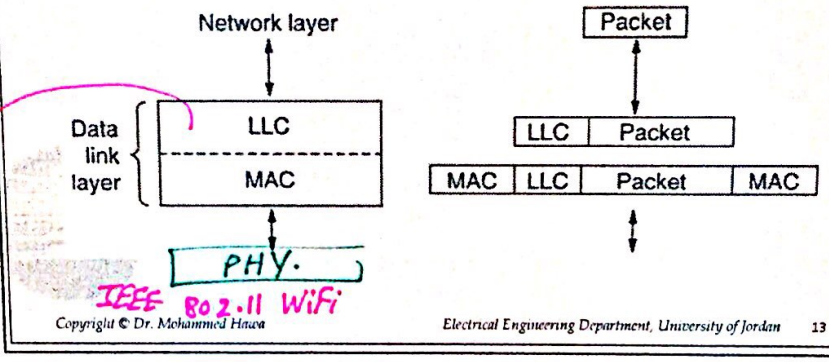
- **Length:** Indicates how many bytes exit in the Data field of the frame. Possible values are 0 (or 8) to 1500. In this case, the Type of the frame is indicated by a special header in the data portion of the frame, called a Logical Link Control (LLC) header, and not by a field in the frame header.
- **Data:** Contains the upper layer PDU (0 to 1500 bytes).
- **Pad:** Frames with fewer than 64 bytes in total length are padded out to 64 bytes with random bytes in the Pad field.
- **CRC:** A 32-bit CRC code is used as an error detection code. The receiver verifies the CRC and if the frame contains errors, the frame is discarded.

LLC header is 8 Bytes
defined in 802.2

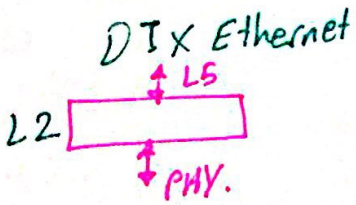
3 3 2
AAAA03 xxxxxx Type

Logical Link Control

- Logical Link Control (LLC) Layer: LLC is defined in the IEEE 802.2 standard.



Demultiplex L2 payload.
to different L3 instances on the same machine.



Communication Networks

Spring 2017/2018

Dr. Mohammad HAWA

By:

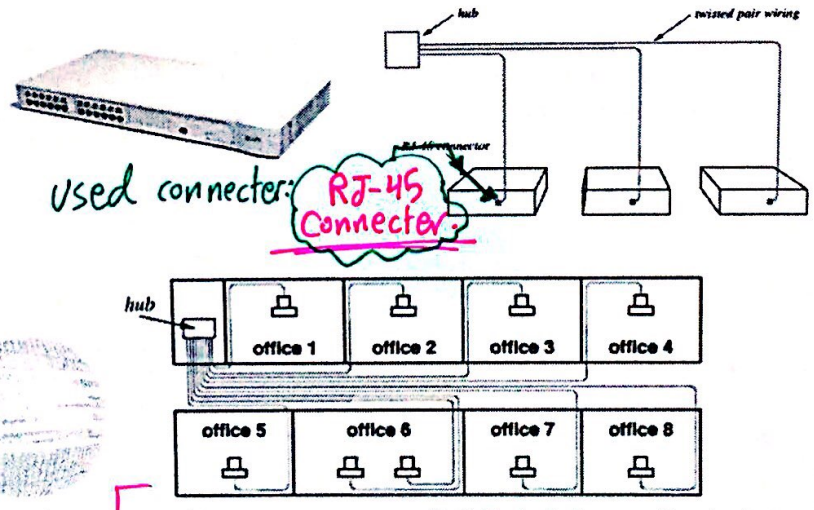
Mohammad
Abu Hashya.

* * *

Lecture 8: Switched Ethernet and Collision Domains

Dr. Mohammed Hawa
Electrical Engineering Department
University of Jordan

Ethernet Installations



it is look like star topology. (physical Topology)
But it Behave as Bus topology (logical Topology).

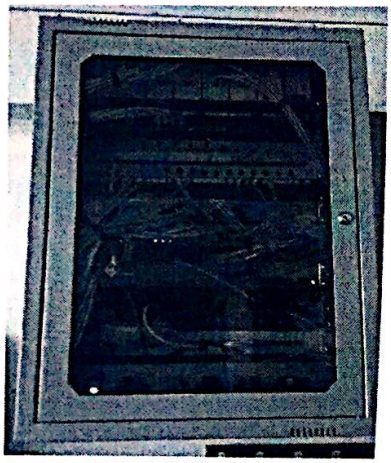
10Base-T ⇒ 10Mbps. → Manchester.
100Base-TX ⇒ 100Mbps. → MLT-3.
1000Base-T ⇒ 1Gbps.

Baseband.

Twisted Pair and Fiber

I stand for Twisted pair.

- Twisted Pair Ethernet: 10Base-T, 100Base-TX, 1000Base-T, etc.
- Fiber Optics: 10Base-F, 100Base-FX, 1000Base-LX, etc.
- Wiring Closet: yellow cables are single mode fibers; orange and blue cables are multi-mode fibers: 50/125 μm OM2 and 50/125 μm OM3 fibers respectively; grey cables are twisted pairs.



→ old name: repeater

old name for switch: Bridge.

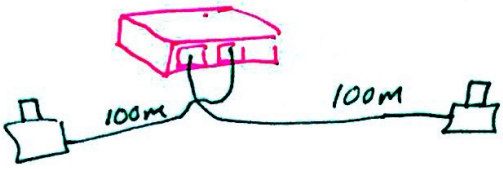
The Ethernet *Hub*

This is port. (Hub port).

- Electronic device at the center of the network that replaces the coaxial cable used in earlier versions of Ethernet.
- The hub has physical *ports* (not to be confused with TCP port number).
- Each machine connects to one of the hub ports using either an unshielded twisted pair (UTP) or an optical fiber cable.
- The hub connects all the cables on its ports electronically (as if they were soldered together inside the hub).
- The hub **does not buffer** incoming frames. Instead if a voltage appears on one if its ports, the hub **retransmits** the same voltage on **all other** ports.
- Hence, the hub acts as a zero-length shared bus (like the old coaxial cable).
- We say that the logical topology is still bus topology, even though the physical topology is a star topology.

* Coax → physical: Bus.
  → logical: Bus.

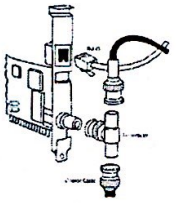
* Hub → physical: star
  → logical: Bus.



*UTP:
- The max. run length (cable run) ⇒ 100m.
- The max dist. between 2-PC's ⇒ 200m.

3/25/2018

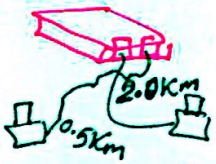
The Ethernet *Hub* [2]



- Provides more reliable connection than a coax T-connector, and does not have impedance mismatch issues when a cable is accidentally disconnected, which means each port disconnection affects only one machine.
- Using twisted pair is popular because it is the cheapest of all cables.
- Maximum UTP cable run from the hub to the PC is only 100 m due to noise & attenuation. → or run length.
- Fiber cables are used for longer runs (to connect different buildings). Runs up to 1 km or 2 km between the computer and the hub are allowed (but maximum distance between any two computers is limited to 2.5 km).
- A hub is different than a switch or gateway or router (*see later*).

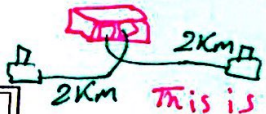
*Max. dist. Between any two computers: 2.5 Km.

we can have the following:



Max = 2.5Km

But the following can't be done:



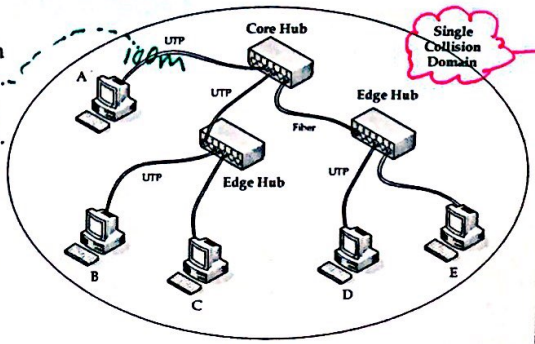
This is wrong.

