CCNA

Book 1
(Networks Fundamentals)

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(DoN)

Session 1 Outlines :

- Network definition.
- Network Importance.
- Network Components.
- Network Topologies.
- Network Types.

Session 1/1

IP Network Definition

It's group of components that are connected together to provide a service (application تطبيق)

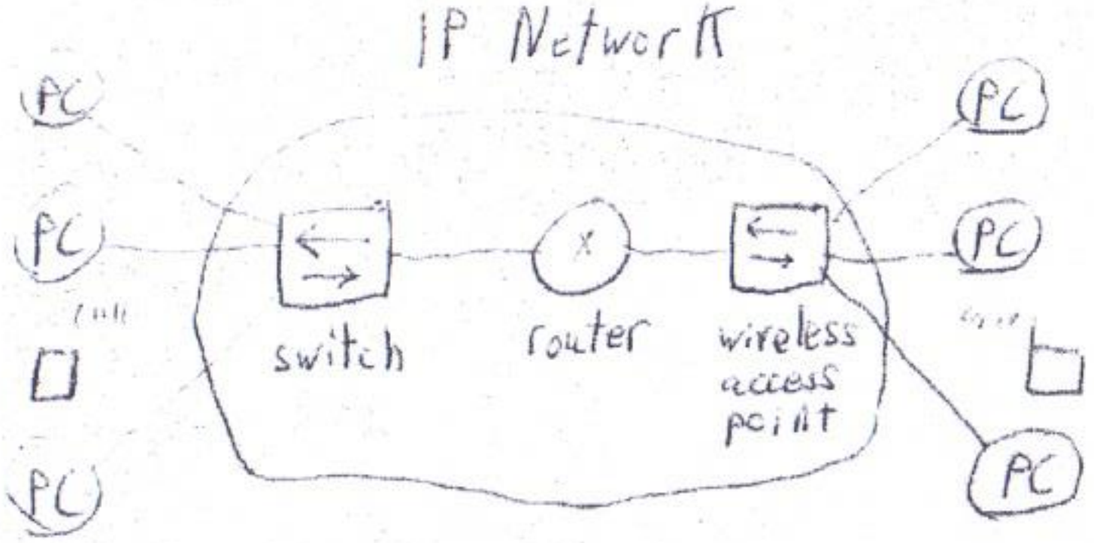
IP Network Importance

1. Easy sharing of files, information & data
2. Easy sharing of expensive devices/resources (1 printer for 20 computers instead of 20 printers)

] Data

3. Voice
4. Video
5. Smell
6. Taste
7. Touch
8. IOT : Internet of Things

] Virtual Reality



- Data Network → Transmits data only
- Integrated Network → Transmits data + voice + video
- Internet Protocol (IP)

IP Network Components

[1] End devices — wireless

Computer, mobile, IP camera, IP TV, playstation (network), printer, ...

End device is a main component, because it's a source of network application

Services can be done with remote devices

[2] Intermediate devices (network devices)

Repeater, Hub, Bridge, switch, Gateway, Router, modem, NIC, Wireless Access Point, Firewall,

IDS (Intrusion Detection System)

IPS (Intrusion Prevention System)

[3] Connectivity

- Cables (Copper, Fiber)
- Wireless

Session 1/2 — Transferring files (text, images, sound, video, ...) on the world wide web.

Ex 1 HTTP (Hyper Text Transfer Protocol) — set of rules

- used for browsing

Ex 2 FTP (File Transfer Protocol) → Huge File

- used for download / upload huge file

Server (4 share - Rapidshare - Megaupload)

Ex 3 Email (SMTP) Simple Mail Transfer Protocol

Retreive Email : PoP 3 (Post Office Protocol) version 3 saves the emails to retreive them later

Ex 4 Telnet (remote login) remote configuration

- Text-based network protocol used for accessing remote computers over TCP/IP networks like Internet.

Session 1/3

Network Topologies

How components are connected?

1 Point-to-Point Topology (2 PCs only)

PC —cable— PC

2 Ring Topology

(العيوب)
- لف ودوران
- كروت كتير
ضعف عدد الأجهزة

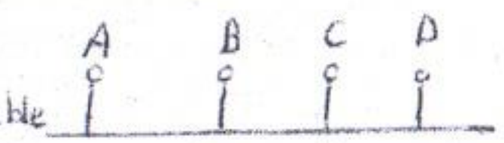
3 Mesh Topology

$\frac{4(3)}{2} = 6$

- مش لف ودوران
- كروت اكتر بكتير

no. of cables $= \frac{n(n-1)}{2}$ n: no. of devices

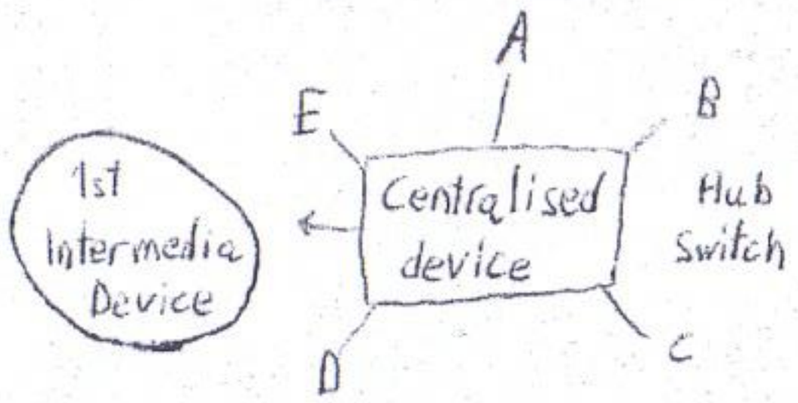
4 Bus Topology



one send & all receive

- مفيش لف ودوران
- كارت واحد بكل pc
- اذا جهازين أرسلوا في نفس الوقت يحدث Interface للمعلومات

5 Star Topology

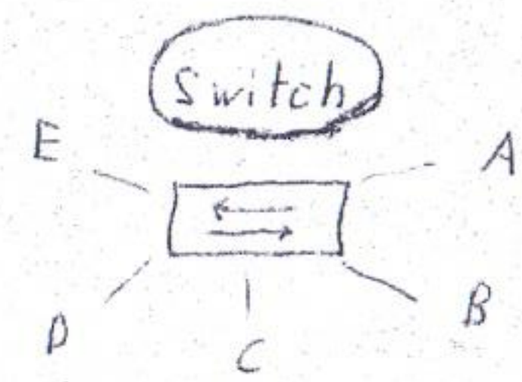


(virtual)

Physical vs. Logical Topology

Physical Topology: star

Logical Topology: Bus
(one send, all receive)



Physical Topology: star

Logical Topology: Mesh

Session 1/4

Types of Networks

1 LAN

Local Area Network

It's a group of computers that are connected together within local area ملكية خاصة - بدون شبكة تحت السيطرة

2 MAN

Metropolitan Area Network

Group of LANs within same city

3 WAN

Wide Area Network

Group of LANs between cities, countries, continents

Public WAN

Private WAN

Network definition :

It is a group of Components that are Connected together to provide a Service.

Network Importance :

1. Easy Sharing of data, Information and files.
2. Easy Sharing of expensive resources.
3. Voice.
4. Video.
5. Smell.
6. Touch.
7. Taste.

. All these points are called Virtual Reality
. Internet of things.

Network Components :

1. Compulers : 10 %

It is the main Component because it is the source of network applications.

example:

FTP (File Transfer Protocal): used for Upload & download.
SMTP (Simple Mail Transfer Protocal): used for Send mails.
POP3 (Post office Protocal version 3): Used for retrive mails.
HTTP (Hyper Text Transfer Protocal): used for browsing.
Telnet : used for remote login (Configuration).

2. Network devices : 80 %

Repeater - Hub - Bridge - Switch - Gateway - Firewall - Router - Modem - Wireless - Access Point - Network Interface Card (NIC) - IDS (Intrusion Detection system) - IPS (Intrusion Protection System).

3. Connectivity : 10 %

Wired - Wireless.

Network Topologies :

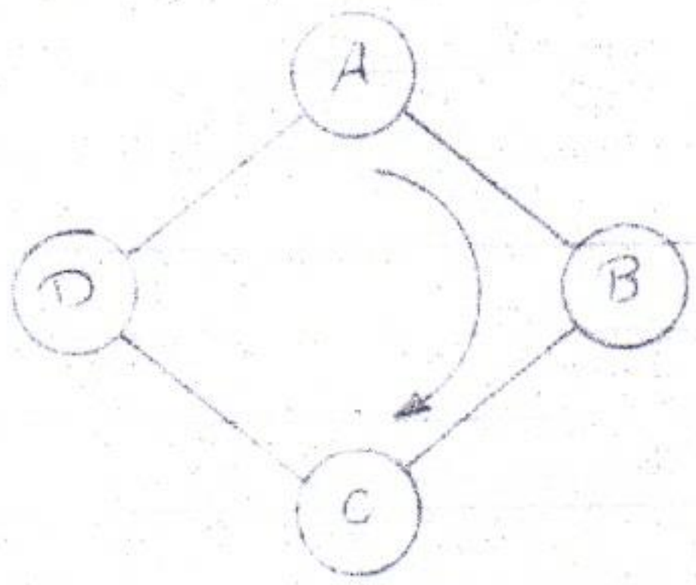
1. Point-to-Point :

Connect two devices

2. Ring Topology :

Made by IBH

to send data from A to C,
transfer from A to B then
B refuse receive it &
resend it to C .



Used in network devices.

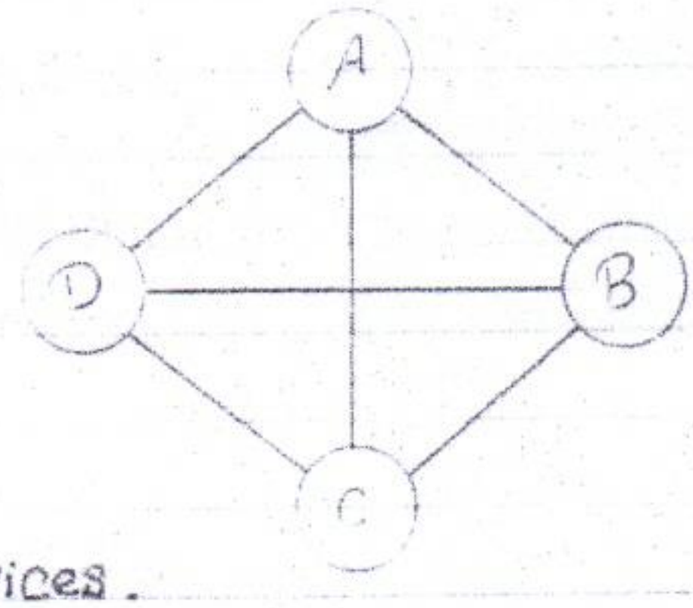
Disadvantages : make loop & alot of cards .

* 3. Mesh topology :

Used in network devices .

Advantage : no make loop.

Disadvantage : more cards .

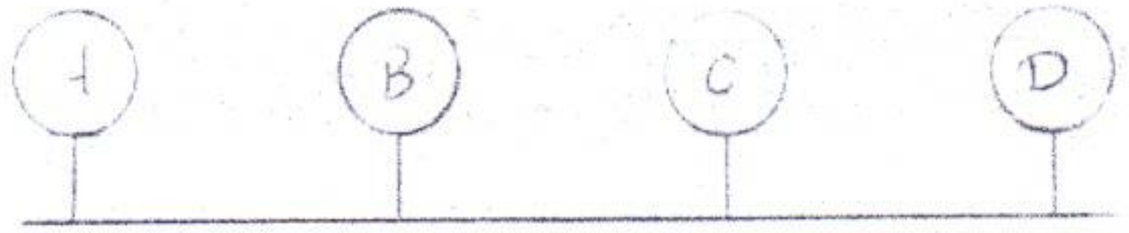


No. of Cables = $\frac{n(n-1)}{2}$

where n is number of devices .

4. Bus Topology :

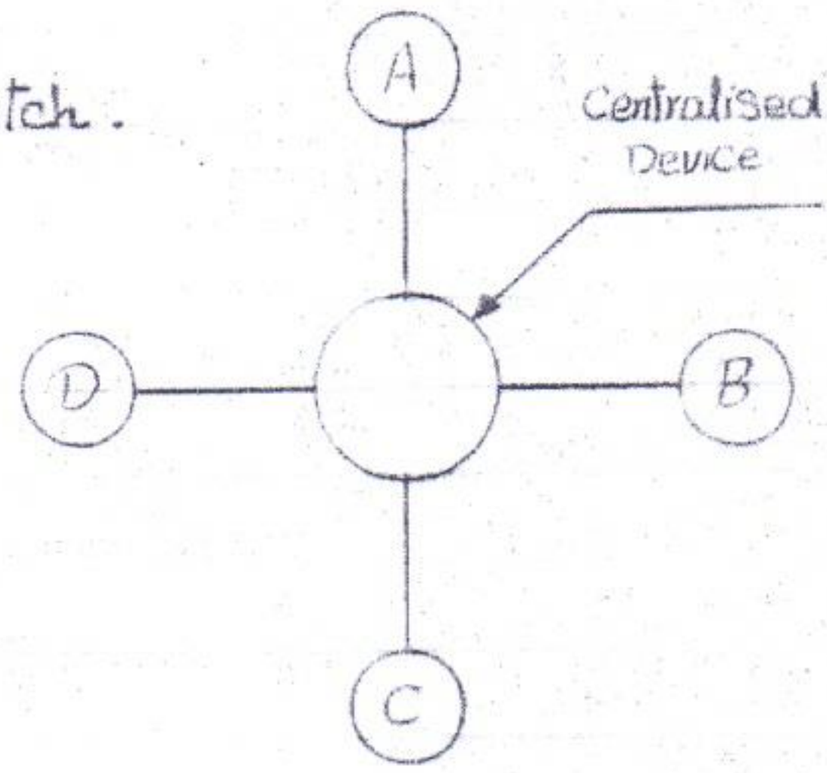
One send, all
receive .



Disadvantage : Interference or Collision .

5. Star Topology:

Centralised Device : Hub or switch.



Physical VS Logical topology:

Physical topology : Star 'is the best physical topology'.

Logical topology : Bus or Mesh.

Centralised Device : Hub or switch.

Network Types:

1. LAN - Local Area Network :

It is group of Components Connected together to provide a service. Under Control..

2. MAN - Metro Area Network :

It is group of LANs within Same City.

3. WAN - Wide Area Network :

It is groups of LANs between Cities, Contries & Continents.

It is group of LANs Connected through service provider.

The biggest WAN is Internet (Public WAN).

The second WAN is Orange (Private WAN).

But internet is public WAN, while there is another type of WAN called Private WAN 'HQ & Branches'. (Enterprise)

Session 2 Outlines :

- Last Session review.
- Network Models (OSI Model).

Session 2/1

LAN (Local Area Network)

Ethernet → 10 Mbps
Fast Ethernet → 100 Mbps
Giga Ethernet → 1000 Mbps = 1 Gbps
Ten Giga Ethernet → 10 Gbps
Hundered Giga Ethernet → 100 Gbps
Wi Fi (wireless ethernet)

] Signal begins to reduce speed after 100m

up to 7 Km

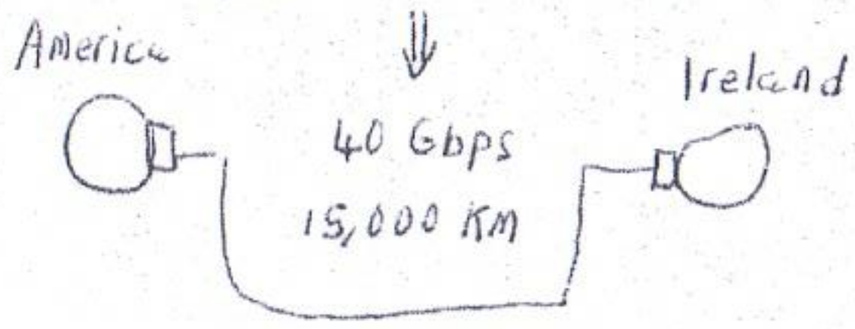
Ethernet Traditional technology for connecting wired LANs enabling devices to communicate each other via a protocol

DSL The way a computer connects to the Internet at high speed using telephone lines

WAN (Wide Area Network)

DSL (Digital Subscriber Line)
↓
Public Wan (Internet)

Private Wan
- X 25
- Frame Relay
- ATM Asynchronous Transfer Mode
- PPP
- HDLC - Cisco

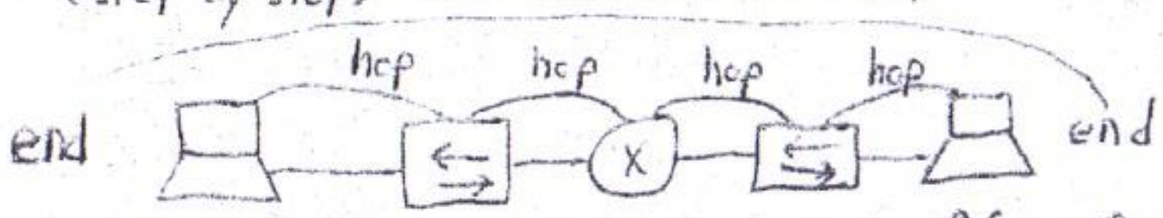


- MPLS

Session 2/2

Network Models

Group of concepts that will help a device to send data hop by hop (step by step) and then end to end.



OS = Operating System

OS

IOS

Internetwork Operating System

- Windows
- Unix
- Linux
- Macos
- ios
- Android

same network model to interconnect each other easily (OSI) / (TCP/IP)

Previously (DOD : Department of Defense)

(Commercial model) TCP/IP (Transmission Control Protocol) / (Internet Protocol)

Network model consists of layers

- What is a layer ?

It's a function that can be done either by software or hardware

S/w H/w

- Why layered ?

Functions are sequenced

OSI (Open System Interconnection) (reference model)

open standard : Public property for companies to interconnect

open source : able to modify & develop

Session 2/3

أول طبقة تستلم الشغل من الكمبيوتر
لتجهيزه يخرج برا الشبكة

OSI

تجهيز	7. Application
تكوين	6. Presentation
تنسيق	5. Session
	4. Transport
	3. Network
	2. Data Link
كابل	1. Physical

L7 : Application Layer

It's responsible for proper أنسب data preparation for the proper service.