Non-Switched (Hub-based) Ethernet

Limitations:

1. Half-duplex transmission (collisions).
2. Signal strength considerations.
3. MAC protocol considerations.
4. Heavy load affects throughput.
5. Broadcast storms are possible.

①&③ could be solved by Buffers.



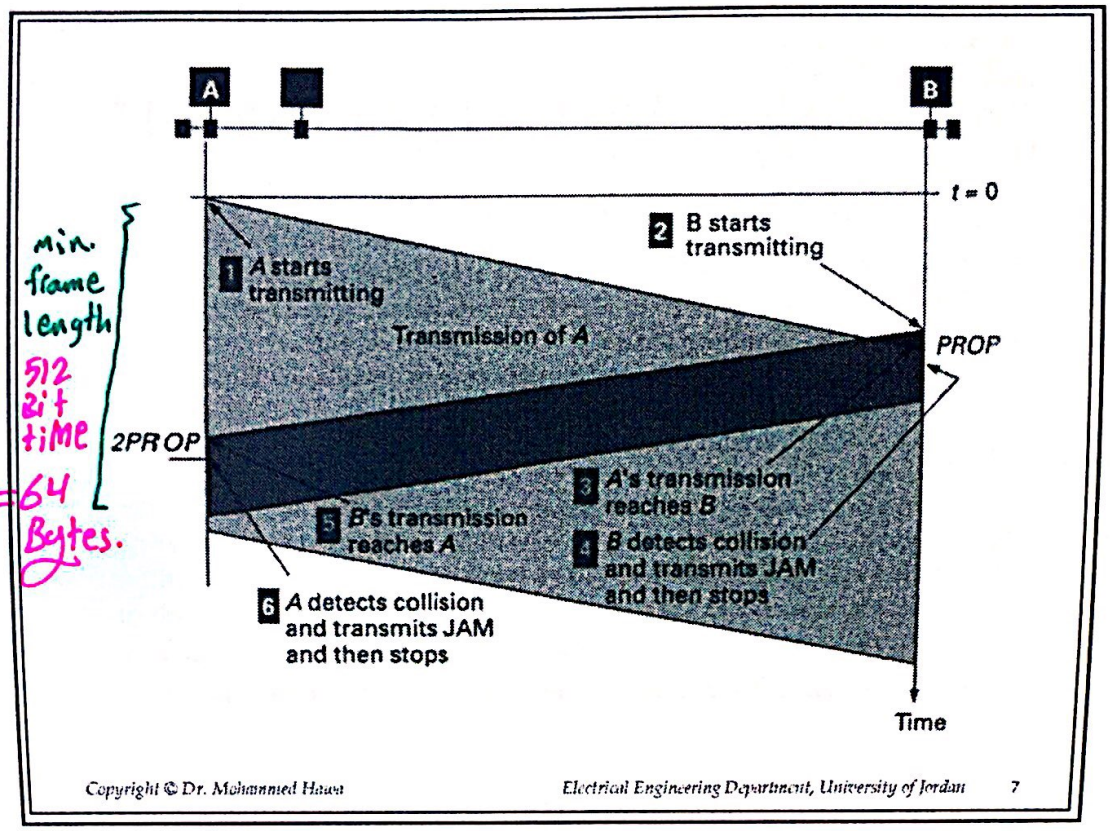
Solved By fiber.

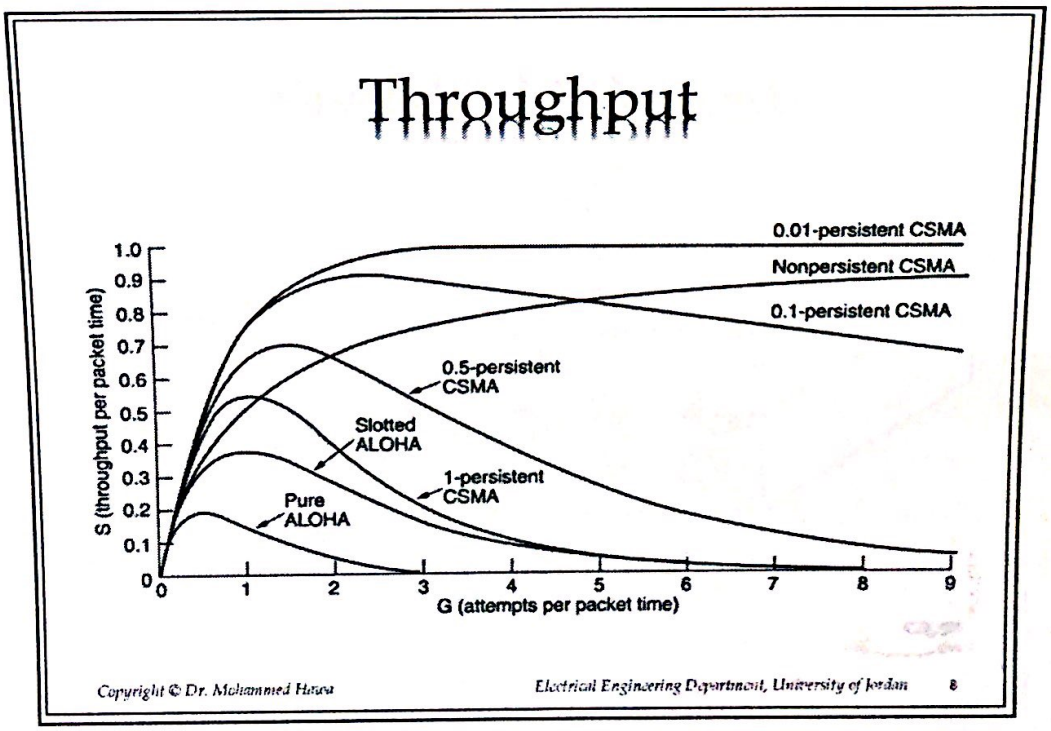
2.5 Km max between any two PC's Because of max collision detection time which decide min. frame length (64 Bytes).

since if one send 5V every one also have 5V.

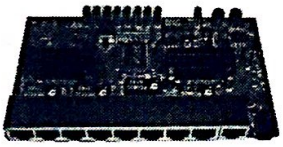
* remember:

Hub ≡ repeater ≡ regenerator ≡ L1 device. ≠ switch.





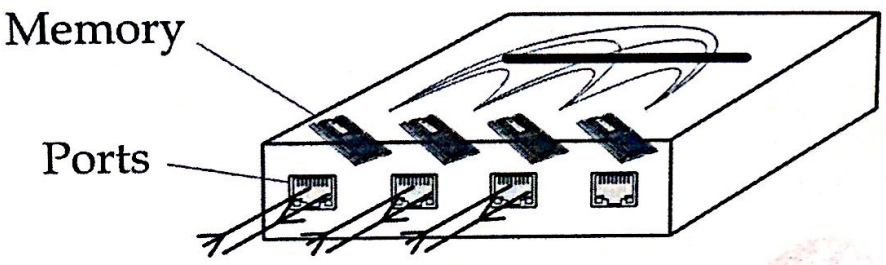
The Ethernet *Switch*



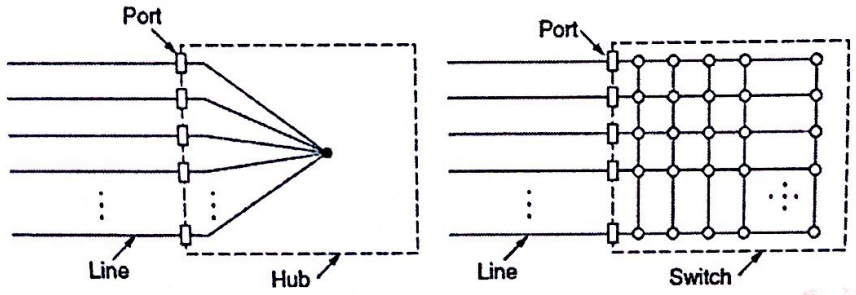
- An Ethernet switch physically resembles a hub, but is different.
- A switch **buffers** any frame it receives on one of its ports into its memory (RAM), then sends the frame on an internal high-speed backplane (switching fabric) to the destination port. The switch uses the backplane to transmit the frame to all other ports without collisions (except maybe the port the frame arrived at).
- Hence, each port of an Ethernet switch is its own **collision domain**.
- Sometimes, the switch is connected to the computer NIC using two pairs of twisted wires (4 wires) to allow full duplex communications without collisions on that port, as data can flow from the computer to the buffers of the switch and backwards simultaneously.
- This was advertised as double the link speed (e.g. 200 Mbps Ethernet instead of 100 Mbps), but is called full-duplex 100 Mbps.