Services	Protocol (Application)
Browsing	HTTP
File upload / download	FTP
send/retreive email	SMTP / POP 3
remote login	Telnet
real time (voice, video, gaming)	RTP (Real time Transfer protocol)

L6 : Presentation Layer

It's responsible for finding common data representation between sender & receiver

ex: ASCII → Text
Jpg, Gif, ... → Pic
Avi, mp4, ... → Video

} ones & zeros with its extension

Session 2/4

L5: Session Layer

It's responsible for making sure that all information required for session opening become ready, and in that case it will give orders for:

- Session Establishment
- Session Management & Control
- Session Termination

L4: Transport Layer

It's responsible for the actual mechanics for:

- Session Establishment
- Session Management & Control
- Session Termination

Ex: I want to send an email:

L7: Use SMTP (application) for email

L6: convert email's content to ones & zeros with extension

L5: CheckList [To, to sender @ _ . com (mailbox@postoffice.com), Subject, Mail body, Attachment Size]

Communication Method:

• LAN:

Ethernet	10 Mbps	
Fast ethernet	100 Mbps	
Giga ethernet	1000 Mbps = 1Gbps	100 meter
10 Giga ethernet	10 Gbps	
100 Giga ethernet	100 Gbps	

• WAN:

DSL
X.25
Frame Relay
ATH — Low Speed — High distance
PPP
HDLC
MPLS #

Network Model:

It is a group of concepts that will help the device to send data hop by hop & then end to end.

→ OS 'Operating System': Windows, Linux, Unix, MAC OS, Android, iOS.

→ IOS 'Internetwork Operating System': Intermediate device.

→ OSI 'Open System InterConnection': Network Model
Developed by ISO to TCP/IP Model

→ Network model is always layered.

What is a layer ?

A layer is a function that can be done either by SIW or HIW.

Why layered ?

These functions are sequential.

So Network Model : is group of functions that should be done in a certain sequence to help data reaches its final end.

OSI Model :

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data link
1	Physical

L7. Application Layer :

It is responsible for making the proper data preparation for the proper service.

ex: Browsing , File Upload / download , & Sending / retriving mail .

L6. Presentation Layer :

It is responsible for finding data representation between Sender & receiver.

ex: ASCII , JPG, Gif , MP3 , AVI & mpeg .

L5. Session Layer :

It is responsible for making sure that all information required for

Session opening become ready & in that case it will give order For :

* Session establishment.
* Session management.
* Session Termination.

Session 3 Out lines :

. Review on last Session.

. TCP/IP Model.

Session 3/1

OSI

تجهيز L7: Application — Browse, upload, download mailings (data only)

تكوين L6: Presentation

تقسيم L5: Session

TPO / TP1 L4: Transport — تقطيع & ترقيم & تعريف

L3: Network

كارت L2: Data Link

كابل L1: Physical

data: 10 110 110 110 0000

20 byte: ses. 1 | seq. 2 | data part — CRC

Header: session1 | seq. 1 | data part — CRC

IP packet: Source IP | Destination IP | Segment

Sr. MAC | Dst. MAC | Packet | crc — Header / Tail — Frame

TCP/IP

Application: HTTP, FTP, SMTP, PoP3, Telnet, RTP

Transport: TCP, UDP

Internet / Network: IP_4 / IP_6

Network Access: Ethernet, Wi-Fi

OSI model — TCP/IP model

L7, L6 & L5 ⟷ (data) ⟷ Application

L4 ⟷ Transport

L3 ⟷ Internet/Network

L1 & L2 ⟷ Network Access

L4: Transport Layer: Dividing data into smaller parts (Segmentation) تقطيع

each data part ≃ 1500 bytes

ترقيم (Addressing) < session no. → 1/1, 1/2, 1/3, 2/1, 2/2, 2/3

sequence no. →

last 1/3, 1/2, 1/1 data

last 2/3, 2/2, 2/1

Error Detection:

أميك 11110000 → 11110010 → X drop/discard — please, send again

error: noise, collision

Transport functions:

1- Segmentation

2- Addressing & Sequencing

3- Error Detection (CRC)

Header: seq. no. + se. no. + CRC | Data Part

Segment

Compress ← CRC (Cyclic Redundancy Check) تمويه

1500 data part + seq. no. + se. no.

↓

2 byte to small-sized part

أميك 11110000 — 1500 Bytes

CRC equation

sum of ones & zeros → CRC result → 4 — 2 Byte

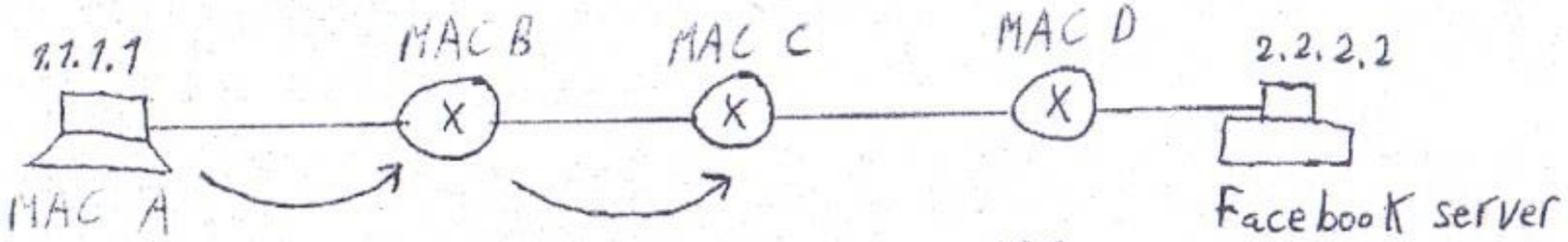
In TCP, Data resent 16 times in case there is error, otherwise it will not send

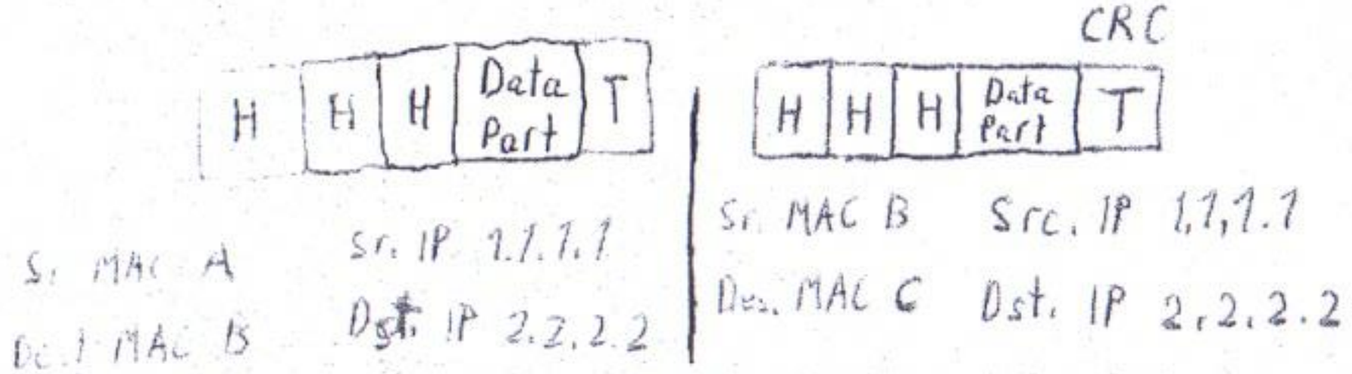
Maged Abd El-Wareth

Session 3/2

L3 : Network Layer End to end data delivery

IP Address = Final end address





(serial number)

MAC Address = next hop address

L4 : Data Part + H = Segment

L3 : Segment + H = Packet

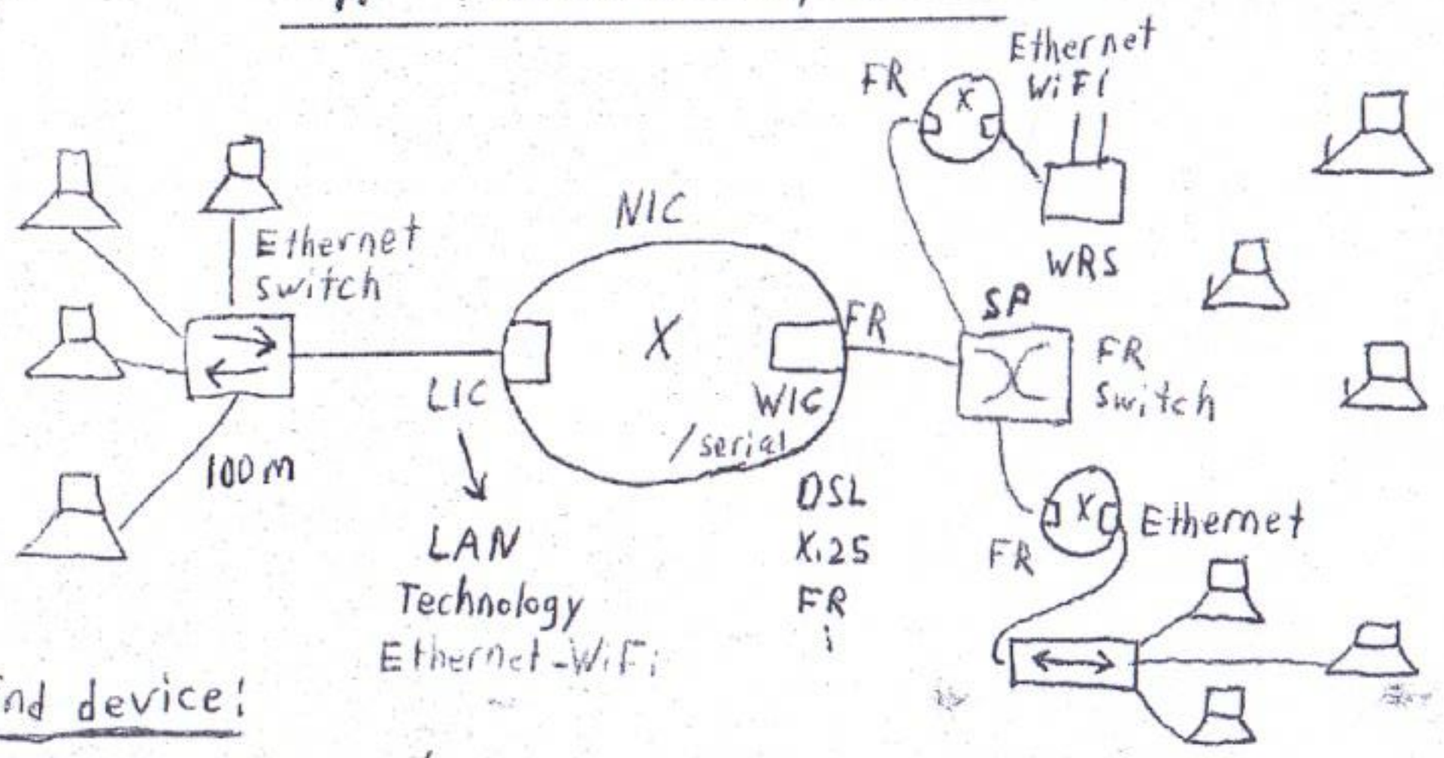
L2 : Packet + H = Frame

L3 : End , IP , Packet

L2 : Hop , MAC , Frame

Session 3/3

Typical Network Components



① End device:

The main component,
The source of network application,
It's Layer 7 device (Application Layer)

- We need Physical Topology
  → star Topology

② Hub:

- A centralised device used to provide physical star topology.
- It doesn't know neither final end (IP), nor next hop (MAC)
- It floods bits & Layer 1 device

③ Switch/Wireless Switch (wireless access point)

- A centralised device that can provide physical star topology
- It doesn't know final end (IP), but knows next hop (MAC)
- It's a Layer 2 (Data Link Layer) / Network Access Layer

* All ports on a switch by H/W can support only single communication technology.

Communication Technology

- LAN
  - Ethernet
  - Fast Ethernet
  - ⋮
  - 100 G Ethernet
  - Wi-Fi

  } 100 m

  Same technology

  Switch: Ethernet & Wi-Fi

- WAN
  - Km
    - DSL
    - X.25
    - FR
    - PPP
    - ATM
  - HDLC

  Different technologies

  DSL Switch / FR Switch / PPP switch

Session 3/3

[4] Router!

It's a device that support by S/W different communication technology.
(Technology Converter) Ethernet → DSL
ATM → PPP

It understands both final end (IP) and next hop (MAC)

It's a Layer 3 / (Internet device)

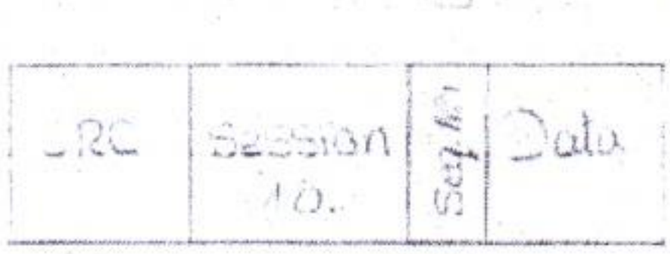
OSI Model VS TCP/IP Model :

<table>
<tr><td>7. Application</td><td rowspan="2">Data</td><td rowspan="2">HTTP , FTP, Telnet, SMTP, POP3, RTP</td><td rowspan="2">Application</td></tr>
<tr><td>6. Presentation</td></tr>
<tr><td>5. Session</td><td></td><td></td><td></td></tr>
<tr><td>4. Transport</td><td>Segments</td><td>TCP , UDP</td><td>Transport</td></tr>
<tr><td>3. Network</td><td>Packets</td><td>IPV4 , IPV6</td><td>Network</td></tr>
<tr><td>2. Data link</td><td>Frames</td><td rowspan="2"></td><td rowspan="2">Network Access</td></tr>
<tr><td>1. Physical</td><td>Bits</td></tr>
<tr><td>OSI Model</td><td>Protocal data Unit (PDU)</td><td></td><td>TCP/IP Model</td></tr>
</table>

Transport Layer :

It is responsible For

* Segmentation. Size : 1500 byte .
* Sequencing & addressing.
* Error detection using CRC (Cyclic Redundacy Check). 2byte



=> Segments

H_1 = 20 byte

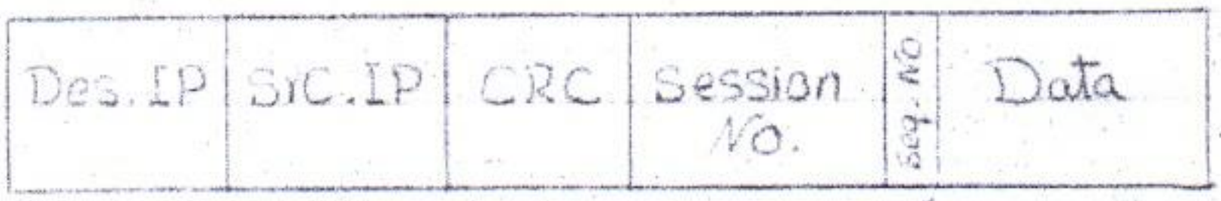
Segmentation : Dividing data into smaller parts .

Addressing : Giving data parts Serial Number.

Network or Internet Layer :

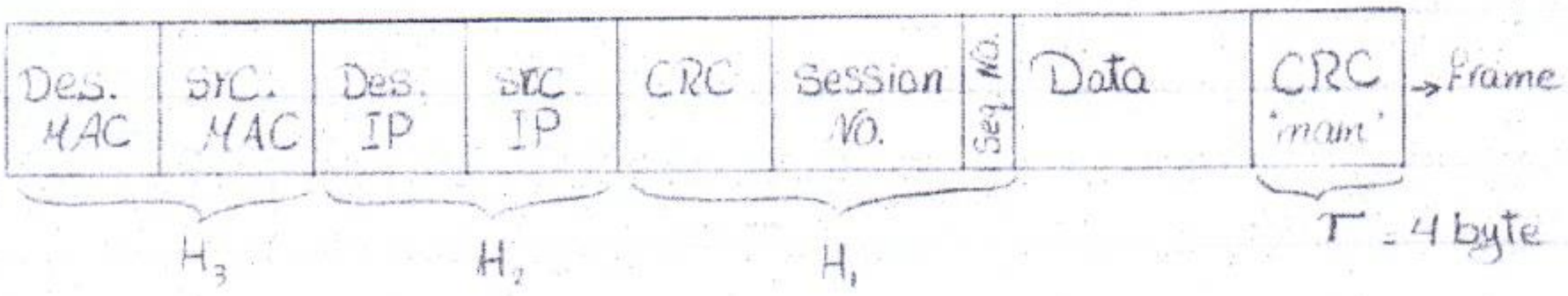
It is responsible For Add

* Source IP.
* Destination IP.



Network Access Layer :

* It is responsible For hop-to-hop Transmission & Control.



Final Note :

L3 = Packet = IP Address = final end.

L2 = Frame = MAC Address = Next hop.

Encapsulation —

- Data
- ↓ Segment
- ↓ packet
- ↓ Frame
- ↓ Bits

Typical Network Model & Components :

1. End Device :

It is the source of Application. It is Layer 7 or Application Layer.

2. Intermediate devices :

* Hub :

It is used as a Centralised device to provide physical star topology. It doesn't Know neither Final end (IP) nor next hop (MAC) It Floods bits. It is Layer 1 device. Used on LAN only.

→ Send bits out of all ports except the receiving port.

* Switch:

It is used as a Centralised device to provide physical star topology. It doesn't Know Final end (IP) but it understands next hop (MAC). It is Layer 2 device or Network Access Layer device. It is Called wireless Switch or wireless Access point also.

⇒ It is by Hardware supports Single Communication Topology :

→ LAN: Ethernet, WiFi.

→ WAN: DSL, X.25, ATM, Frame Relay, ISDN.

Network Card types :

- NIC : Network Interface Card
- LIC : LAN Interface Card
- WIC : WAN Interface Card.

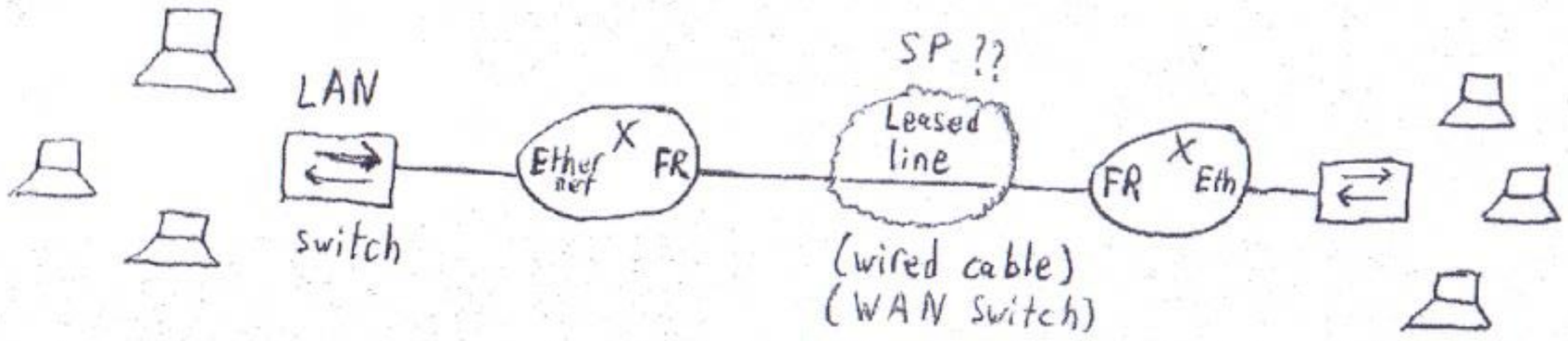
Session 4 outlines :

- Typical network model & Components .