NIC: Network Interface Controller.

Switched Ethernet



Switching Fabric



The Ethernet Switch [2]

Between 2 different machines

- Since collisions are avoided in an Ethernet switch, the different ports are allowed to receive and transmit frames at the same time, for parallel, full-duplex operation, something not possible with CSMA/CD on a single shared channel (a single collision domain).
- When full-duplex mode is used, the CSMA/CD protocol is switched off (new Ethernet NICs auto negotiat working in full-duplex or half-duplex depending if they are connected to a hub or switch).
- Ethernet switches are Layer 2 devices while hubs are Layer 1 devices. Switches understand the MAC layer of Ethernet, MAC addresses, etc, and they can negotiate half-duplex (with CSMA/CD) or full-duplex (no CSMA/CD) modes based on the situation.
- CSMA/CD limitation are removed in switched Ethernet, and performance (in terms of throughput and delay) is enhanced.
- Switches are also called bridges (bridges were used to connects LAN segments, or interface between different LAN technologies, such as Ethernet and Wi-Fi).

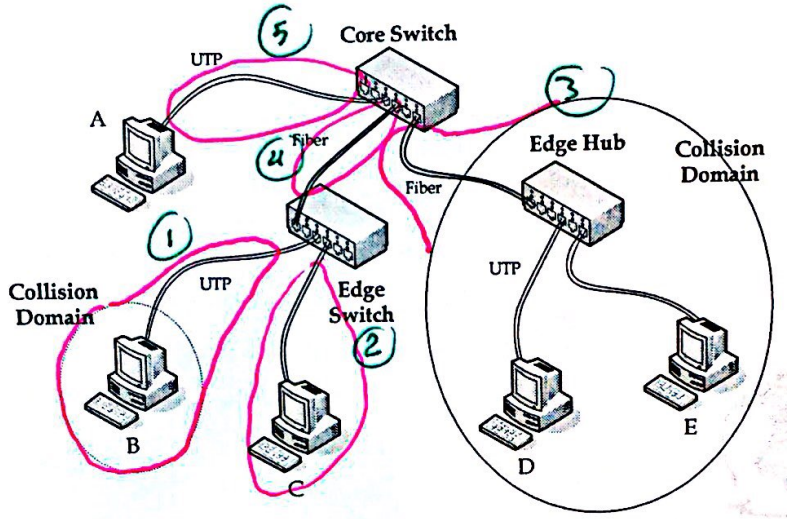
Data link layer
physical layer.

* switch is backward compitable with hub.

* Bridge ≡ switch ≡ L2 Device ≠ hub ≠ Router.

switch splits collision domain.

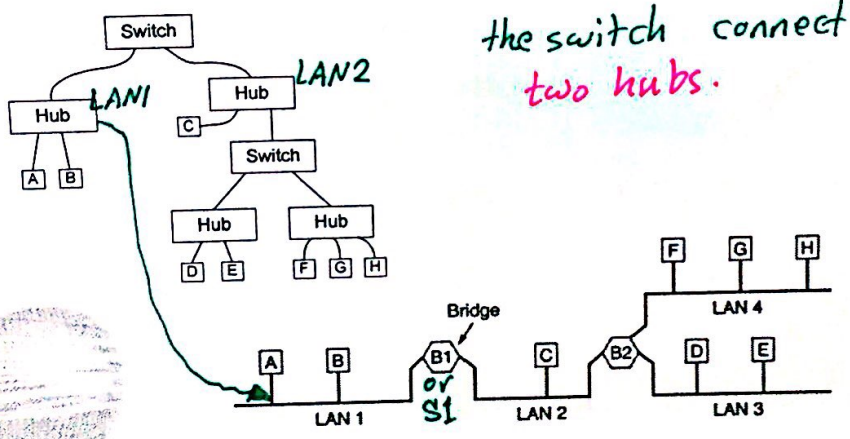
Switched Ethernet



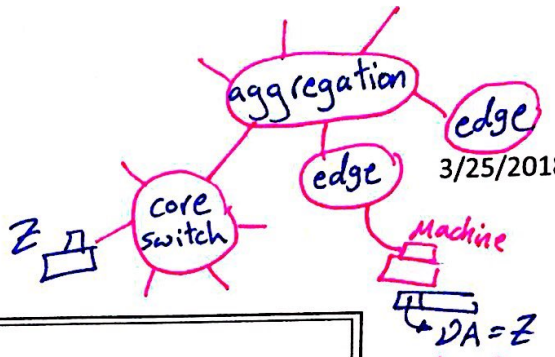
⇒ How many collisions Domain we have?

5.

Physical vs. Logical Diagram



the switch connect two hubs.

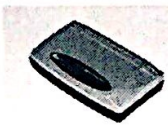
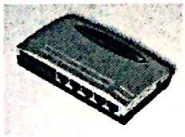


3/25/2018

Actually everyone will see Z.

Equipment

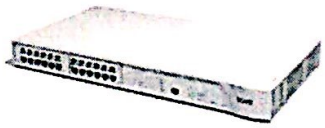
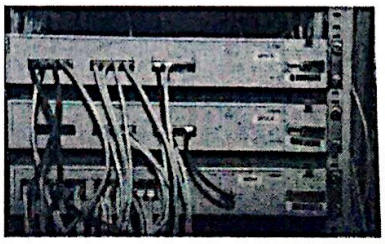
- A Cat-5 UTP cable with connectors (RJ-45 connector)
- Low-end switches (used at the edge of the network) (Cost: $10 – $100)

RJ 11
4 wire.

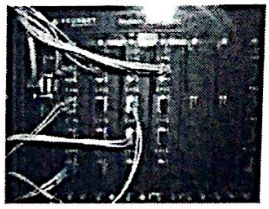
Equipment [2]

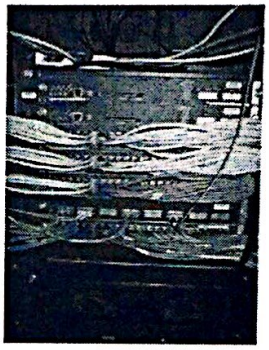
- Medium-end switches (used at the edge and aggregation points of the network) (Cost: $300 – $1,000)
- Wiring closet

Equipment [3]

- High-end switches (used at aggregation points and the core of the network)
- (Cost: $2,000 – $60,000 depending on selected modules)
- (e.g, Cisco Catalyst 3500 Series, Cisco Catalyst 6500 Series, Juniper EX series, HPE, Huawei, Arista, etc).





Communication Networks

Spring 2017/2018

Dr. Mohammad HAWA

By:

Mohammad
Abu Hashya.

* * *

Lecture 9: Switched Ethernet Features: STP and VLANs

Dr. Mohammed Hawa
Electrical Engineering Department
University of Jordan

Ethernet Switch Features

- The following features in modern Ethernet switches are quite useful to the network administrator:

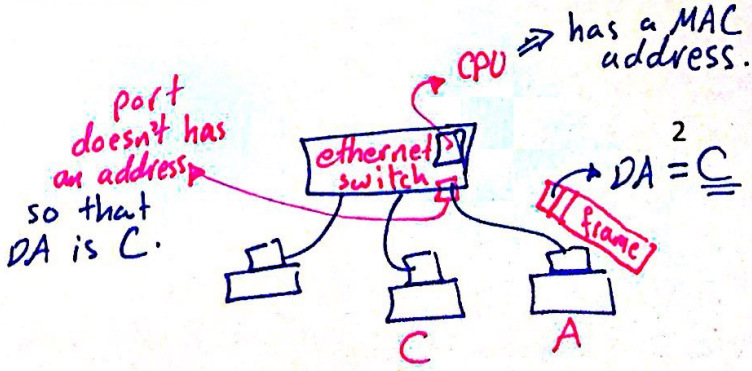
1. Self-learning (backwards-learning)
2. Spanning Tree Protocol (STP)
   - IEEE 802.1D
3. Virtual LAN (VLAN)
   - IEEE 802.1Q

Ethernet Switch is Transparent

- Switches were designed to mimic hubs, so they are transparent to the Ethernet machines attached to them.
- In other words, a switch acts like a shared medium, but without the possibility of collisions.
- When a frame arrives at one port of a switch, the switch forwards that frame to *all* ports *except* the one that the frame arrived on.
- This behavior is known as flooding. It makes the switch look like a shared medium.