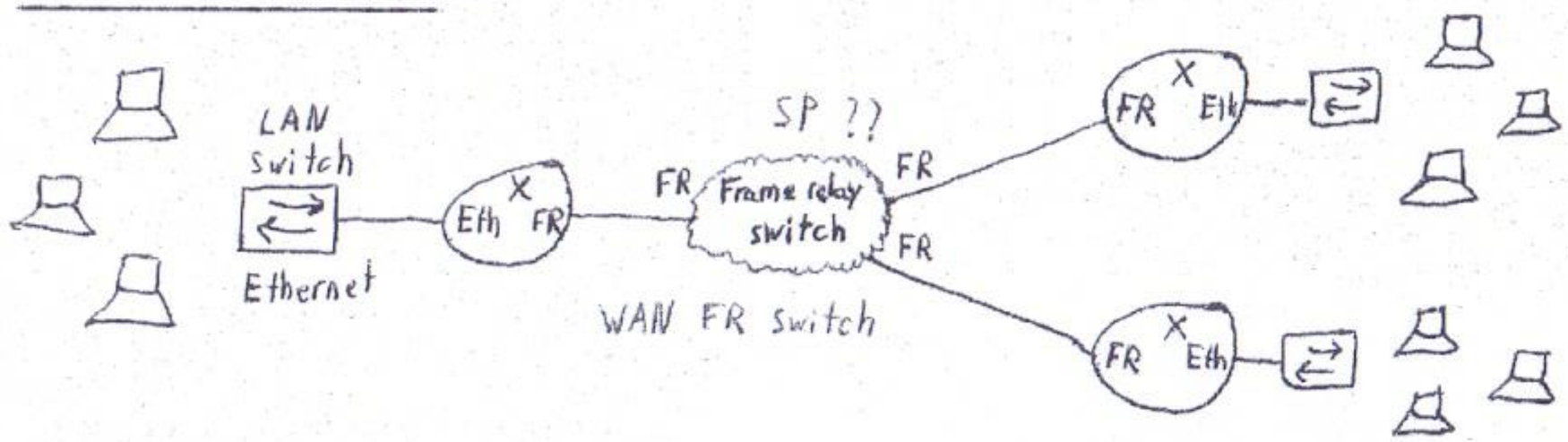
Session 4/1

For the shown networks, find the most proper missing network component:

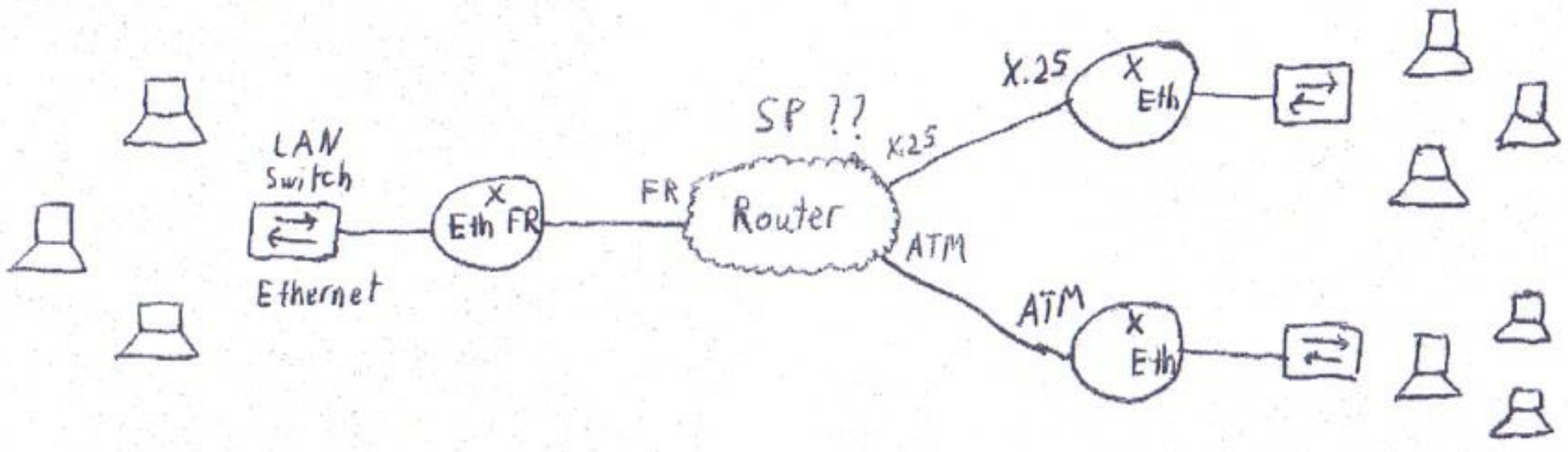
Ex 1: Two LANs only



Ex 2: Three LANs (Same tech.)



Ex 3: Three LANs (Different tech.)



L1: Hub — No IP (L.3), No MAC (L.2)

↓

used in LAN only

L2: switch — No IP (L.3), Yes MAC (L.2)

Fast & Lower cost by (H/w)

- LAN Switch: NIC = LIC = Ethernet, short distance
- WAN Switch: WIC - serial, DSL switch - Frame Relay switch (long distance)

L3: Router (gateway) — Yes IP (L.3), Yes MAC (L.2)

- Different communication technology

LIC - NIC (Ethernet) — WIC (DSL - X.25 - FR - PPP - ...)

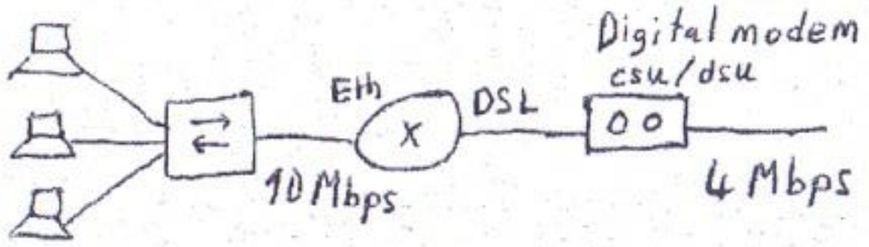
* slower by S/W & higher cost

Session 4/2

Digital modem : (Modulator / De-Modulator)

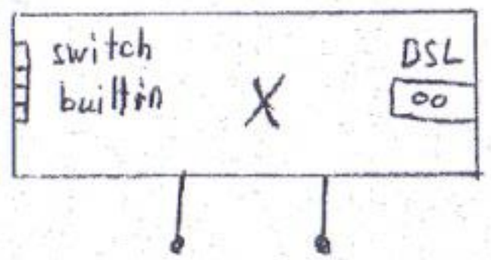
CSU/DSU (channelised service unit / data service unit)

- Provides clocking & Synchronization ضبط السرعة

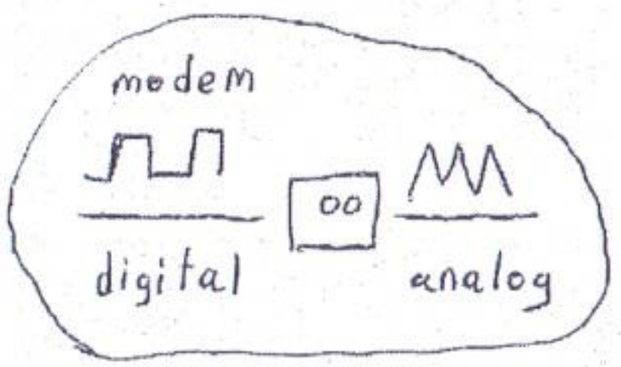


is set after the router

Home Device



Wireless Access Point



modem : analog

DSU/CSU : pure digital (digital modem)

Network Component Classification

DTE (Data Terminal Equipment)	DCE (Data Communication Equipment)
It's a device that can either be source or destination for data & information	A device that can either be:
الشغل: Browsing, download, voice, mail	• Providing Physical topology (star) (or) • Providing clocking & Synchronization
ضبط الشغل: Routers signaling for (Routing Tables)	
* It's a Layer 3 or more	* It's a Layer 2/1
* It understands IP	
Ex : End devices, Router	Ex : Hub, Switch, WRS CSU/DSU (digital modem)

Maged Abd El-Wareth

Session 4/3

(Protocol Data Unit)

Layer 1 : Physical Layer PDU "bits"

LAN Physical Layer

- Cables
- Cards' Standards
- Connectors
- L1 Devices

Protocol Data Unit (PDU)

Data

Segment | H | Data

Packet | H | Segment

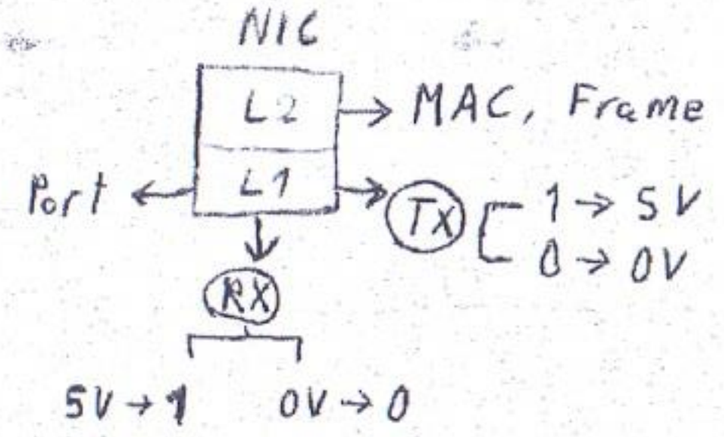
Frame | H | Packet | T

Bits

TCP/IP		OSI
Application		L7: Application
		L6: Presentation
		L5: Session
Transport		L4: Transport
Internet / Network		L3: Network
Network Access		L2: Data link
		L1: Physical

TX: Transmitter

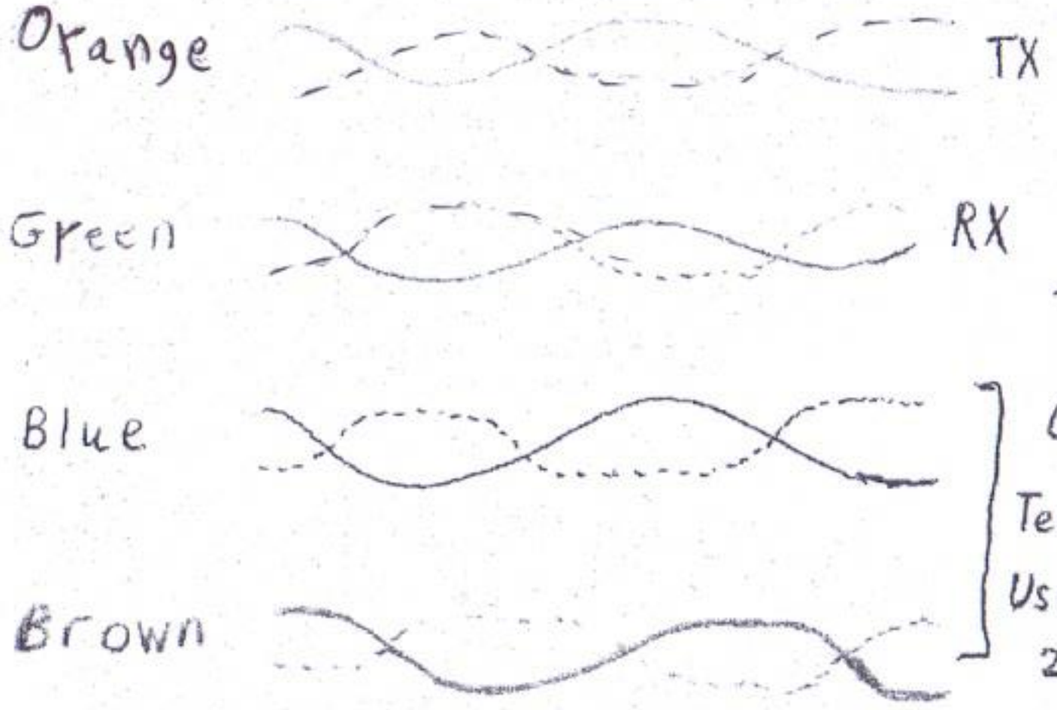
RX: Receiver



[1] LAN Cables : Ethernet Cables

(A.) UTP : Unshielded Twisted Pair

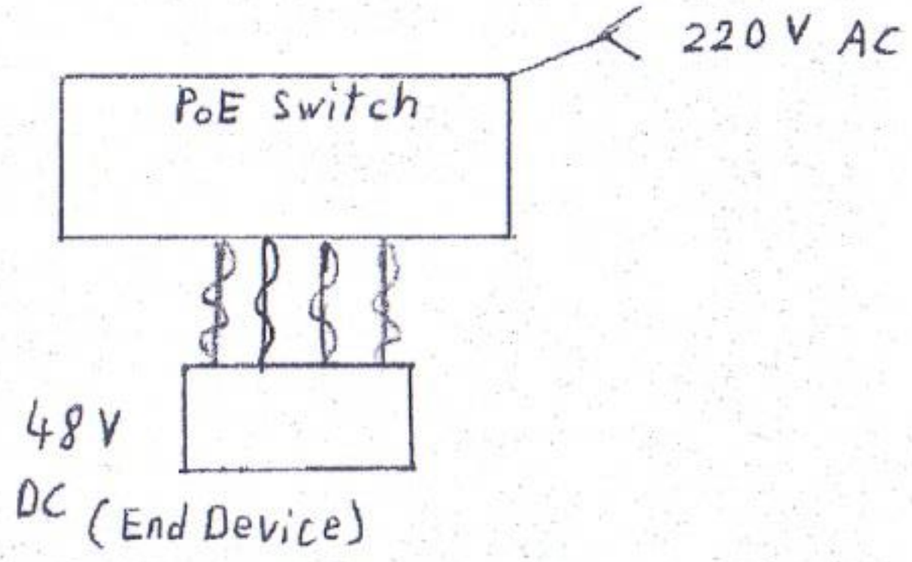
8 Copper wires (4 pairs)



PoE (Power over Ethernet)

orange TX — Ethernet — blue +

green RX — Ethernet — brown −



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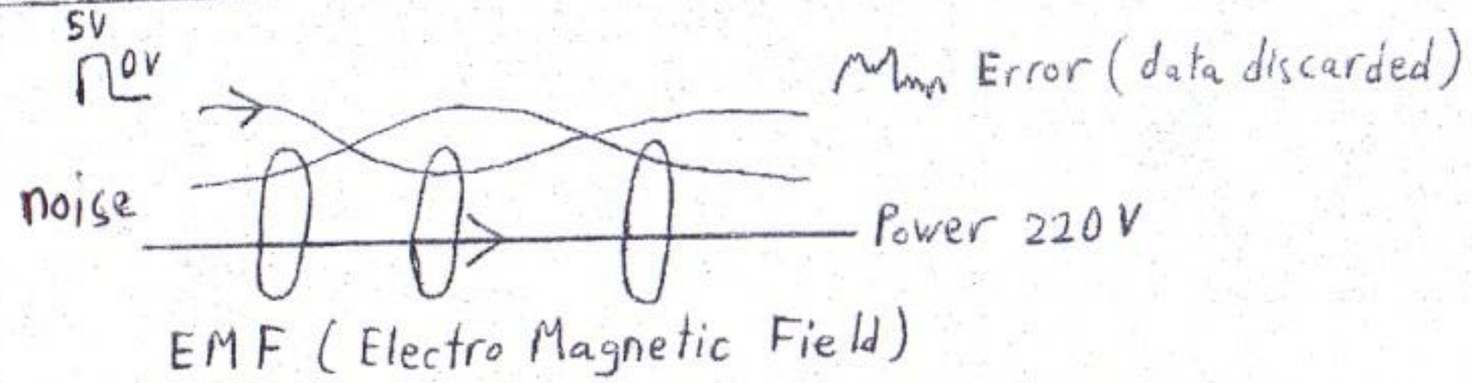
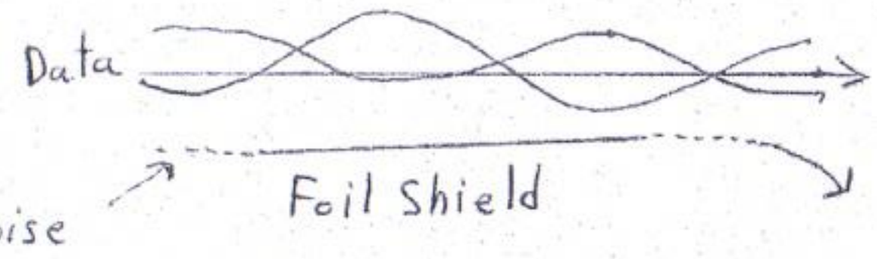
(UTP)

Disadvantage: unshielded, vulnerable to noise

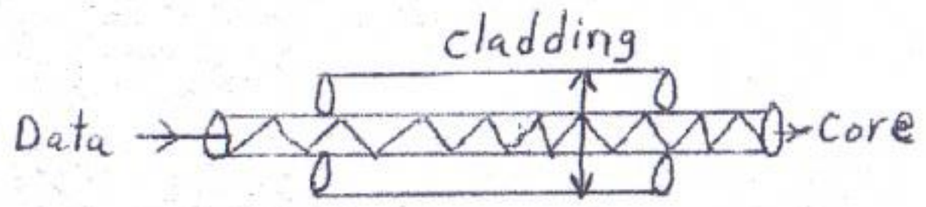


(B.) STP: Shielded Twisted Pair

immune against Interference



(C.) Fiber: consists of glass/plastic components



1 = high light intensity

0 = low light intensity

Advantages

- Longer distances 100 Km
- Higher speeds 100 Gbps
- Immune against EMI (Electromagnetic Interference)

* Router:

Mixed technology. It is by software supporting different Communication technology. It is understands final end (IP) and next hop (MAC). It is Layer 3 device or Network/ Internet Layer device.

* Digital Modem:

It is used for Clocking & Synchronization. It is Layer 1 device. CSU (Channalized service Unit) / DSU (Data Service Unit).

Hub	Switch	Router
Layer 1	Layer 2 (LAN / WAN)	Layer 3
Low Cost	Low Cost	High Cost / High Cost
Very Fast	High Speed	Low Speed / Low Speed

All devices are classified:

Data Communication Equipment: DCE

It is a device that can either be supporting star topology or supporting clocking & Synchronization. It is layer 2 or 1.
ex: Hub, Switch, Wireless Access Point, Digital Modem.

Data Terminal Equipment: DTE

It is a device that can either be source or destination for data & information. It is at least layer 3. ex: End device, Router.

Session 5 outlines :

Physical Layer

- Cables.
- Standards (Card type).
- Connectors.

Session 5/1

LAN cables (Ethernet cables)

A. UTP
B. STP
] Copper cables, Electrical signals

* Twisted Pair Categories:

- Cat 3 → 8 Mbps (used in WAN only) — not used in LAN
- Cat 5 → 100 Mbps
- Cat 5e (enhanced) → 1 Gbps (copper more effecient and pured)
- Cat 6 → 4 Gbps
- Cat 6a/6e → 10 Gbps a: advanced
- Cat 7 → 40 Gbps

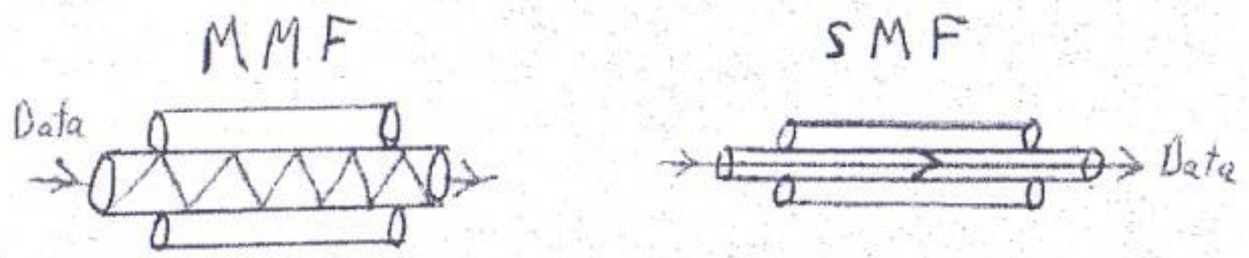
100 m

Disadvantage: Ethernet with these cables 100 m

* Fiber Cable Categories:

- MMF - Multi Mode Fiber
- MMF 62.5/125 → core: 62.5 micro meter & 400 m, cladding: 125 mm & 100 Gbps
- MMF 50/125 → core: 50 mm & 2 - 4 Km, cladding: 125 mm & 100 Gbps

- Single Mode Fiber
- SMF 9/125 → core: 9 mm & 10 Km, cladding: 125 mm & 100Gbps
- SMF 8/125 → core: 8 mm & 100 Km, cladding: 125 mm & 100 Gbps



Bigger Core (62.5/125 - 50/125)

Smaller Core (9/125 - 8/125)

(2) LAN Cards Standards : Ethernet cards (NIC = LIC)

IEEE 802.(3) related to Ethernet

802: 1980 Feb

3: T : Twisted Pair < UTP / STP

- 10 Base T → 10 Mbps
- 100 Base T → 100 Mbps
- 1000 Base T → 1 Gbps
- 10 G Base T → 10 Gbps

Base : Base banned (no modulation)
no modifications in signals

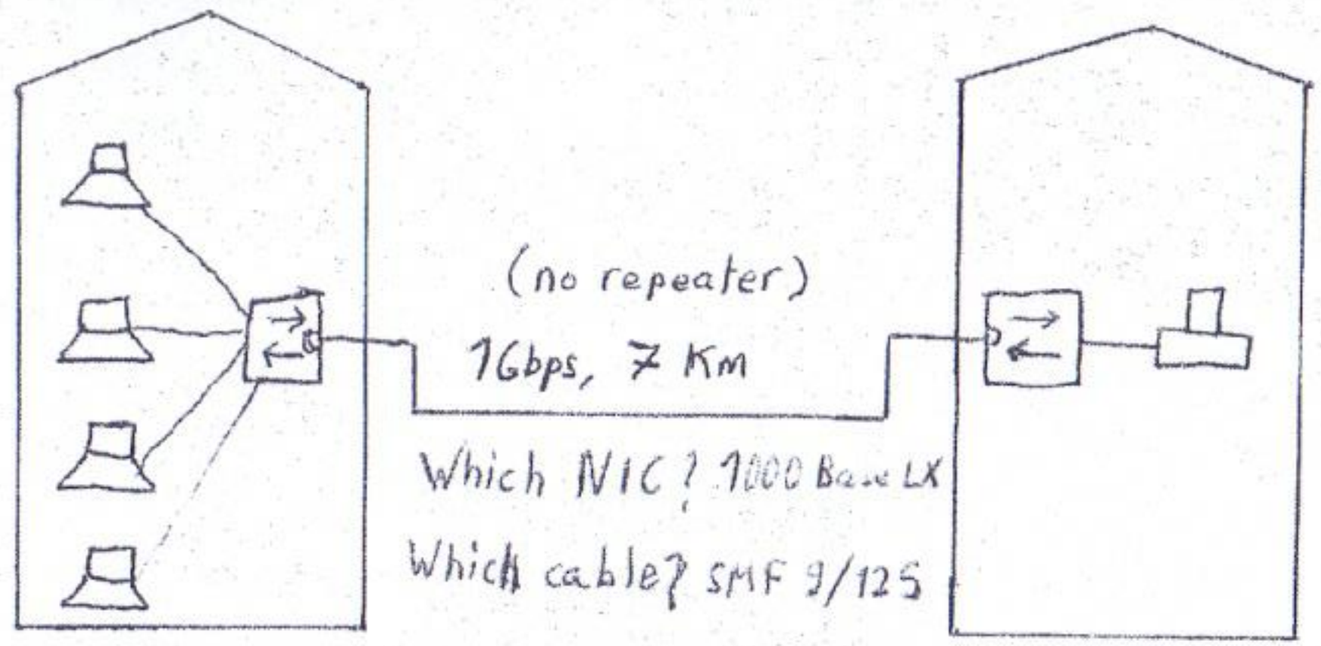
in LANs
* CSU/DSU is not used

- 10 Base T → starting Cat 5
- 100 Base T → starting Cat 5
- 1000 Base T → starting Cat 5e
- 10 G Base T → starting Cat 6a / 6e

(Fiber) 10 Base F – 100 Base F

- 1000 Base SX → short distance, 400m (MMF 62.5/125) — 4 Km (MMF 50/125)
  1000 Base LX → long distance, 10 Km SMF 9/125
  1000 Base ZX → extra long distance, 100 KM SMF 8/125
- 10 G Base SX
  10 G Base Lx
  10 G Base ZX
- 100 G Base SX
  100 G Base LX
  100 G Base ZX

Ex!



3 LAN Connectors:

* Fiber Connector

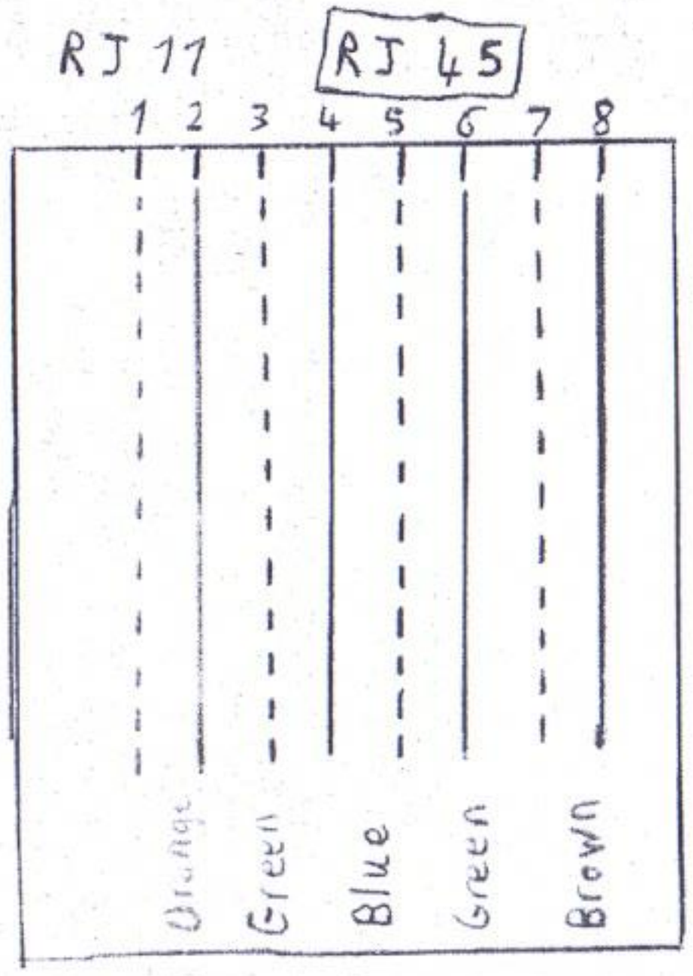
SC = Square Connector
ST = Straight Tip Connector

* Copper Connector

DB = D-shaped 

DB - 60 (60 pins)
DB - 21
DB - 15
DB - 9
DB - 8

* RJ (Registered Jack)



IEEE Colour Coding Standard:

- T 568 B (B-Standard)

Pin 1, 2 Orange TX
Pin 3, 6 Green RX

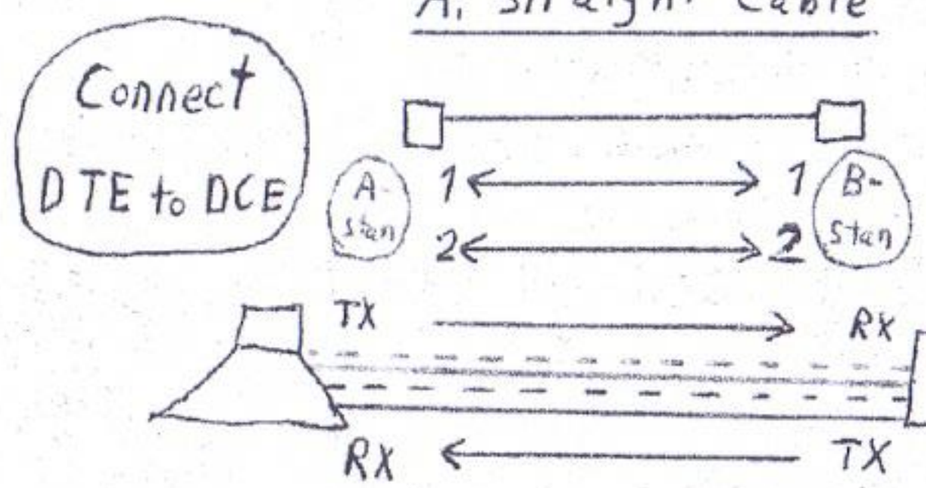
- T 568 A (A-Standard)

Pin 1, 2 Green TX
Pin 3, 6 Orange RX

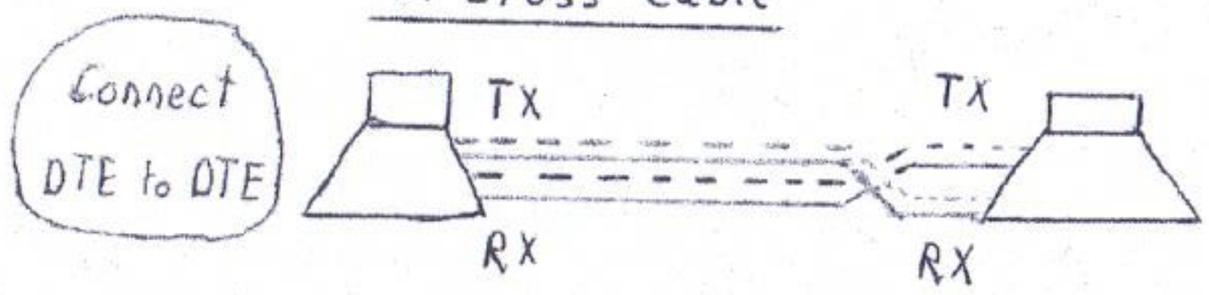
Connection Types:

LAN DTE	LAN DCE
End device, Router	Hub, Switch
TX : Pin 1, 2	TX : Pin 3, 6
RX : Pin 3, 6	RX : Pin 1, 2

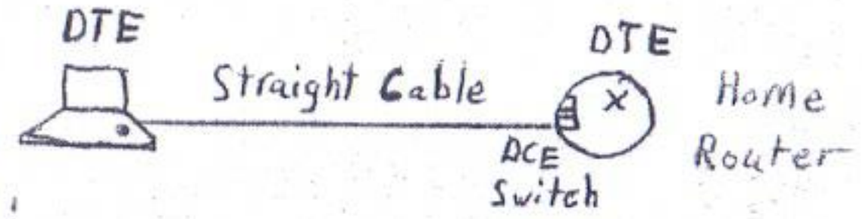
A. Straight Cable



B. Cross Cable

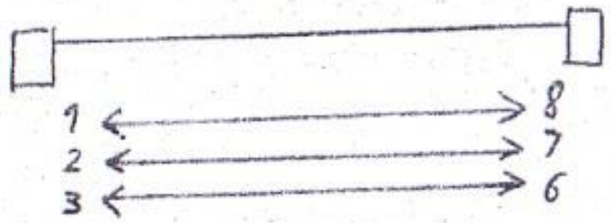


Special Case:



* There is an Internal circuit (IC) in the LIC:
Auto-Sensing (MDI/MDIX): Converter
Medium Dependant Interface Cross

C. Rollover Cable

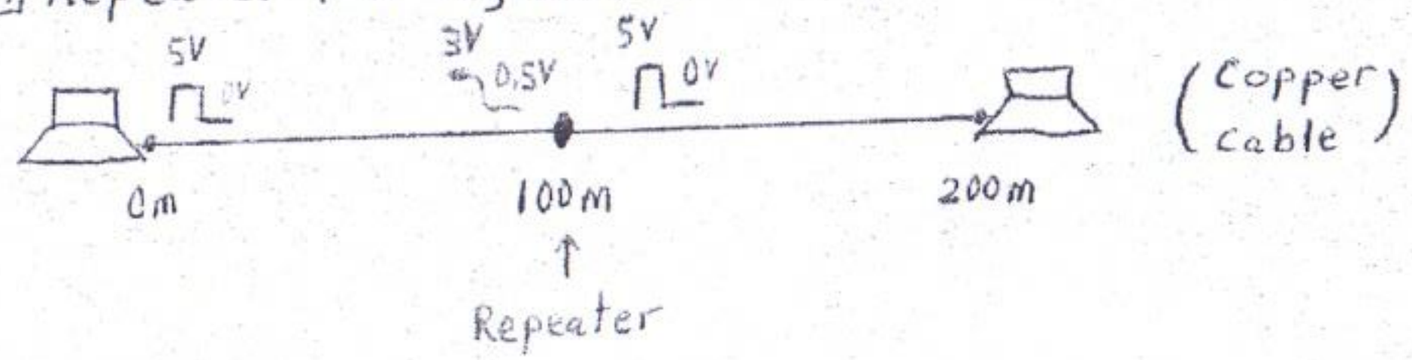


used for console port (Configuration port) in < switch / router

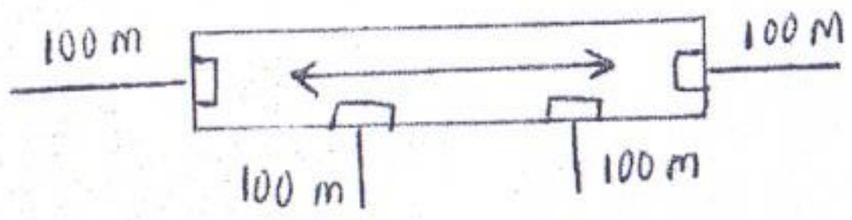
Computer to Switch/Router to configure them

4 Layer 1 Devices:

A. Repeater : It regenerates the signal



B. Hub : It's a multiport repeater

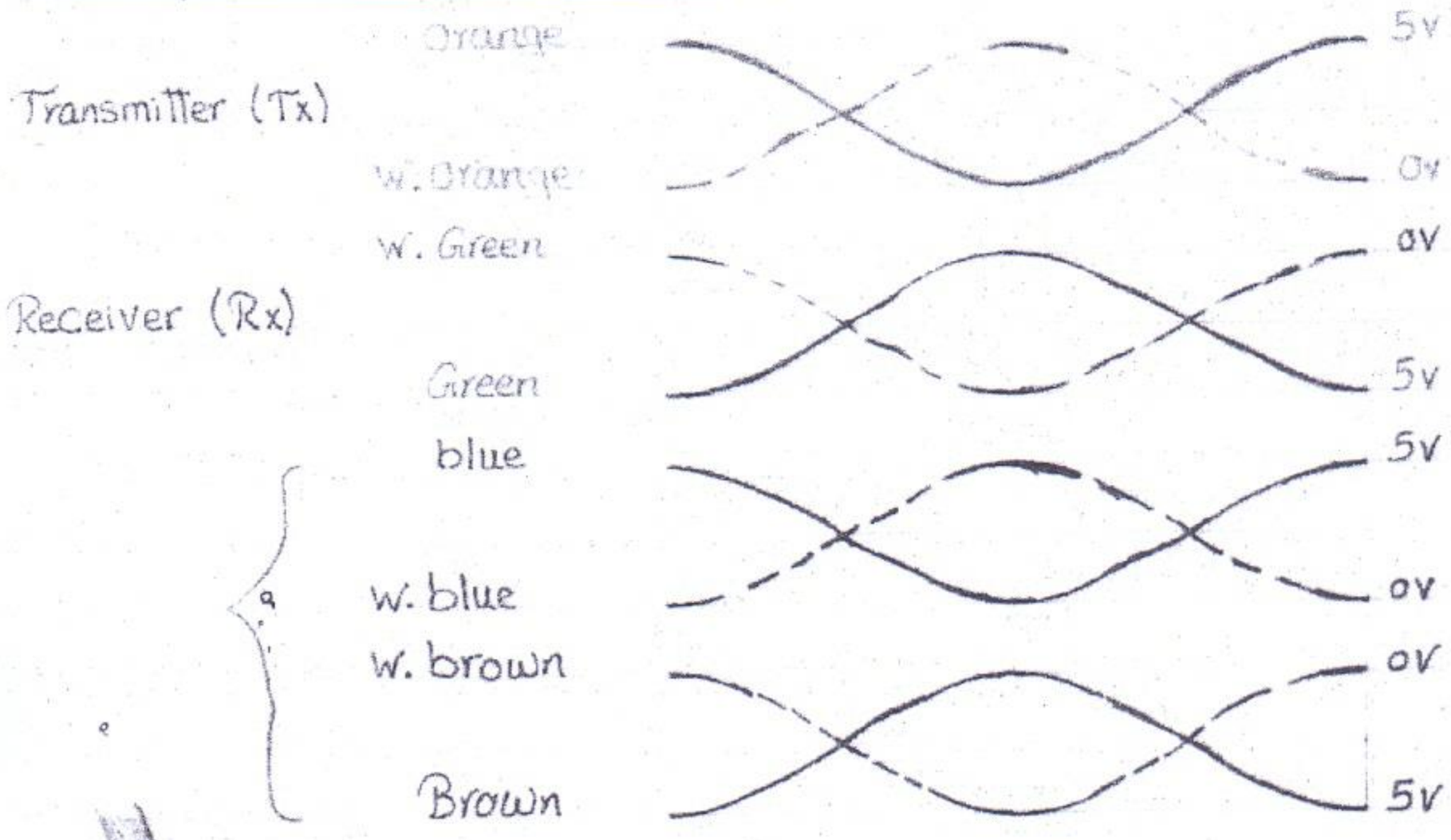


Disadvantage : It floods bits (Sending bits/data out of all ports except receiving port)

Physical Layer:

1. LAN Cables or Ethernet Cables :

- **UTP (Unshielded Twisted Pair) :**



Spare on ethernet and Fast ethernet cables.