Ethernet Switch is Transparent

- *Remember*: Ports on the switch do NOT have MAC addresses (nor IP address). A switch is not like a router. Each interface on a router has its own MAC address and IP address (see *later*).
- An exception is if the switch has a controller inside it to allow the administrator to control the switch.
- In such case, only the controller (which shows a Web page sometimes) has a MAC address, not the switch ports themselves.



Advanced Switch: Forwarding

- *Flooding* makes sure that each frame is seen by *all* machines on the Ethernet LAN, but wastes resources since most communications are unicast (intended to one destination).
- *Forwarding* was introduced in newer switches. The switch forwards the frame to only one port where the destination machine is connected (not to all ports).
- The switch (Layer 2 device) can read the unicast destination address (DA) in the frame and decide where to send the frame based on this DA.
- Forwarding (rather than flooding) reduces the number of packets processed by each switch port (and station), and enhances privacy.

• Feature (1):

Self-Learning (or Backward-Learning) Switches

- Problem: How can the switch know the MAC address (global or local) of each machine the administrator connects to its ports?
- Table lookup of MAC addresses connected to each of the switch ports.
- Configuring an Ethernet switch with a static table by the administrator is:
  - Time consuming.
  - Error prone.
  - Moving a station from one LAN to another LAN requires maintenance of the tables.

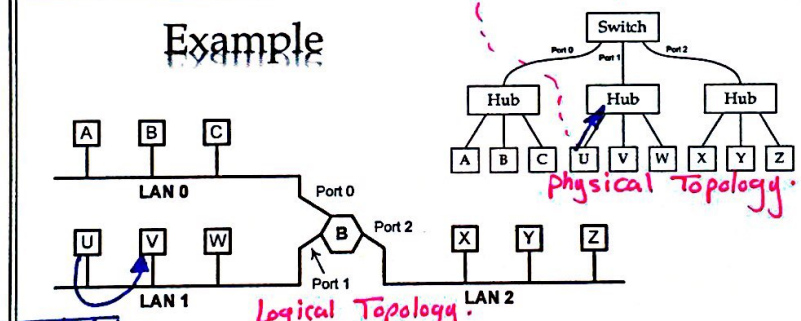
Self-Learning Algorithm

- When the switch boots, its self-learning hash table is *empty*.
- When the switch receives a frame to forward, the switch inspects the DA and SA of the frame:
  - DA: If the switch knows the port belonging to the DA the switch forwards *only* to that port; otherwise the switch *floods* (i.e., forwards to all ports *except* the one that the frame arrived on).
  - SA: The hash table is updated by the SA information.
- Hash tables are treated as cache entries:
  - *New* information overrides *old* information
  - Each entry is assigned a timeout, after which it is erased.

SA = MAC$_U$
DA = MAC$_V$

we have {3} collision domain & {1} Broadcasting domain.

Example



Event	Port 0 List	Port 1 List	Port 2 List	Bridge Action
Bridge boots	-	-	-	Empty Tables
U sends to V	-	U	-	Flood (to Ports 0 and 2)
V sends to U	-	U, V	-	Discard
Z broadcasts	-	U, V	Z	Flood (to Ports 0 and 1)
Y sends to V	-	U, V	Z, Y	Forward to Port 1
Y sends to X	-	U, V	Z, Y	Flood (to Ports 0 and 1)
X sends to W	-	U, V	Z, Y, X	Flood (to Ports 0 and 1)
W sends to Z	-	U, V, W	Z, Y, X	Forward to Port 2

SA = MAC$_V$
DA = MAC$_U$

if V send to U

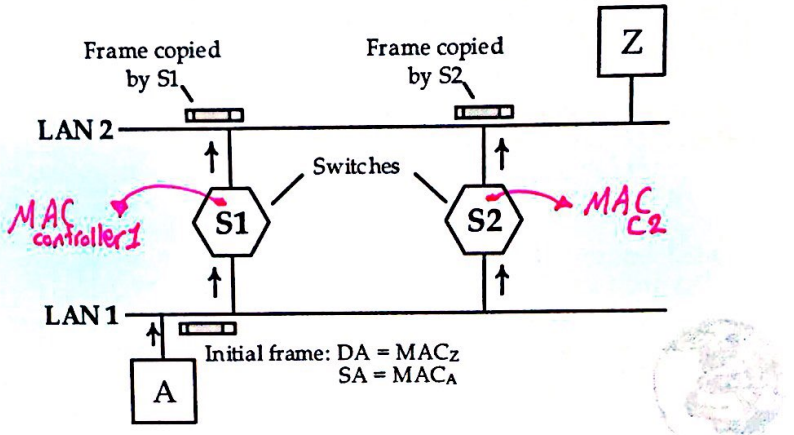
y sends to V

DA = V
SA = Y.

we already Know that V is on port 1 so forward to port 1
Then we will be Known that Y is on port 2
& so on.

• feature (2):

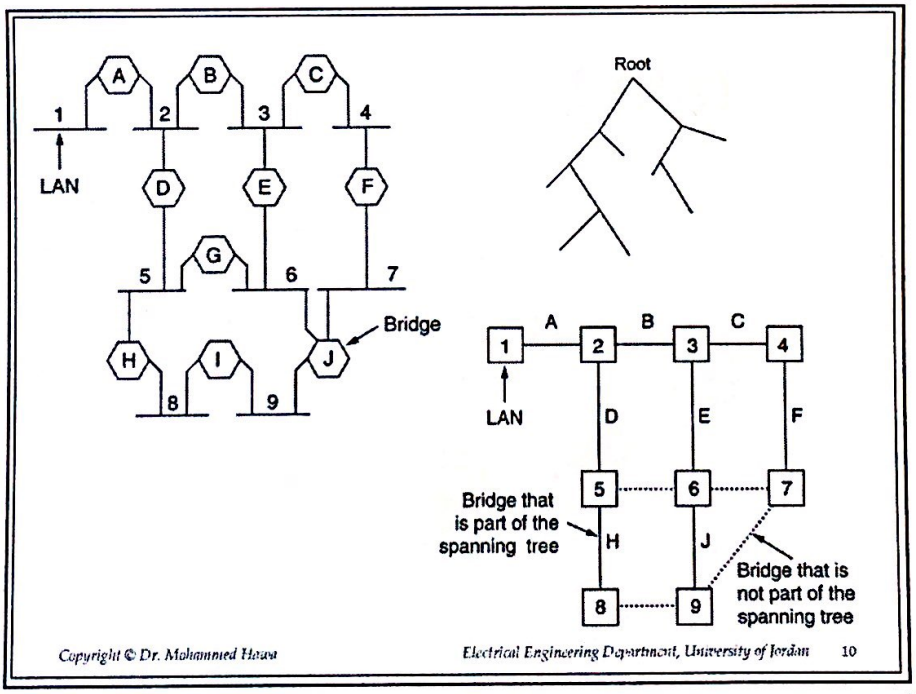
Spanning Tree Protocol (STP) = Avoids Loops



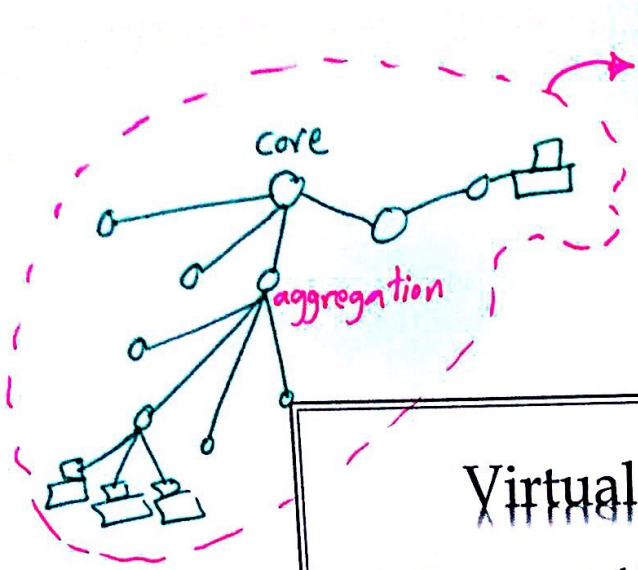
S_1 & S_2 just booled.