Used on Giga ethernet and 10 Giga ethernet cables.
POE (Power Over Ethernet).

- **STP (Shielded Twisted Pair):**

It is the same UTP but more protection.

※ Twisted Pair Categories :

Type	Speed	Distance
Cat 3	3Mbps	
Cat 5	100 Mbps	
Cat 5e	1000 Mbps	100 meter
Cat 6	4 Gbps	
Cat 6A/Cat 6E	10 Gbps	
Cat 7	40 Gbps	

- Fiber :

It is better than Copper on longer distance, higher speed and immune against EMI (electro magnetic interference).

※ Fiber Categories :

	Multi Mode Fiber (MMF)		Single Mode Fiber(SMF)	
Cladding Diameter	125 μm	125 μm	125 μm	125 μm
Core Diameter	625 μm	50 μm	9 μm	8 μm
Distance	400 m	4 Km	10 Km	100 Km
Speed	100 Gbps	100 Gbps	100 Gbps	100 Gbps

2. LAN Standards :

IEEE 802.3 ≡ 1980 Feb. Ethernet

- Types of NICs :

Type	Speed	Distance	Cable	
10 Base T	10 Mbps			
100 Base T	100 Mbps	100 meter	Copper (Twisted Pair)	Baseband = No modulation = No need for modem
1000 Base T	1 Gbps			
10G Base T	10 Gbps			
10 Base F	10 Mbps			
100 Base F	100 Mbps			
1000 Base SX	1Gbps			
10G Base SX	10 Gbps	400m : 4Km	Fiber (MMF)	
100G Base SX	100 Gbps			

Type	Speed	Distance	Cable
1000 Base LX 10G Base LX 100G Base LX	1 Gbps 10 Gbps 100 Gbps	10 Km	Fiber SMF 9
1000 Base ZX 10G Base ZX 100G Base ZX	1Gbps 10 Gbps 100 Gbps	100 Km	Fiber SMF 8

3. LAN Connectors :

- Fiber Connectors :
  - : ST = Straight Tip .
  - . SC = Square Connector .

- Copper Connectors :
  - . DB = D-Shaped .(DB-60) . No. of pins.
  - . RJ = Register Jack (RJ-45).

Physical Layer:

Colour Coding Standard:

- Standard T568B (Standard B):

Pin 1,2 Orange.		End device
Pin 3,6 Green.	like	Router

- Standard T568A (Standard A):

Pin 1,2 Green.		Hub
Pin 3,6 Orange.	like	Switch

Cables:

1. Straight Cable:

Connect DTE to DCE. Two terminal is the same standard.

2. Cross Cable:

Connect two DTEs or two DCEs. Different standard in 2 terminal.

3. Roll over Cable:

Used for Configuration only "Console cable". Terminals is reverse.

⇒ Auto Sensing IC: MDI / MDIX

... Media Dependent Interface / Media Dependent Interface Cross ...

4. LAN Physical Layer devices:

1. Repeater:

Regenerates the signal. But Many repeaters add delay "latency" and Collision.

2. Hub:

It is multi-port repeater. It floods bits. All devices on a hub should work in half duplex. Can either Tx or Rx at the same time.

Session 6 Outlines :

. Physical Layer :
    * Connectors (review).
    * Layer 1 devices.

. Data Link layer:
    * MAC Address.
    * MAC Frame.

Session 7 Outlines:

. Layer 2 devices:

* Bridge.
* Switch: (Switching Operation)
  . Learning.
  . Forwarding.

Session 6/1

L2: Data Link Layer (Network Access Layer)

LAN

MAC Address | MAC Frame | L2 Devices

L2: It's responsible for hop to hop data delivery

[1] MAC Address Media Access Control, used to send data

- It's a 48 bit address burnt on ROM of NIC (hardware address / physical address)
- It is used to send data hop to hop
- It is represented in Hexadecimal (0, 1, 2, ... 9, A, B, C, D, E, F)
  10 11 12 13 14 15

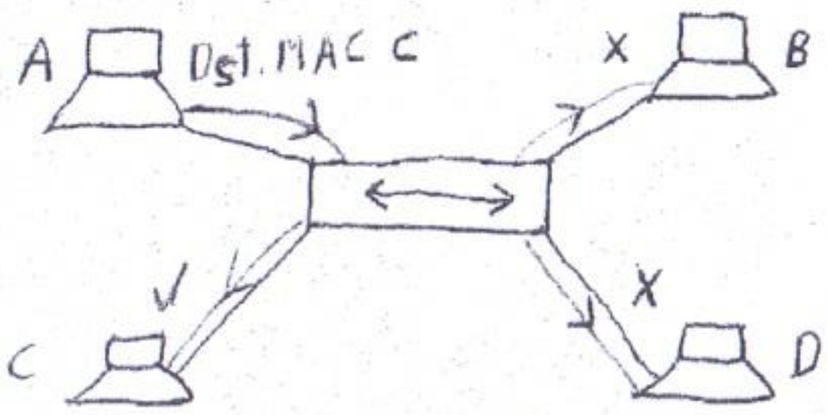
1 Hexa = 4 bit
12 Hexa = 48 bit
6 Hexa = 24 bit

6 Hexa: 0 1 C 2 3 D — Vendor Part
6 Hexa: 1 2 5 F 3 C — Host Part (DTE)

* OUI: Organization Unique Identifier

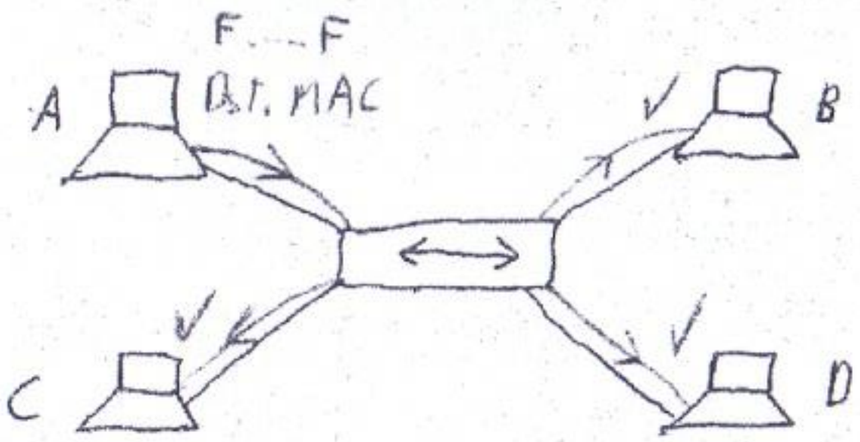
- Types of Destination MAC (Next hop MAC)

[1] Unicast MAC: one send & only one process (one receive)



[2] Broadcast MAC: FFFFFF FFFFFF

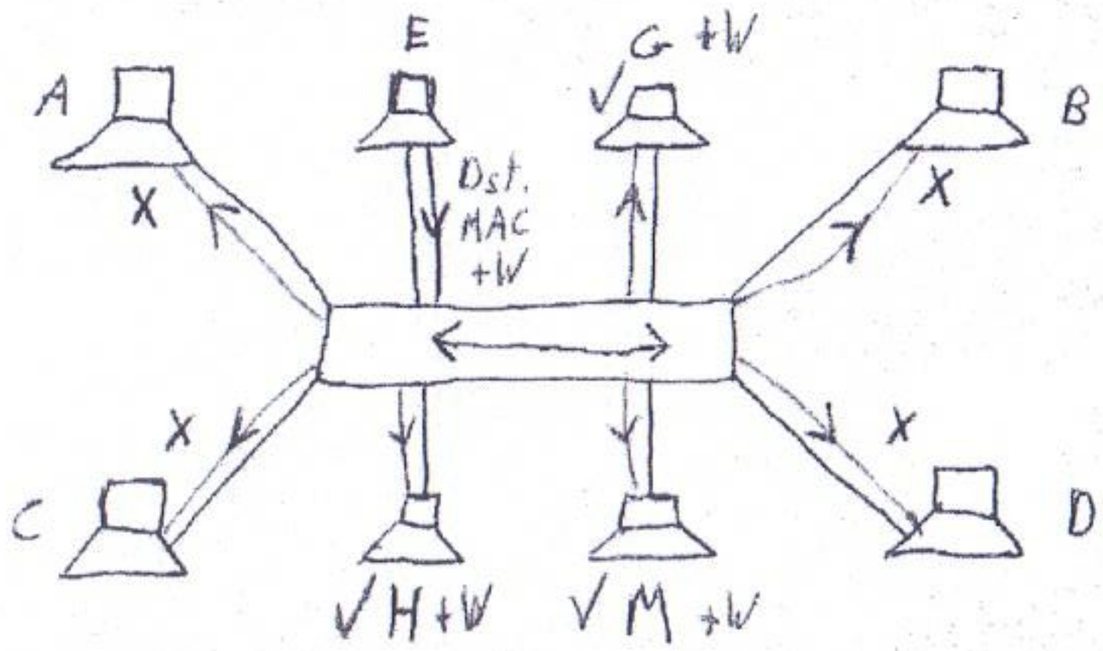
one send & all process (all receive)



Flood: Data sent to all devices, one receives it.
Broadcast: Data sent to all devices, all receive it.

[3] Multicast MAC: one send & group process

No. of devices must have an application to connect to each other (send & receive data) through the application's MAC address.



Session 6/2

(2) MAC Frame — Hop to hop frame

8 byte	6 byte	6 byte	2 byte	46 - 1500 byte	2 byte
Pre-amble	Destination MAC	Source MAC	Type	Packet	T CRC (FCS)

Pre-amble ↓ Bits: 10101011
- Pre-communication (preparing for sending data)
- Auto clocking & Synchronization (data speed control)

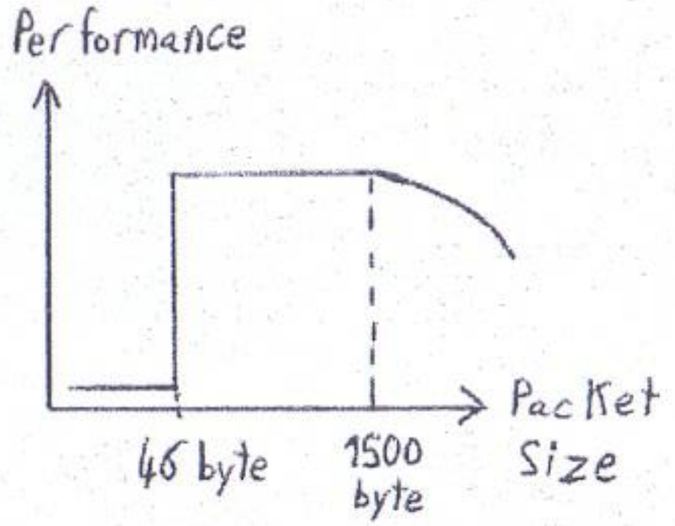
- Dst. MAC : Unicast - Broadcast - Multicast MAC
- Type of Packet : 4 → IP_{V4} | IPX
  41 → IP_{V6} | AppleTalk

CRC → FCS (Frame Check Sequence)
Refers to bits & information added to data packets for error detection & control.

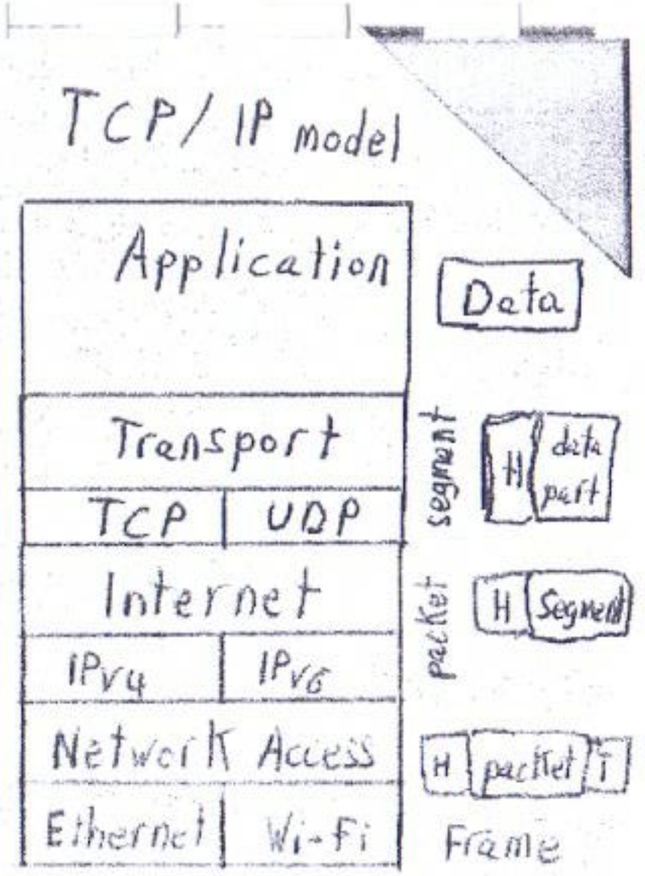
* Pre-amble is added to the 1st frame only.

- NIC takes an Idle Time (8 byte = 64 bit) between two frames.

Dest. MAC	Source MAC	Type	Packet	T	Idle Time	Pre-amble	Dst. MAC	Sr. MAC	Type	Packet	T
2nd Frame						1st Frame					



MAX Transfer Unit (MTU) = MAX packet size



Frame Size = H + T + Packet
Min. size Frame = 14 + 4 + 46 = 64 byte
Max. size Frame = 14 + 4 + 1500 = 1518 byte

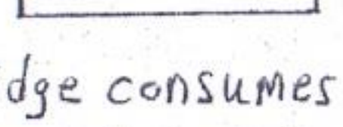
Session 6/3

3 L2 Devices

It is a device that understands MAC < Address / Frame

A. NIC: Network Interface Card
It has MAC

B. Bridge: It operates by S/W (Program + CPU)
by slow

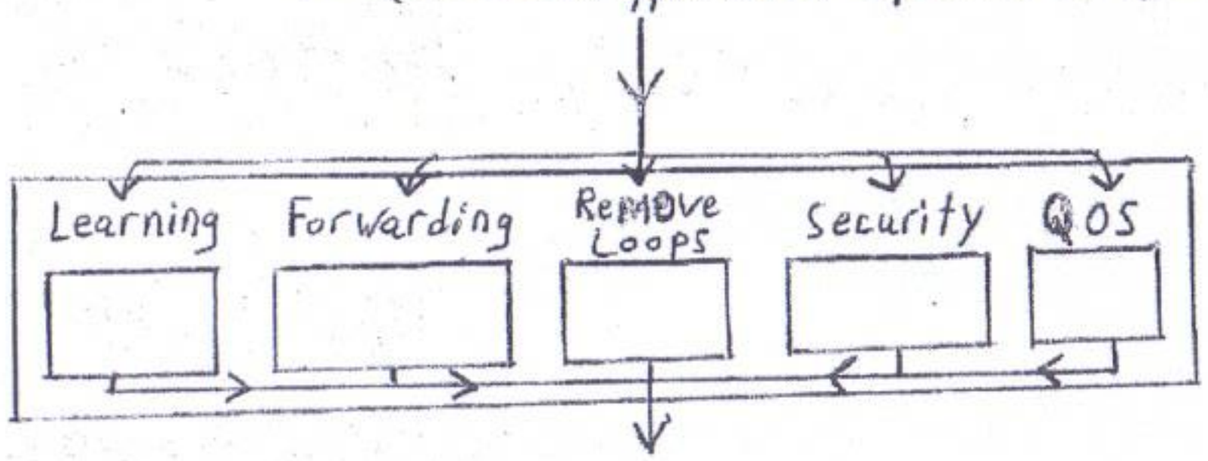


maximum no of ports = 16

* The bridge consumes its program & cpu's usage to transmit the data.

Disadv.: The more the ports are used (program+CPU) to transmit data, the slower the bridge will operate.

C. Switch: It's a multiport bridge, it operates by H/W (ASIC: Application Specific Integrated Circuit)



Security (MAC Filter)

QOS (Quality of Service)

* The switch has 5 ASICs, each one has its own function

* When the data is transmitted to the switch, the switch copies the data to the all ASICs in parallel.

- ASIC's speed = wire speed

Cisco Catalyst 6513	576 ports 720 Gbps 1.4 Tbps
Juniper 8208 8216	768 ports 6 Tbps 12 Tbps
Cisco Nexus 9500	4096 ports 15 Tbps - 30 Tb - 60 Tbps

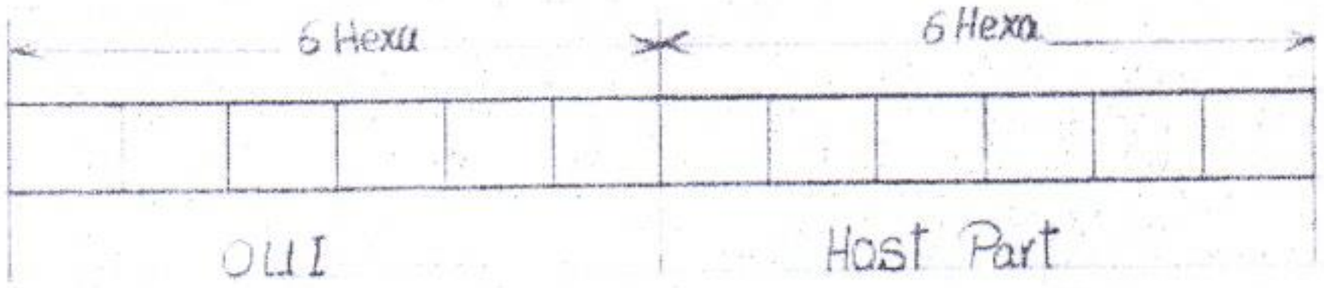
Layer 2 Data Link Layer :

It is responsible for hop-to-hop data delivery & Control.

PDU: Frame.

MAC Address :

Media Access Control, It is 48 bit address burnt on ROM of DTE NIC. It is represented in Hexadecimal. It is called also Hardware Address or Physical Address.



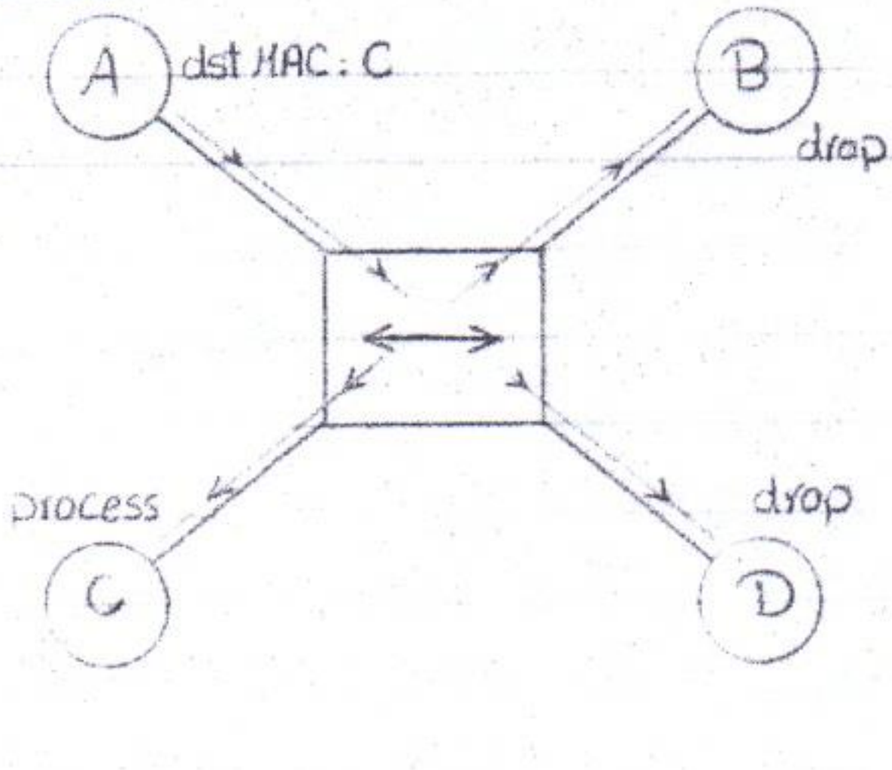
Organization Unique ID
"Vendor Part"

Types of destination MAC:

1. UniCast :

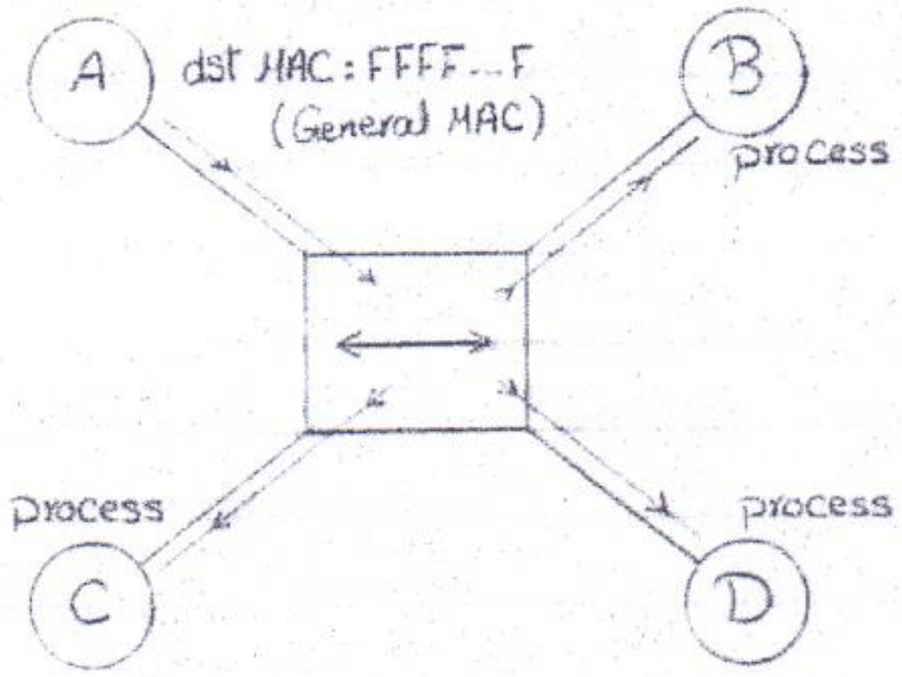
One send & only one process.

- Hub make flood Process بدون إجبار على



2. Broad Cast :

One Send & all process .



إجبار على process

3. Multi Cast :

One Send & group process .

ex: online games - Every device Connect to game server take new MAC like "0100 5e xxxxxx"

MAC Frame :

Pre-amble 8-byte	DST. MAC 6-byte	SRC. MAC 6-byte	Type 2-byte	Packet 46 : 1500 byte "MTU"	CRC 4-byte

- Pre-amble: Training bits. Auto Clocking & Synchronization.
- DST. MAC: UniCast. Broad Cast. Multi Cast.
- Type: Type of next protocol.
- CRC: Frame Check Sequence without Pre-amble.

※ In First Frame only.

Idle Time between Frames : 8 byte .

Minimum Frame size = 6+6+2+46+4 = 64 byte .

Maximum Frame size = 6+6+2+1500+4 = 1518 byte .

Data Link Layer devices:

It is a device that understands MAC (hop-to-hop).

- MAC address (48-bit)
- MAC method (CSMA/CD) (Software on ROM use half duplex in Case of Collision)
- MAC Flow Control (Buffer)
- MAC Frame

- Bridge:

Maximum No. of ports 16 based on programing so it is slow.

- Switch:

It is multi-port bridage. It is hardware based using ASIC (Application Specific Integrated Circuits).

⇒ Cisco

Type	Max Fabric BW per System	No. of ports
Catalyst 6513	720 Gbps	576
Catalyst 6513-E	1.4 Tbps	
Nexus 9504	15 Tbps	1024
Nexus 9508	30 Tbps	
Nexus 9516	60 Tbps	4000

⇒ Jumper

Type	Max Fabric BW per system	No. of ports
Ex-8216	6 Tbps	768
	12 Tbps	

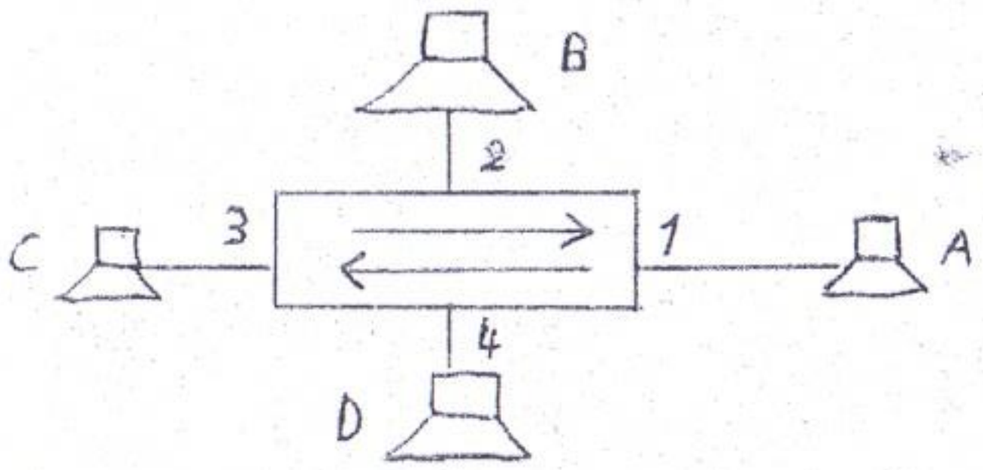
Session 7 Outlines :

- Layer 2 devices :
  - * Switching Modes.
  - * Switching Operations.
- Internet Layer / Network Layer.
  - * Logical Address.
  - * Routing Operation.

Session 6/4
Session 7/1

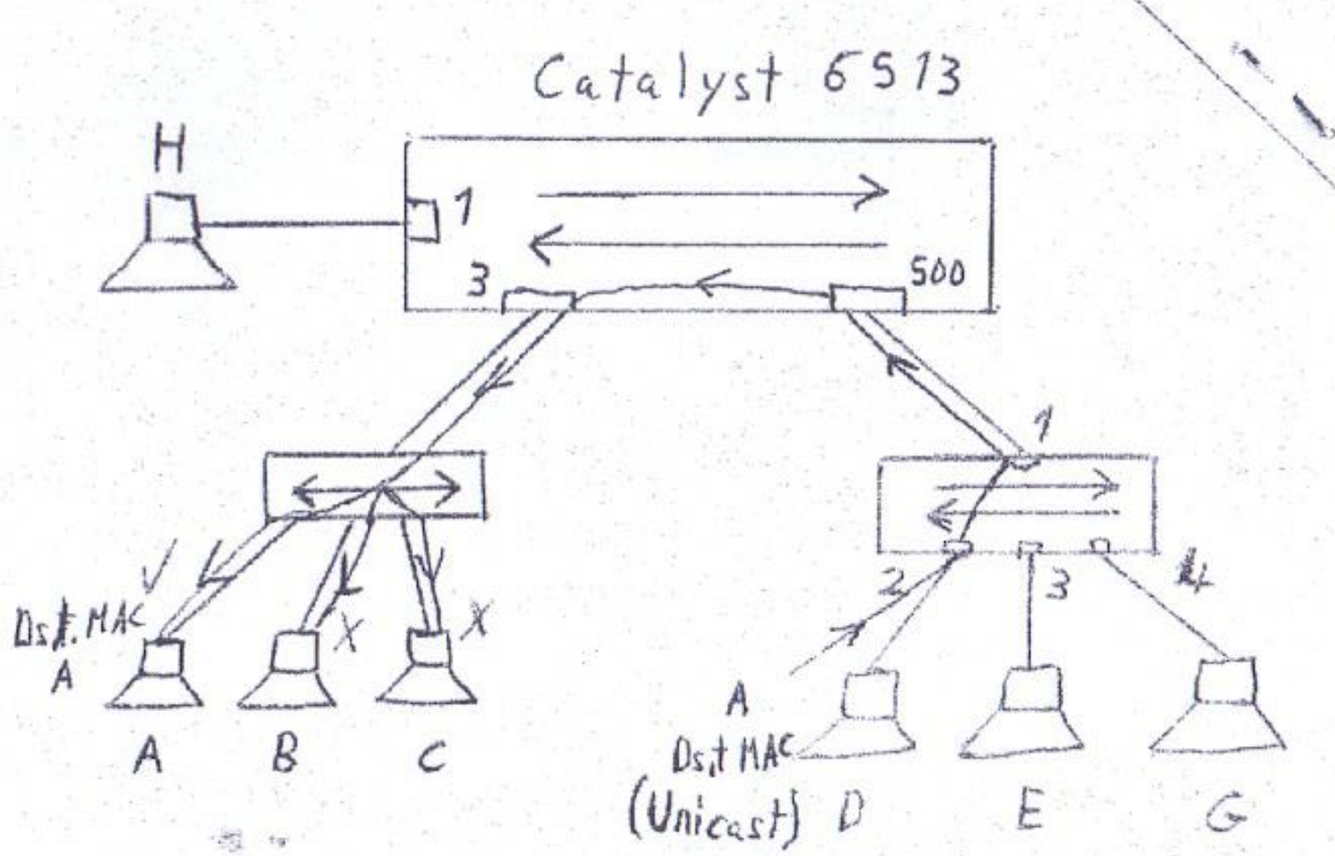
LAN Switch Functions:
- Learning
- Forwarding
- Removing L2 Loops (Listening)

Learning: It is forming MAC Address Table by checking Source MAC in incoming frames.



MAC Table (RAM)

MAC	Port
A	1
B	2
C	3
D	4



MAC Table

MAC	Port
H	1
A	3
B	3
C	3
D	500
E	500
G	500

MAC Table

MAC	Port
D	2
E	3
G	4
A	1
B	1
C	1
H	1

* **Note A:** Switch will flush inactive entries after 5 mins of inactivity by default.

* **Note B:** Switch can learn many devices/MAC on same switch port.

* **Note C:** Switch can never learn same device on different ports.

* **Note D:** Switch understands MAC Address, but does not have it.

* **Note E:** Hub doesn't have ASIC & Table (because it doesn't understand MAC Address)

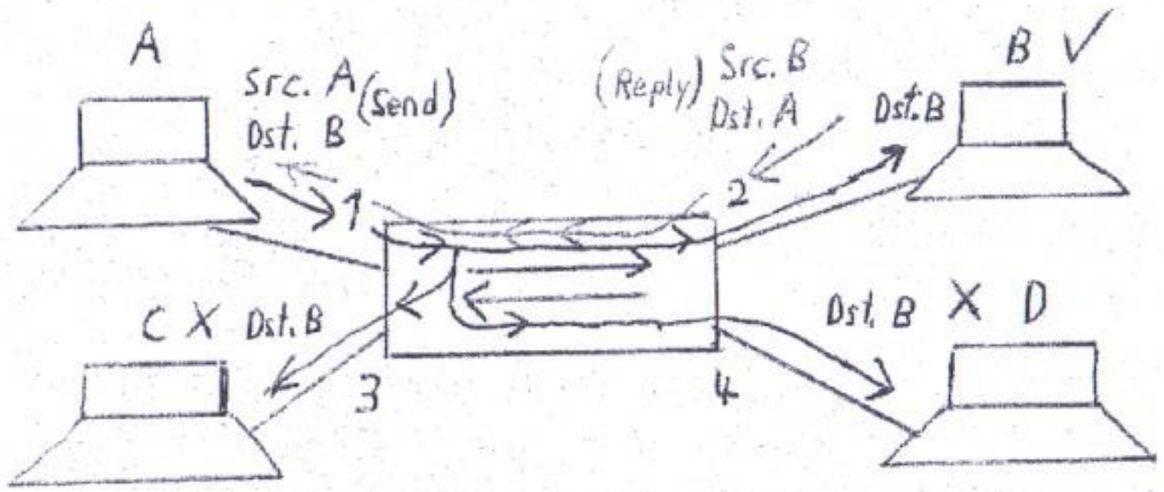
* **Note F:** Switch can never learn same MAC on two different ports.

MAC	Port	
~~A~~	~~1~~	
A	15	Last Update

* The switch will never learn the devices (even they are linked to it) if they do not connect to each other.

* Once the devices connect to each other, the switch will learn the devices (MAC Addresses) and their link to its ports.

2 Forwarding: Switching Frames hop to hop (DTE to DTE), by checking Destination MAC in Frames.



MAC Table (RAM)

MAC	Port
A	1
B	2

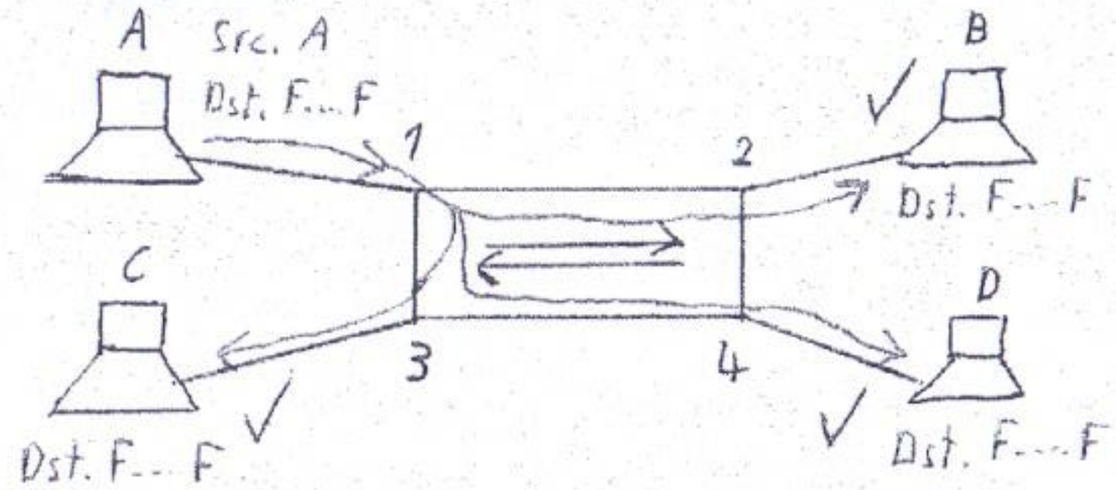
* If Dst. MAC is unknown (not in MAC Table), the switch will flood the data to all devices

Switch will flood if Dst. MAC is BUM (Broadcast, UnKnown, Multicast)

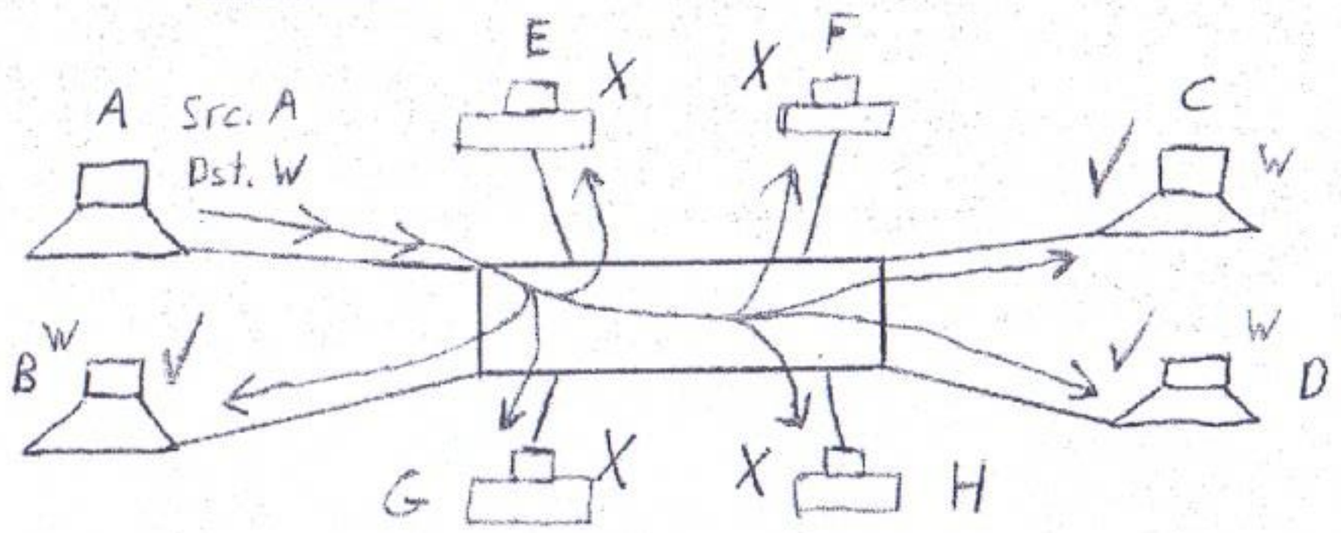
* Note: All devices on Hub & Switch are in the same broadcast domain = LAN