S_1: port 0, port 1 — S_2: port 0, port 1

* we want to get rid-off loops. (STP gives NO loops).



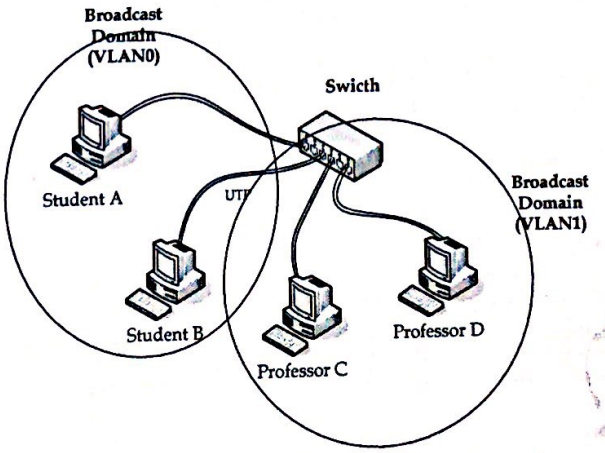
in the tree you always have a path.

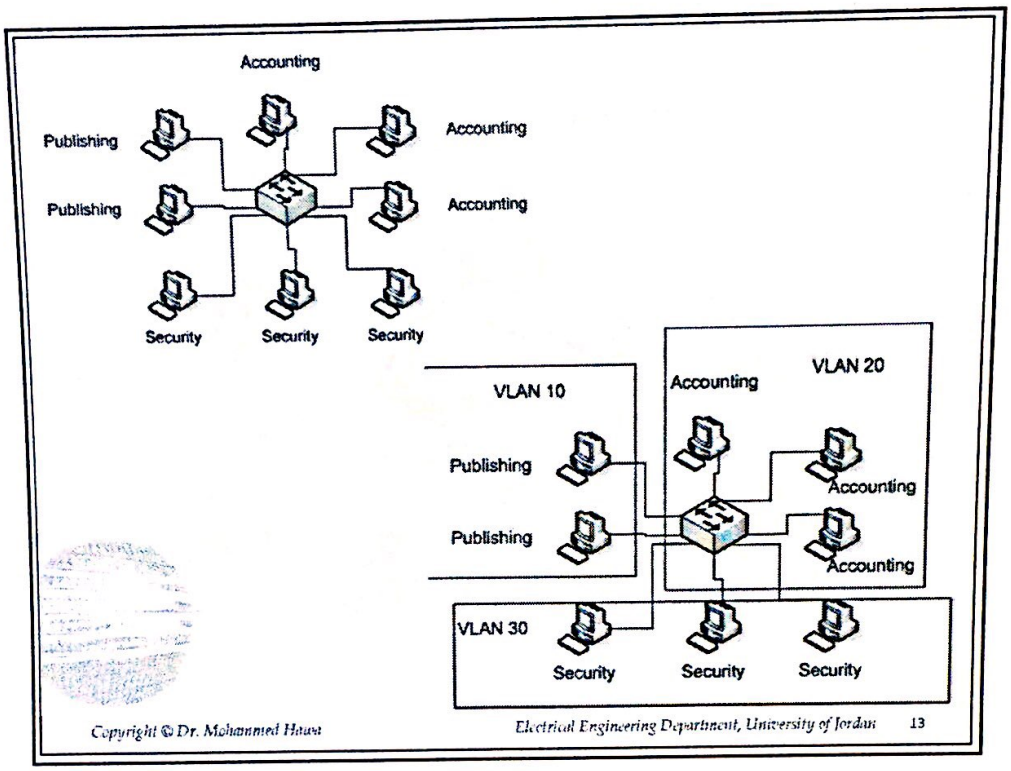


Virtual LANs (VLANs)

- All hosts connected to an Ethernet LAN (consisting of one or more switches) are in the same **broadcast domain**. If one host connected to the LAN sends a broadcast, all of the other hosts receive the broadcast, wasting bandwidth.
- For some protocols, a broadcast received by a host results in that same host transmitting a broadcast of its own. Then when all the hosts receive the first broadcast, they all end up transmitting even more broadcasts. All these broadcasts snowball into a **broadcast storm**.
- Typically few hosts on each LAN really need to broadcast to each other. VLANs *isolate broadcast domains* by splitting an Ethernet switch into multiple virtual switches.
- This reduces overall traffic, avoids broadcast storms, improves security by isolating traffic, and improves privacy.
- All is done by software.

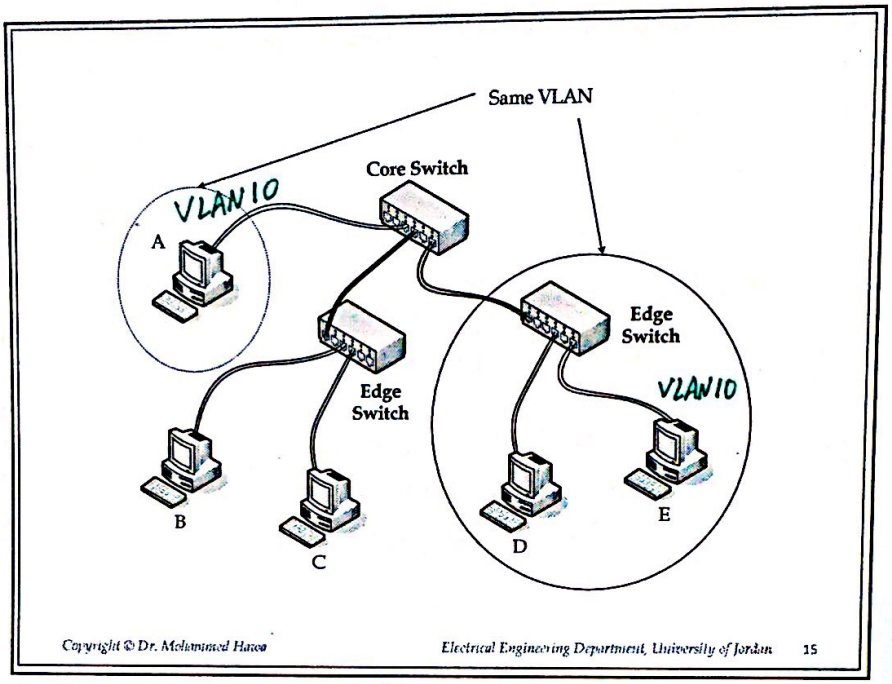
Virtual LANs (VLANs)



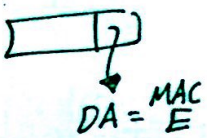


VLAN: Administrator Power

- Most switches require assigning a number to a VLAN when it is created, such as VLAN 10, VLAN 20, etc.
- No traffic is able to go from one VLAN to another. By default, there will be no inter-VLAN traffic on the switch, unless a router (Layer 3 device) is involved (probably along with a firewall for security).
- When using VLANs, Ethernet frames contain the optional IEEE 802.1Q tag to identify to which VLAN it belongs.
- Common approaches to assigning VLAN membership:
- **Static VLANs** (port-based VLANs): assigns ports on a switch to a VLAN. The device automatically assumes the VLAN of the port.
- **Dynamic VLANs**: created through a software package (VLAN Management Policy Server), where an administrator assigns VLANs dynamically based on information such as the source MAC address of the device connected to the port or the username used to log onto that device, etc.



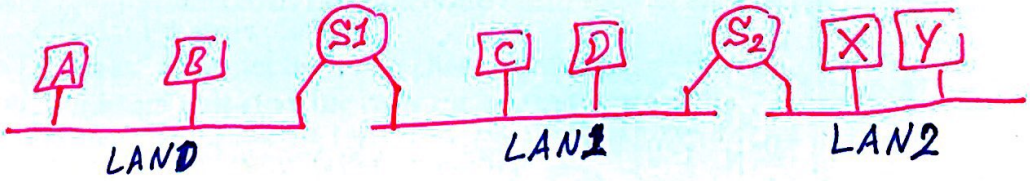
if D send a frame



if D is booted in the system

E & A will receive.