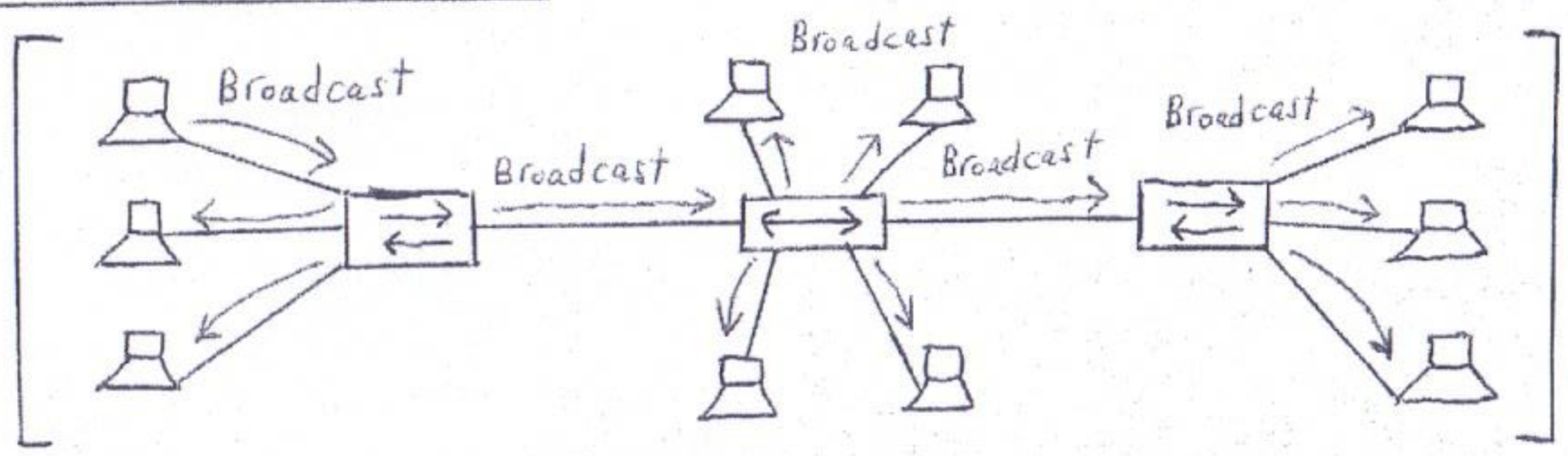
Session 7/2 Session 7/1 → Revision on Session 6/4

* If Dst. MAC is Broadcast (F.... F), the switch will flood



* If Dst. MAC is Multicast (software) (01005e)(xxx xxx), the switch will flood





Session 7/3

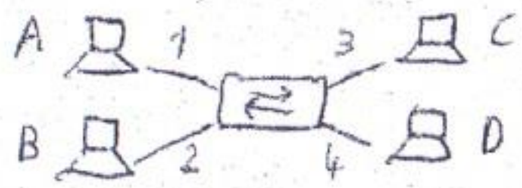
[2] Forwarding: is done using micro segmentation
↓
Switch's interior wires

Half Duplex: CSMA/CD
Carrier Sense Multiple Access/Collision Detection

* Note: All devices on a Switch can operate in full duplex.
[can both (TX: Transmit & RX: Receive) at same time]

All devices on a Hub can operate in half duplex
[can either TX or Rt at same time]

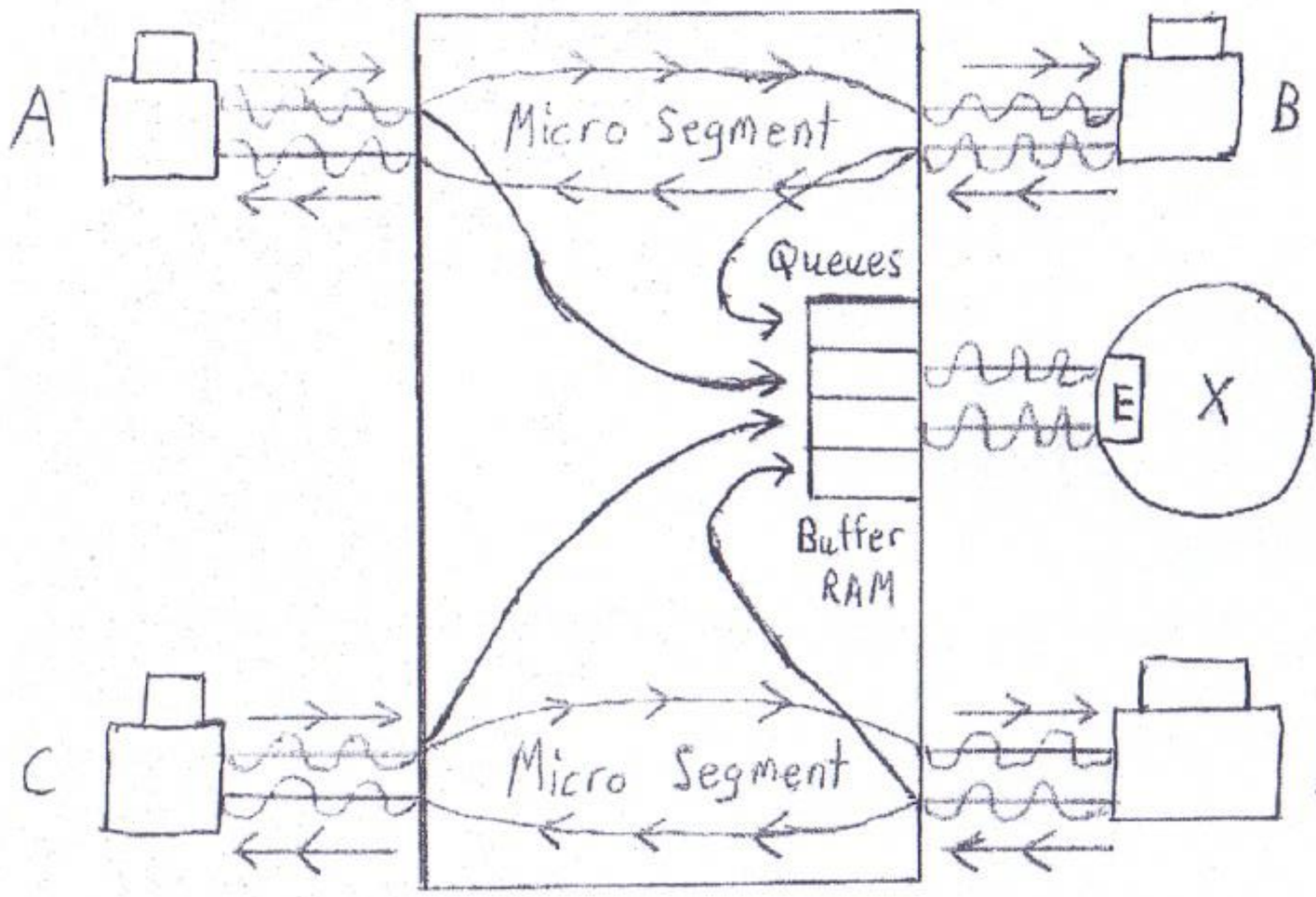
* Note: All devices on a Switch are in separate collision domains
(No collision/Interface) & (Logical Topology = Mesh).



④ separate collision domains

All devices on a Hub are in same collision domain
(Collision/Interface) & (Logical Topology = Bus)

CSMA/CD: It defines how network devices respond when two devices use a data channel simultaneously and encounter data collision.



(FIFO)
First In, First Out ⇒ Organize data's Traffic ~~(Largest to smallest)~~

No Collisions:
- Micro Segmentation: (Separate Collision Domains)
- Buffering: Area of memory (RAM) where the switch stores the data. When all devices send data to WAN (Congestion), Buffers will be used to prevent Collision by passing the data through Queues → FIFO

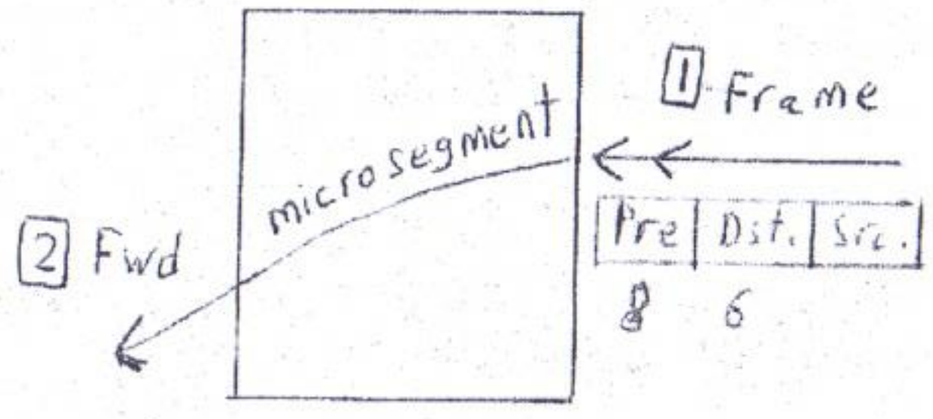
Switching methods/modes!

Forwarding methods/modes!

Session 7/4

[A] Cut through!

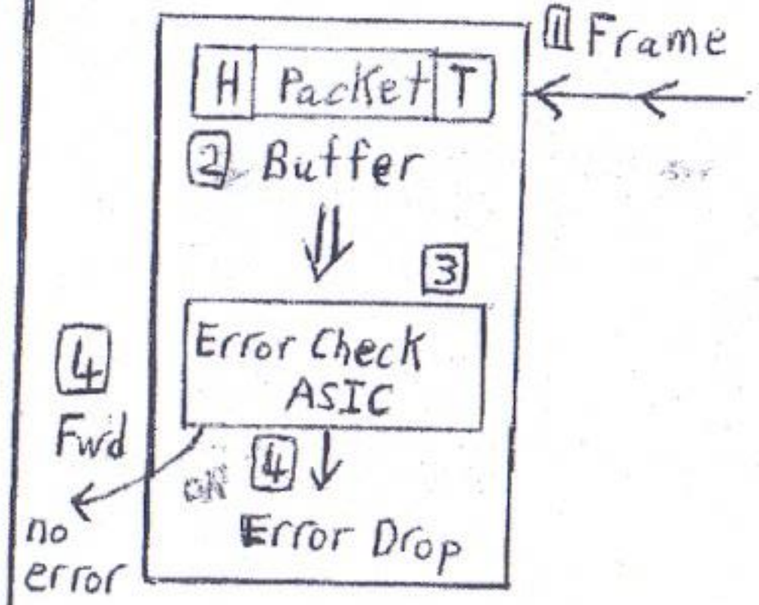
- Switch wait 14 bytes of frame then forward
  - ↓ Dst. MAC
  - ↓ micro segment of frame



Disadv: It forwards the frames without checking errors.

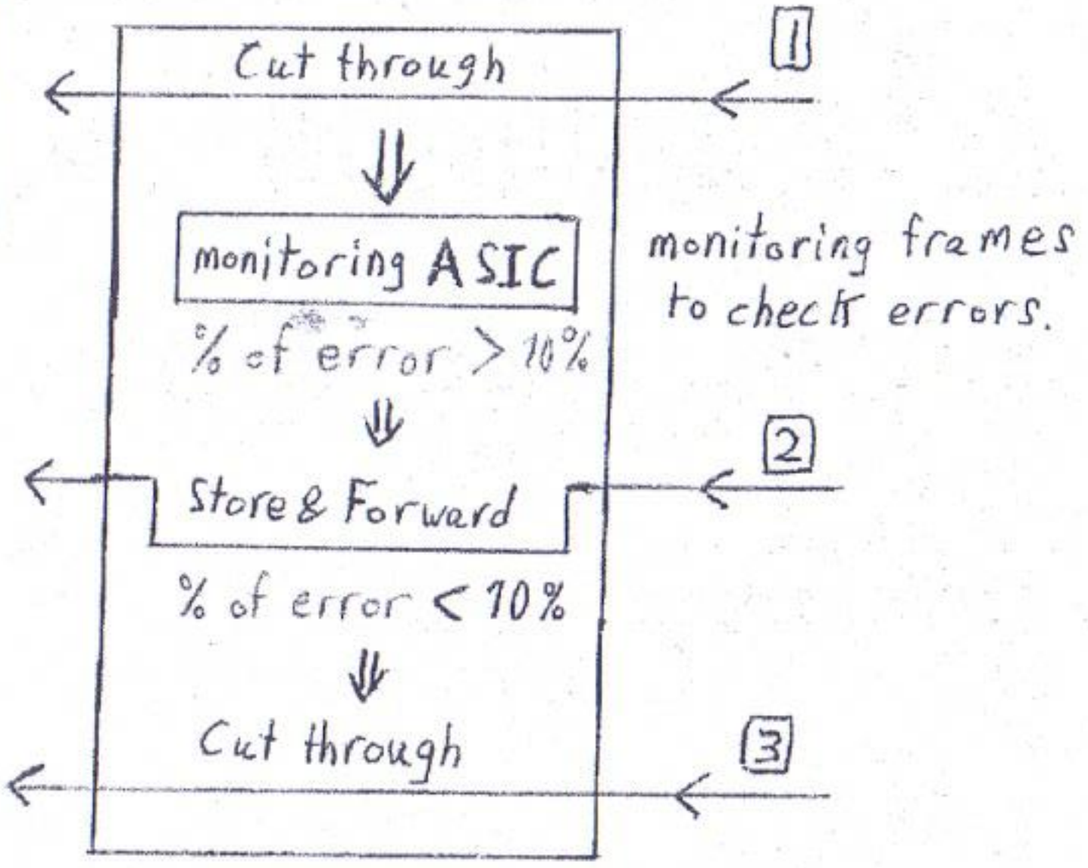
[B] Store & Forward!

- Switch wait full frame to check errors, then forward



Dis! It take time to check error, then Forward

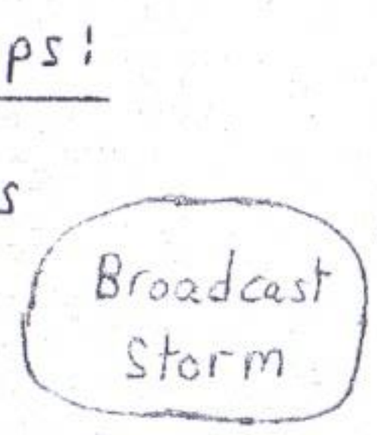
[C] Adaptive Cutthrough! [Cisco]

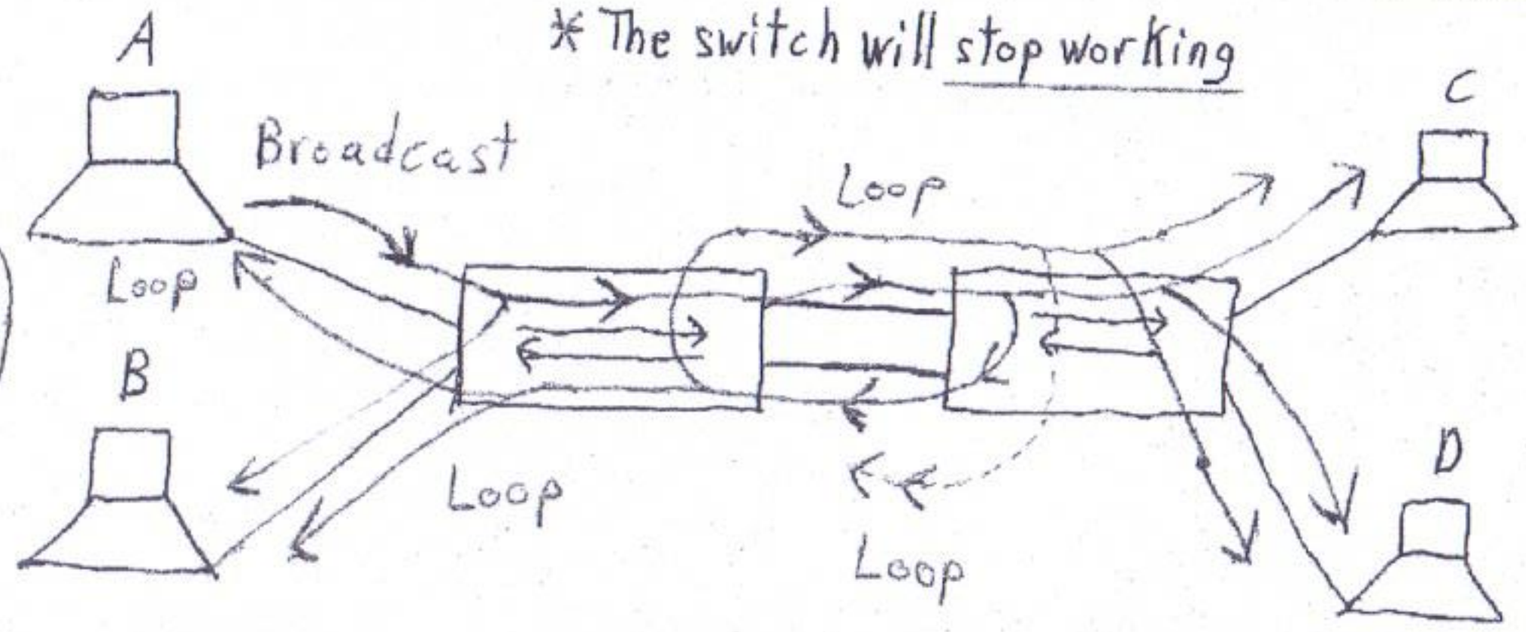


- Cut through & Store & Forward combined

[3] Removing L2 Loops!

- In case 2 switches are connected by 2 wires.





* The switch will stop working

* We use STP to remove the loops.