Homework:



S_1 & S_2 are self learning.

A → X
X → C
B → D
Y broadcasting.

Communication Networks

Spring 2017/2018

Dr. Mohammad HAWA

By:

Mohammad
Abu Hashya.

* * *

This is the last lecture about Ethernet (802.3)

Lecture 10: Ethernet Standards and Ethernet Wiring

Dr. Mohammed Hawa
Electrical Engineering Department
University of Jordan

Classical Ethernet (10 Mbps)

- "Classical Ethernet" (e.g., 10Base-5 thick coaxial, 10Base-2 thin coaxial, 10Base-T twisted pair) is mostly obsolete.
  - 500m segment length.
  - 200m segment length.
  - data rate 10 Mbps. (Baseband)
- Common standards nowadays are Fast Ethernet and Gigabit Ethernet (GbE).
- Classical Ethernet used Manchester encoding.
- *Advantage*: Self-clocking code for any sequence of 1's and 0's, which allows the PLL at the receiver to work properly at all times (after preamble).
- *Disadvantage*: Bandwidth = $2f_0 = 2 \times 10 = 20$ MHz.
- Fast Ethernet and Gigabit Ethernet do NOT use Manchester encoding since they would then require a bandwidth of 200 MHz and 2000 MHz, respectively.

Fast Ethernet : 100 Mbps.
Gigabit " : 1000 Mbps.

use MLT-3

Fast Ethernet (100 Mbps)

- Fast Ethernet was standardized as IEEE 802.3u.
- Approved by IEEE in 1995 as an addendum to the IEEE 802.3 standard.
- Fast Ethernet is backwards compatible with Classical Ethernet: Uses the same frame format (with minimum and maximum frame lengths), same 48-bit MAC address structure and same CSMA/CD rules.
- The main difference is that bit time is reduced from 100 ns to 10 ns.
- In Fast Ethernet, only twisted pairs and optical fibers are allowed (not coaxial cable).
- Half-duplex (with hubs) and full-duplex (with switches) modes are possible.

Better → CAT 7, CAT 6, CAT 5, CAT 3 ← Expensive.

distance from the hub/switch to the Machine

Main Variants of Fast Ethernet

Name	Cable	Max. Segment	Comments
100 Base-TX	UTP (CAT 5)	100 m	Half-duplex or Full-duplex
100 Base-FX	Fiber optics	2000 m	Full-duplex only; long runs

for fiber we use only switches

Full duplex has NO Collision. Half duplex has collisions.

⇒ so in full duplex Disable CSMA/CD & half duplex Enable CSMA/CD.

- CAT 5 (Category 5) cable has 4 pairs (8 wires) of copper. Replaces the older CAT 3 cables.
- Each pair in CAT 5 can carry a bandwidth of about 125 MHz for about 100 m distance. → Not enough for Manchester
- To send bits on 100 Base-TX:
- 4B/5B followed by MLT-3 line encoding. $f_0 = 100\text{Mbps} \Rightarrow BW = 200\text{MHz}$
- As an example of 4B/5B encoding, let us encode the data stream 0111010000100000.

using one switch:
- What is the max. dist between 2 PC's using Fiber (100 Base-FX)? 4Km.
- " " " " " " PC & switch using Fiber? 2Km.

send 5 bits instead of 4 bits.

4B/5B Encoding

	0	1	2	3	4	5	6	7
4-bit Nibble	0000	0001	0010	0011	0100	0101	0110	0111
5-bit Code	11110	01001	10100	10101	01010	01011	01110	01111

	8	9	10	11	12	13	14	15
4-bit Nibble	1000	1001	1010	1011	1100	1101	1110	1111
5-bit Code	10010	10011	10110	10111	11010	11011	11100	11101

send 01111 instead.

Data stream:	0111	0100	0010	0000
4 bit nibbles:	0111	0100	0010	0000
5-bit stream:	01111	01010	10100	11110

- Avoids a long sequence of consecutive 0's in MLT-3.
- Bandwidth = $0.9 \times f_0 = 0.9 \times 5/4 \times 100 = 112.5$ MHz

maintain synch. at PLL Rx.

max consecutive 0's is 2.

4B/5B Encoding

Data (Hex)	Data (4-bit Nibble)	5-bit code
0	0000	11110
1	0001	01001
2	0010	10100
3	0011	10101
4	0100	01010
5	0101	01011
6	0110	01110
7	0111	01111

Data (Hex)	Data (4-bit Nibble)	5-bit code
8	1000	10010
9	1001	10011
A	1010	10110
B	1011	10111
C	1100	11010
D	1101	11011
E	1110	11100
F	1111	11101

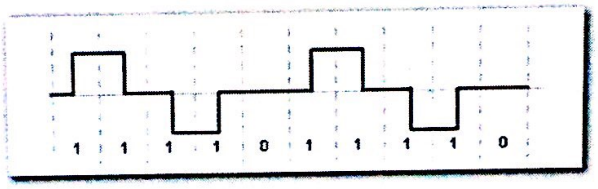
Control character	5-bit symbols	Purpose
JK	11000 10001	Sync, Start delimiter
I	11111	100BASE-X idle marker
TR	01101 00111	100BASE-X end delimiter
HH	00100 00100	HDLC0
HI	00100 11111	HDLC1
HQ	00100 00000	HDLC2
RR	00111 00111	HDLC3
RS	00111 11001	HDLC4
QH	00000 00100	HDLC5

No need to do Bit/Byte stuffing in the middle of the frame since (0 to F) are the only cases here.

4B/5B encoding with MLT-3

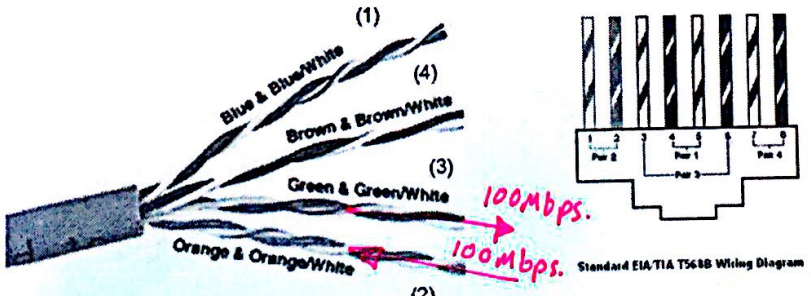
- When applying 4B/5B encoding before MLT-3, we ensure transitions occur even when a long series of 0's are sent.
- As an example let us encode the data stream 00000000.

Data stream:	0 0 0 0 0 0 0 0	
4 bit nibbles:	0000	0000
4B/5B Stream:	11110	11110
MLT-3 Stream:	+0-00	+0-00



advantage: small BW.
disadvantage: long seq. of 0's.

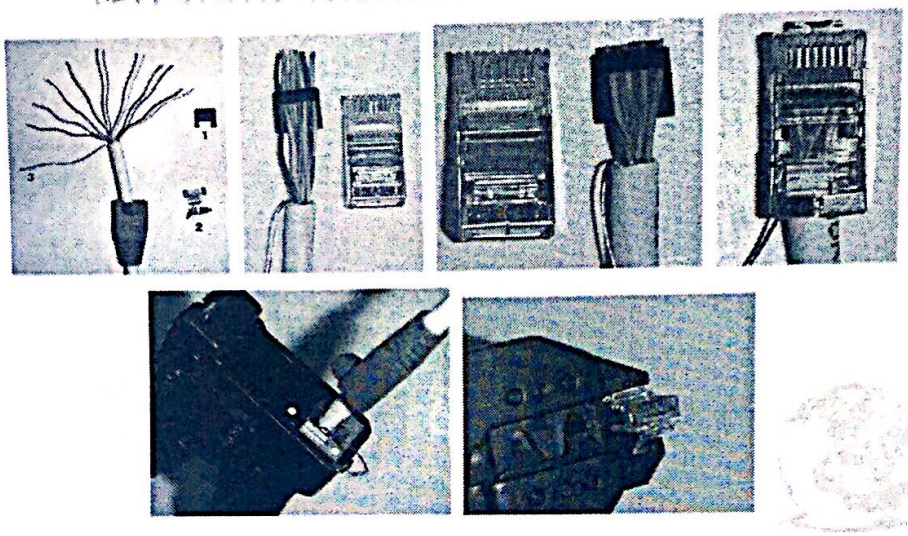
100Base-TX Wiring



RJ-45 Connector

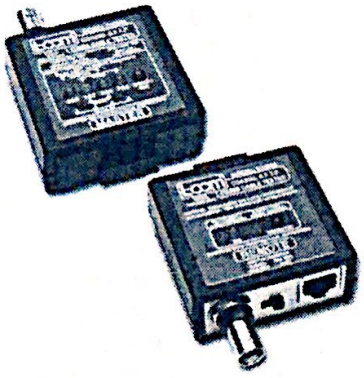
we use 2 pairs the other 2 for future expansion.

How to create a CAT-5 Cable (straight-through or crossover)



What you need…

RJ45 Crimper



CAT-5 Tester

Ethernet Ports and Cables

- An Ethernet **Cable** can be:
  - Straight-Through (or Patch) cable.
  - Crossover cable.
- An Ethernet **Port** can be:
  - Uplink Port (TX on 1 & 2) (sometimes called WAN port).
  - Normal Port (TX on 3 & 6) (sometimes called LAN port).

Pins on plug face (jack is reversed)

Memorize.

Uplink Port		Normal Port	
TX+	1	1	RX+
TX-	2	2	RX-
RX+	3	3	TX+
RX-	6	6	TX-

① & ② for Tx.
③ & ⑥ for Rx.

PC (uplink port)		Hub/Switch (normal port)	
TX+	1	1	RX+
TX-	2	2	RX-
RX+	3	3	TX+
RX-	6	6	TX-

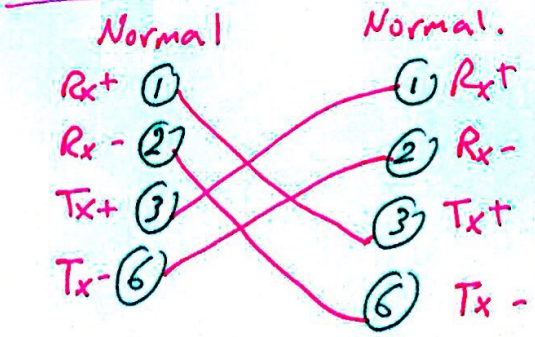
Straight-Through Patch Cable

PC (uplink port)		PC (uplink port)	
TX+	1	1	TX+
TX-	2	2	TX-
RX+	3	3	RX+
RX-	6	6	RX-

Crossover Cable

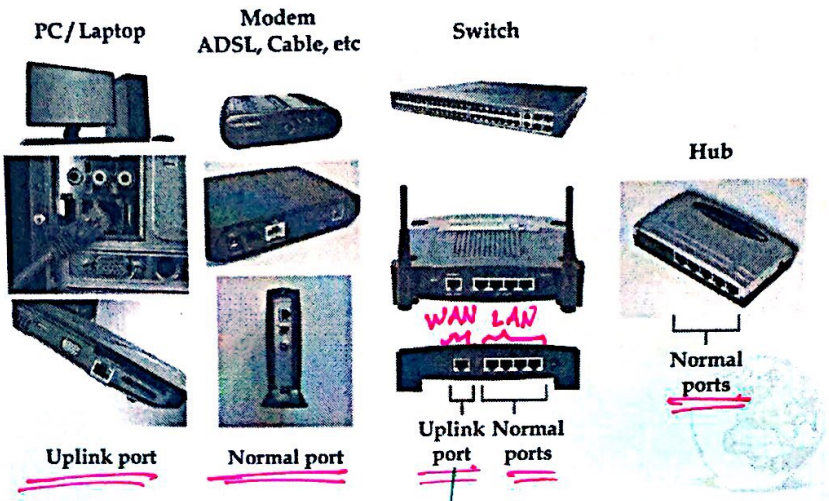
Note: Pins 4, 5, 7 and 8 are not used

memorize:



Memorize.

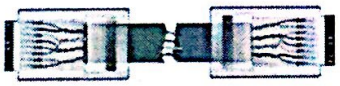
Etherent Ports



Typically one port.

if the uplink Not existed ⇒ Need crossover cable To connect Normal with Normal.

Memorize

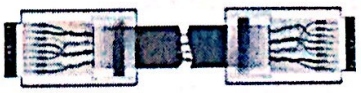


Pin number	Wire Color
Pin 1	Orange/White
Pin 2	Orange
Pin 3	Green/White
Pin 4	Blue
Pin 5	Blue/White
Pin 6	Green
Pin 7	Brown/White
Pin 8	Brown

Straight-Through

1	1
2	2
3	3
6	6

Pin number	Wire Color
Pin 1	Orange/White
Pin 2	Orange
Pin 3	Green/White
Pin 4	Blue
Pin 5	Blue/White
Pin 6	Green
Pin 7	Brown/White
Pin 8	Brown



Crossed-Over

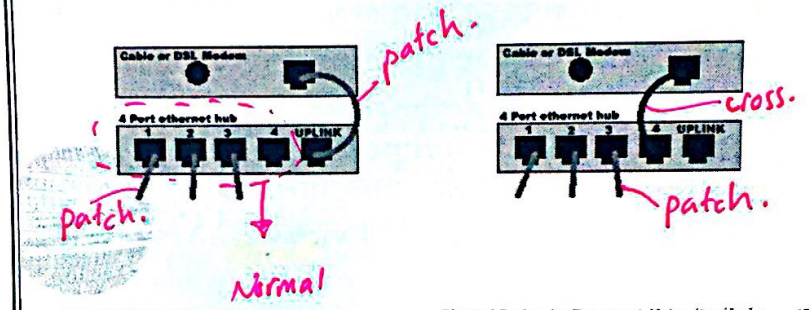
1	3
2	6
3	1
6	2

Pin number	Wire Color
Pin 1	Orange/White
Pin 2	Orange
Pin 3	Green/White
Pin 4	Blue
Pin 5	Blue/White
Pin 6	Green
Pin 7	Brown/White
Pin 8	Brown

Pin number	Wire Color
Pin 1	Green/White
Pin 2	Green
Pin 3	Orange/White
Pin 4	Blue
Pin 5	Blue/White
Pin 6	Orange
Pin 7	Brown/White
Pin 8	Brown

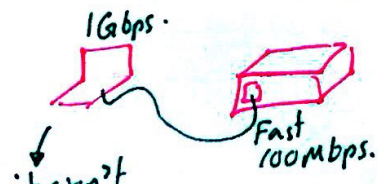
Ethernet Connections

- Exercise 1: What type of cable do you use to connect a normal port of a switch to a normal port of another switch or router? Crossover.
- Exercise 2:

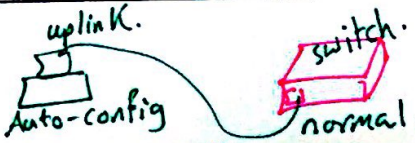


Advanced Switche Ports

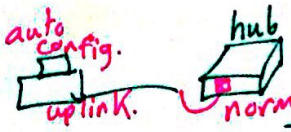
- **Auto-sensing:** Automatically sense (negotiate) data rate (100 or 1000 Mbps, etc).
- **Auto-configure:** Automatically negotiate duplexity (half- or full-duplex) using a short circuit in the port (called *loopback*).
- **Auto-uplink:** Automatically adjust the port into normal or uplink port, using built-in analog switches. Also called Auto-MDIX (MDIX: media-dependent interface crossed).



it won't work unless it has an auto-sensing then it will work @ 100Mbps.

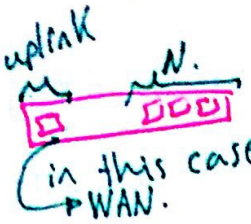


works @ full duplex. No CSMA/CD.



⇒ works @ half duplex. CSMA/CD.

8



N→N (cross)
N→U (patch)

Exercises

- Modem to a PC/Laptop? ⇒ patch.
- PC to an Ethernet switch?
- Modem to an Ethernet switch? ⇒ cross.
- Ethernet core switch to aggregation switch?
- Ethernet core router to aggregation switch?
- PC to PC (If Auto-uplink on at least one of them? If no Auto-uplink but Autoconfig on both? If no Auto-uplink and no Autoconfig)?
- PC to an Ethernet Hub? patch

Copyright © Dr. Mohammed Hawa Electrical Engineering Department, University of Jordan 17

in general, we consider it Normal, so use patch.

① straight. U→N auto uplink. yes, full duplex.

② straight. auto-config. autoconfig. YES, halfduplex.

③ there will be No connection.

in this case both sides must have autoconfig.

Gigabit Ethernet (GbE) (1000 Mbps or 1 Gbps)

Memorize.

- Gigabit Ethernet was standardized as IEEE 802.3z.
- Ratified by IEEE in 1998.
- Backwards compatible with previous Ethernet standards.
- 1000Base-T is IEEE 802.3ab.

Name	Cable	Max. Segment	Comments
1000 Base-T	UTP	100 m	Deployed CAT 5e or CAT 6 UTP.
1000 Base-SX	Fiber optics	550 m	Multimode fiber.
1000 Base-LX	Fiber optics	5 km	Single or Multimode fiber.
1000 Base-LH	Fiber optics	10 km	Single mode fiber.

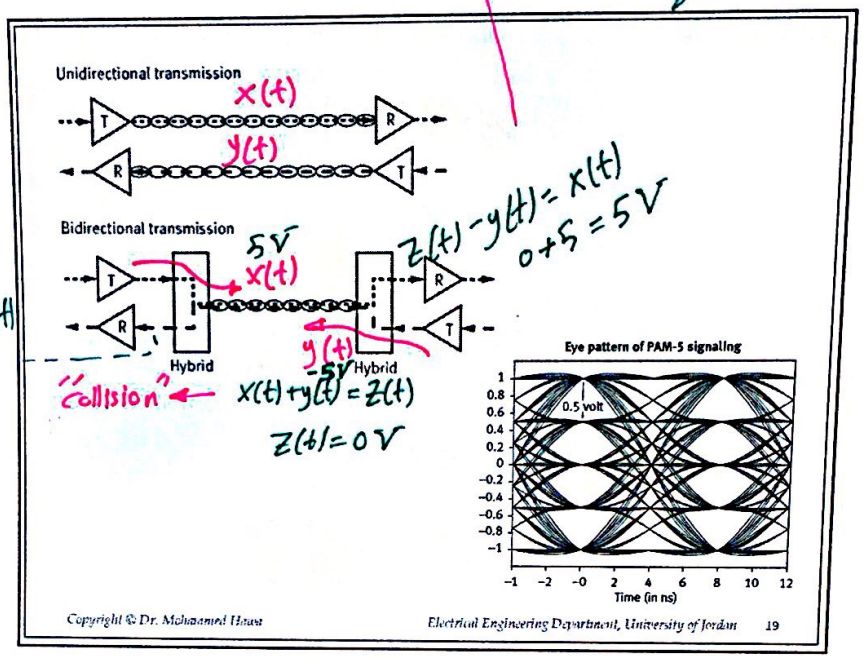
Copyright © Dr. Mohammed Hawa Electrical Engineering Department, University of Jordan 18

Better than CAT5 since it has a lot of interference.

S: for short haul.
L: Long
LH: Long haul

4/2/2018

* Requires Very Powerful DSP & Echocancellation + equalization.



1000Base-T Encoding

memorize.

- Uses 8B1Q4 (8-bit to 1 four quinary "five" symbol) combined with 4D-PAM5 (Four-dimensional Pulse Amplitude Modulation 5-levels) encoding method.
- 8B1Q4: divide each group of 8 bits into four 2-bit groups. Each 2-bit group is converted to a 3-bit group to allow for forward error correction. Each 3-bit group is called a quinary symbol.
- The quinary symbols are then line encoded using 4D-PAM5, where each 3-bit group is mapped into one of five possible voltage levels through a non-trivial linear feedback shift register. The mapping varies continuously during transmission. Four symbols are transmitted in parallel in each symbol period.
- A total of 125 Msymbols (4D-PAM5 symbols) is sent per second over the four pairs. This translates into a total of 8 bits per symbol x 125 Msymbol/s = 1000 Mbps for the cable.

Copyright © Dr. Mohammed Hawa
Electrical Engineering Department, University of Jordan 20

M-ary ≡ PAM.

5 possible levels:
1V
0.5V
0V
-0.5V
-1V
(3 bits)

0 0 0	0V
0 0 1	0.5V
0 1 0	1V
0 1 1	-0.5V
1 0 0	0V
1 0 1	0.5V
1 1 0	-1V
1 1 1	-0.5V

the levels are reused but the Rx knows which one on the Top & which one on bottom.

this extra bit is FEC. ⇐ Convert into 3 bits

Ex.

10 11 10 01

2bit 2bit 2bit 2bit

101 111 100 010

data bits rate = 8 * 125 M symbol

Total bit rate = 12 * 125 M symbol.

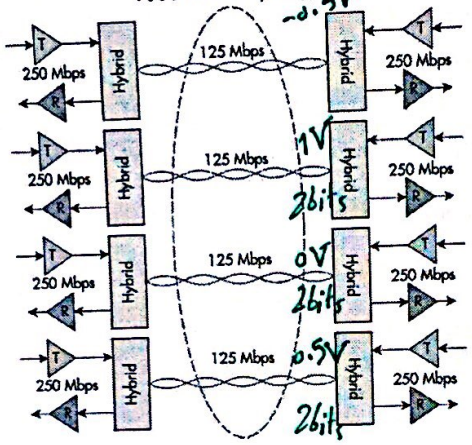
10

1Gbps.

1Gbps

1000Base-T

1000Base-T topology



-0.5V ⇒ 2bits

1V 2bits

0V 2bits

0.5V 2bits

8bits.

2ch.

*125M symbol/s

= 1000 Mbps.

= 1Gbps.

* symbol rate decided by Bch.

* bit/symbol decided by SNR.

Copyright © Dr. Mohammed Hawa

Electrical Engineering Department, University of Jordan 21

Memorize:

10 Gigabit Ethernet (10GbE)

Baud Rate * bit/symbol = Bit Rate

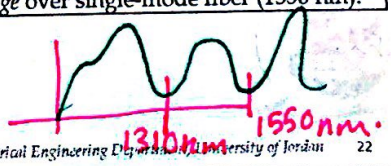
The following three varieties use the LAN PHY:

Name	Max. Segment	Comments
10GBASE-SR	26 m – 82 m	*Short Range* over deployed multi-mode fiber.
10GBASE-LR	10 km	*Long Range* over single-mode fiber (1310 nm).
10GBASE-ER	40 km – 80 km	*Extended Range* over single-mode fiber (1550 nm).

The following use the WAN PHY, designed to interoperate with OC-192/STM-64 SDH/SONET equipment using a light-weight SDH/SONET frame.

SDH/SONET (10Gp/s).

Name	Max. Segment	Comments
10GBASE-SW	26 m – 82 m	*Short Range* over deployed multi-mode fiber.
10GBASE-LW	10 km	*Long Range* over single-mode fiber (1310 nm).
10GBASE-EW	40 km – 80 km	*Extended Range* over single-mode fiber (1550 nm).



Copyright © Dr. Mohammed Hawa

Electrical Engineering Department, University of Jordan 22

10GBASE-T (IEEE 802.3an)

- IEEE 802.3an was released in 2006.
- 10 Gbps over UTP or STP cables over distances up to 100 m.
- Uses Cat-6A (or CAT-7) cable, or 55 m with older Cat-6 cables.
- Encoding: Tomlinson-Harashima precoded (THP) version of pulse-amplitude modulation with 16 discrete levels (PAM-16), encoded in a two-dimensional checkerboard pattern known as DSQ128 (Double Square 128).
- Powerful low-density parity-check (LDPC) linear error correcting code.
- The IEEE 802.3bm standard, released in 2015, defines 100G/40G Ethernet for optical fiber.
- The IEEE 802.3bs standard (December 2017) introduces 200GbE (200 Gbit/s) over single-mode fiber and 400GbE (400 Gbit/s) over optical physical media.

memorize.

Upgrading your Infrastructure