STP (Spanning Tree Protocol)

Session 8/1

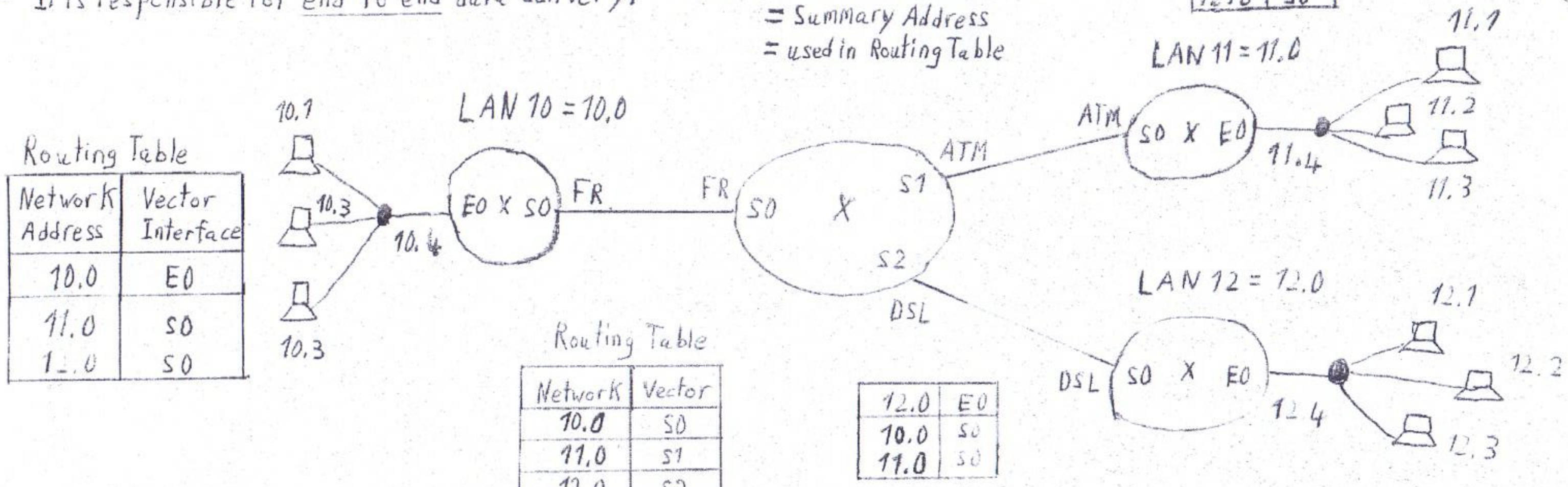
Session 7/5

L3: Internet/Network Layer PDU = **Packet**

- It is responsible for end to end data delivery.

LAN# = Network Address
= Summary Address
= used in Routing Table

11.0	E0
10.0	S0
12.0	S0



Routing Table

Network Address	Vector Interface
10.0	E0
11.0	S0
12.0	S0

Routing Table

Network	Vector
10.0	S0
11.0	S1
12.0	S2

12.0	E0
10.0	S0
11.0	S0

(IP Address)

I Logical Addressing:

It is S/W address given by configuration, used to send data from end to end.

Network Part	Host Part
10	1
10	2

IANA → Service Provider

Function	Router	Switch
Learning	Forming IP Address Table (Routing Table) using S/W: Routing Protocol (RIP-OSPF	Forming MAC Address Table by checking Src. MAC
Forwarding	Compare Dst. IP to the Routing Table! - Known → Forward - UnKnown → Drop - Broadcast → Process	Compare Dst. MAC to the MAC Table! - Known → Forward - UnKnown → Flood - Broadcast → Flood

⇒ Switch Operation :

* Learning:

- Forming MAC address table by Checking Source MAC in an incoming Frames.
- Switch will Flush inactive entries after 5 min of inactive by default.
- Switch Can learn many devices on same Switch port.
- Switch Can never learn same device on different ports.

* Forwarding:

- Switching Frames to next hop by checking destination MAC in Frames.
- The switch will Flood, IF the dst MAC unknown (not in Table) or multicast or broadcast . "BUM" ...
- All devices on a switch are in the same broadcast domain.
- Forwarding is done using microsegmentation.
- All devices on switch operate in Full duplex (Can both Tx & Rx at the same Time) ...
- All devices on Switch are in Separate Collision domains.
- All devices on all hub same Collision domains.

No. of Cables (microsegmentation) = $n(n-1)$

- n : No. of devices.

⇒ Switching Modes (Forwarding Methods):

1. Cut through:

- Wait 14 byte (8 byte Pre-amble + 6 byte dst MAC) then Forward (open microsegmentation).

2. Store & Forward:

Wait full frame then forward.

Store frame in buffer → Error Check by ASIC → Forward / Drop

errors type:

* CRC error.
* Giant Frame (Frame > 1518).
* Runt Frame (Frame < 64).

3. Adaptive - Cut through: By Cisco.

Mix. Cut through & store and forward.

Start For 1min as cut through then check error "<10%" still the same.

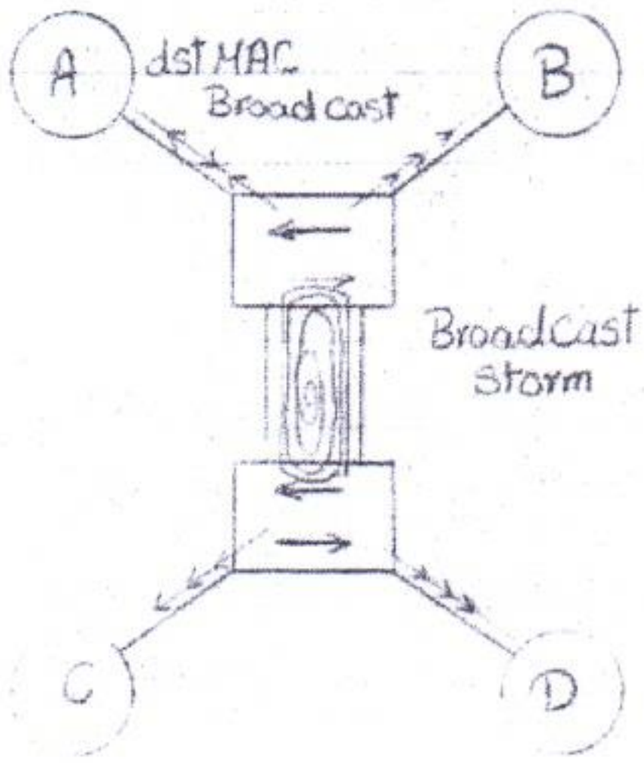
If error ">10%" run as store and forward.

⇒ Monitoring ASIC "up to 60 Tbps"

⇒ Switch Operation:

* Remove layer 2 loops:

Using STP (Spanning Tree Protocal)



Internet Layer / Network Layer :

It is responsible for end-to-end data delivery. PDU : Packet .

- Logical Addressing :

It is software address giving by Configuration used to send data end-to-end .

ex: IPv4 , IPv6 (TCP/IP) , Apple Talk , IPx (Not for internet access) ..

... IANA (Internet Assigned Number Authority) ...

... Network part , Host part ...

MAC Address	IP Address
- Physical Address - Burnt on ROM of NIC - Hardware Address - Hop-to-hop 'IEEE'	- Logical Address - Given by Configuration - Software Address - End-to-end 'IANA'

Layer 2 Technology	Layer 2 Address
- Ethernet , WiFi	- MAC 48-bit
- X.25	- X.25 8-bit
- Frame Relay	- DLCI 10-bit
- ATM , DSL	- VPI/VCI 16-bit

Data link Circuit ID

Virtual Path ID/Virtual Circuit ID

=> Switching Operation :

* Learning : Forming MAC table through src MAC .
* Forwarding : Compare dst MAC to MAC table . If Know, will Foward .
  If BUM , will Floud .

⇒ Router Operation:

* Learning: Forming routing table using routing Protocals.
* Forwarding: Compare dst IP to routing table. If dst IP Known, router will Forward. If dst IP Unknown, router will drop. If dst IP broadcast, router will process.

Routing:

. Finding best path to final end using Routing Protocol.

Session 8 Outlines:

Internet Layer / Network Layer :

- IPv4.
- IPv4 Shortage.
- Subnetting.

Session 8/11

L3: Internet Layer Protocols

IP_{v4} (Internet Protocol version 4)

It's responsible for:

1. Logical Address: End to End Address. (IP Address)
2. Encapsulation: Data from end to end. (IP_{v4} Header)

IP_{v4} Address: It is 32 bit ⇒ 4 billions of IP

Addresses, represented in dotted decimal octet.

10101010 . 1111 1111 . 00000000 . 0000 1111

170 . 255 . 0 . 15

8 bit . 8 bit . 8 bit . 8 bit

- Binary to Decimal Conversion:

X X X X X X X X

128 64 32 16 8 4 2 1

- 1 0 0 0 0 0 1 0 = 130
- 0 0 0 0 1 1 1 1 = 15

192.168.1.260: invalid IP

0000 0000 = 0

1111 1111 = 255

1 bit = x < 0 / 1 $2^1 = 2$	8 bit $2^8 = 256$
2 bit = xx < 00 / 01 / 10 / 11 $2^2 = 4$	16 bit $2^{16} = 65,536$
3 bit = xxx < 000 / i / 111 $2^3 = 8$	24 bit $2^{24} = 16,777,216$
	32 bit $2^{32} = 4,xxx,xxx,xxx$

Session 8/2

IP$_{V4}$ Classes:

IANA

(Fixed) (Variable)

Class A: Network . Host . Host . Host

8 bit | 24 bit

First Octet : 1 - 126

Ex: 41 . X . X . X

N H

No. IPs = $2^H - 2$

No. IPs = $2^{24} - 2 = 16,777,214$

Network Address: 41.0.0.0

H=0 → 41.0.0.1 | 41.255.255.254

H=1 → 41.255.255.255 Direct Broadcast

* Network Address & Direct Broadcast Addresses cannot be obtained by any host in any network.

Class B: First Octet : 128 - 191

(128-191) (0-255)

Network . Network . Host . Host

16 bit | 16 bit

Ex: 170.5.X.X (N N H H)

No. IP = $2^{16} - 2$

$= 65,534$

Network Address: 170.5.0.0

170.5.0.1 | 170.5.255.254

Direct Broadcast: 170.5.255.255

Class C: First Octet : 192 - 223

24 bit [Network . Network . Network . Host

(192-223) (0-255) (0-255) 8 bit

Ex: 200.7.8.X

Network Address: 200.7.8.0

200.7.8.1 | 200.7.8.254

Direct Broadcast: 200.7.8.255

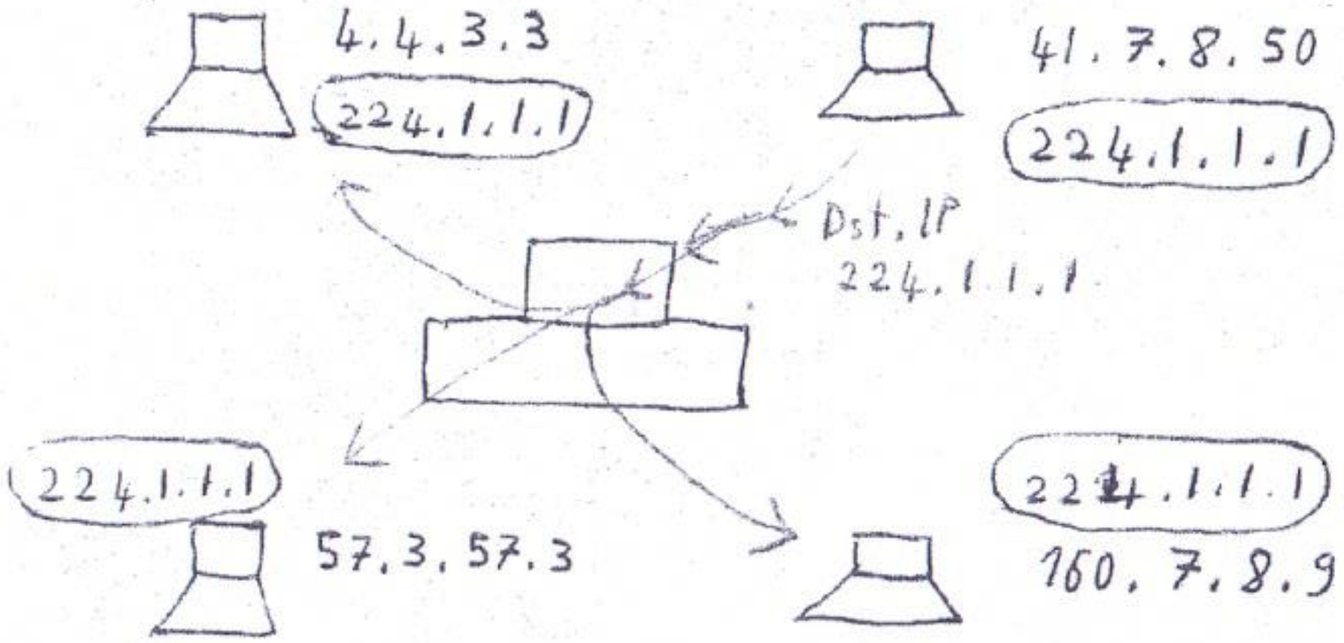
Session 8/3

IP_{v4} Classes: (First Octet)

Used for Unicast:
- Class A: 1 - 126 → 2,xxx,xxx,xxx IPs
- Class B: 128 - 191 → 1,xxx,xxx,xxx IPs
- Class C: 192 - 223 → 500,xxx,xxx IPs

Class D: used for Multicast → 250,xxx,xxx IPs

First Octet: 224 - 239 | 224.X.X.X → 239.X.X.X



(at the same time)

- It sends data simultaneously to multiple receivers, so it does not burden the source (sender)
- The devices share same IP & same application.

Class E:

First Octet
240 - 254 → 250,xxx,xxx IPs

- used for researches & military applications.

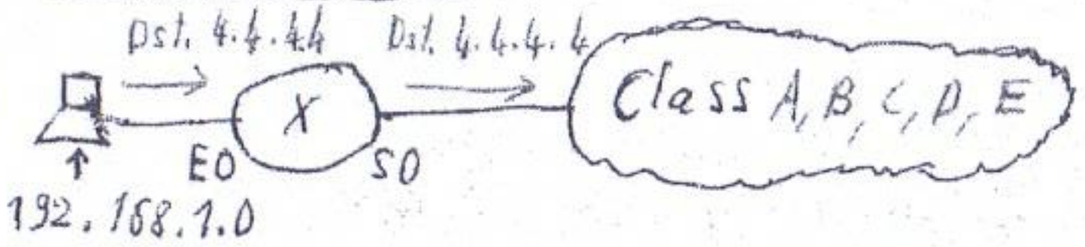
Classless IP 0.X.X.X / 127.X.X.X / 255.X.X.X

* 0: 0.X.X.X — used (0.0.0.0) ⇒ All IP_{v4} Networks Addresses

1.X.X.X → 1.0.0.0
2.X.X.X → 2.0.0.0
41.X.X.X → 41.0.0.0
→ 0.0.0.0 = Internet

Routing Table

192.168.1.0	E0
0.0.0.0	S0



* 127: 127.X.X.X — used (127.0.0.1) ⇒ (S/W) Address TCP/IP model Address

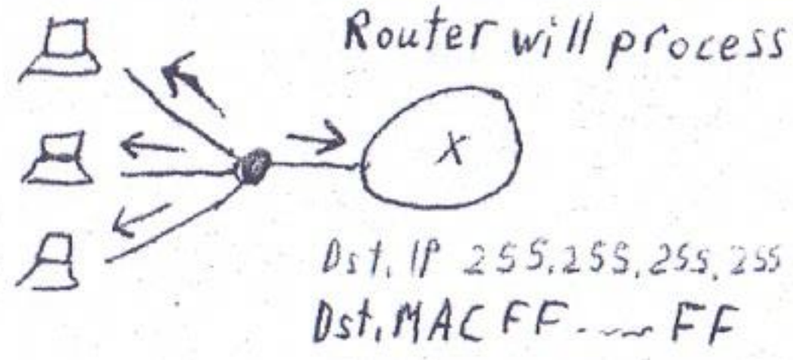
PC — Ping (127.0.0.1) check → success / fail

- used for TCP/IP stack Layers, Loopback test (Internal S/W)

* 255:

255.X.X.X

(255.255.255.255) General Broadcast (Local Broadcast) used in LAN only



IP_{V4} shortage: Year (2000)

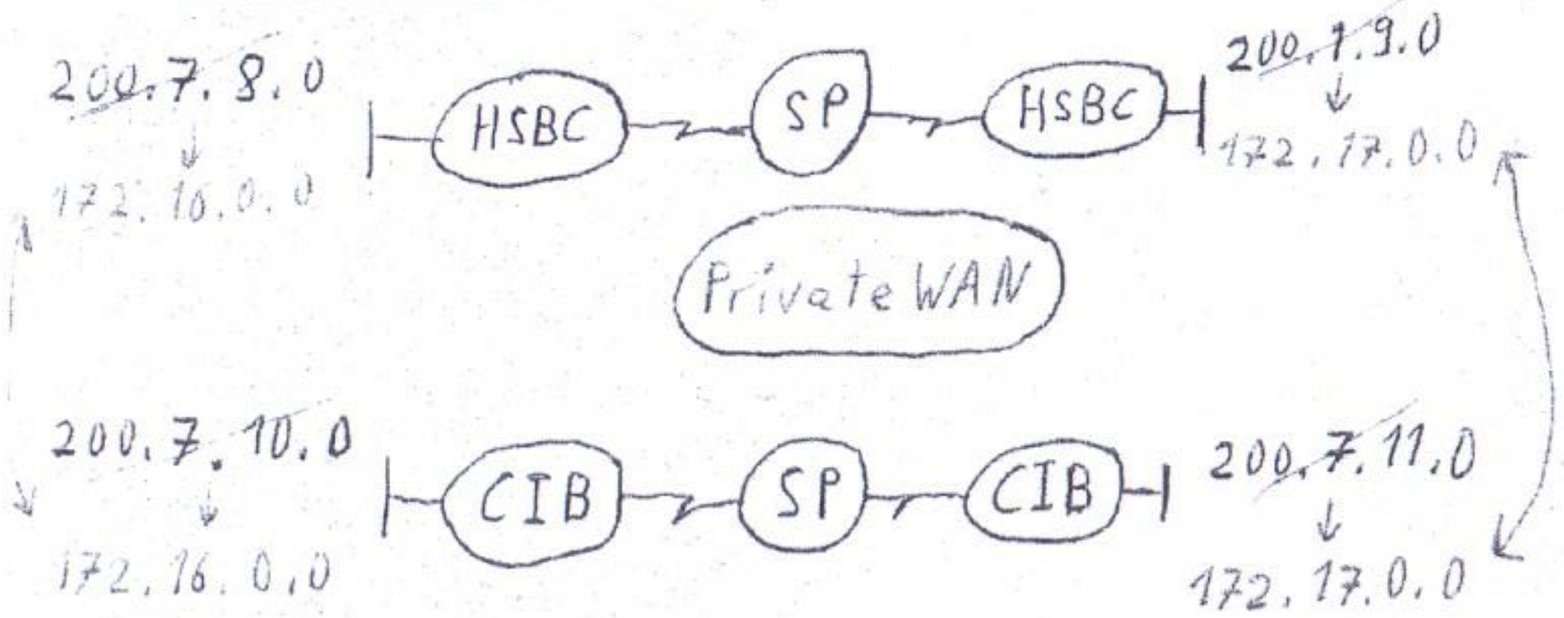
Network Needs	Class (Package)	Wasted IP
6 IP	C (256)	250
536 IP	B (65,536)	65,000
300,000 IP	A (16,xxxxx)	16,477,216

IP_{V4} Solutions

1 New Version:

- IP_{V5} (64 bit) → Researches only
- IP_{V6} (128 bit) → $2^{128} = 3.4 \times 10^{38}$
  $= 5 \times 10^{28}$ IP_{V6} / human

2 Private Addressing:

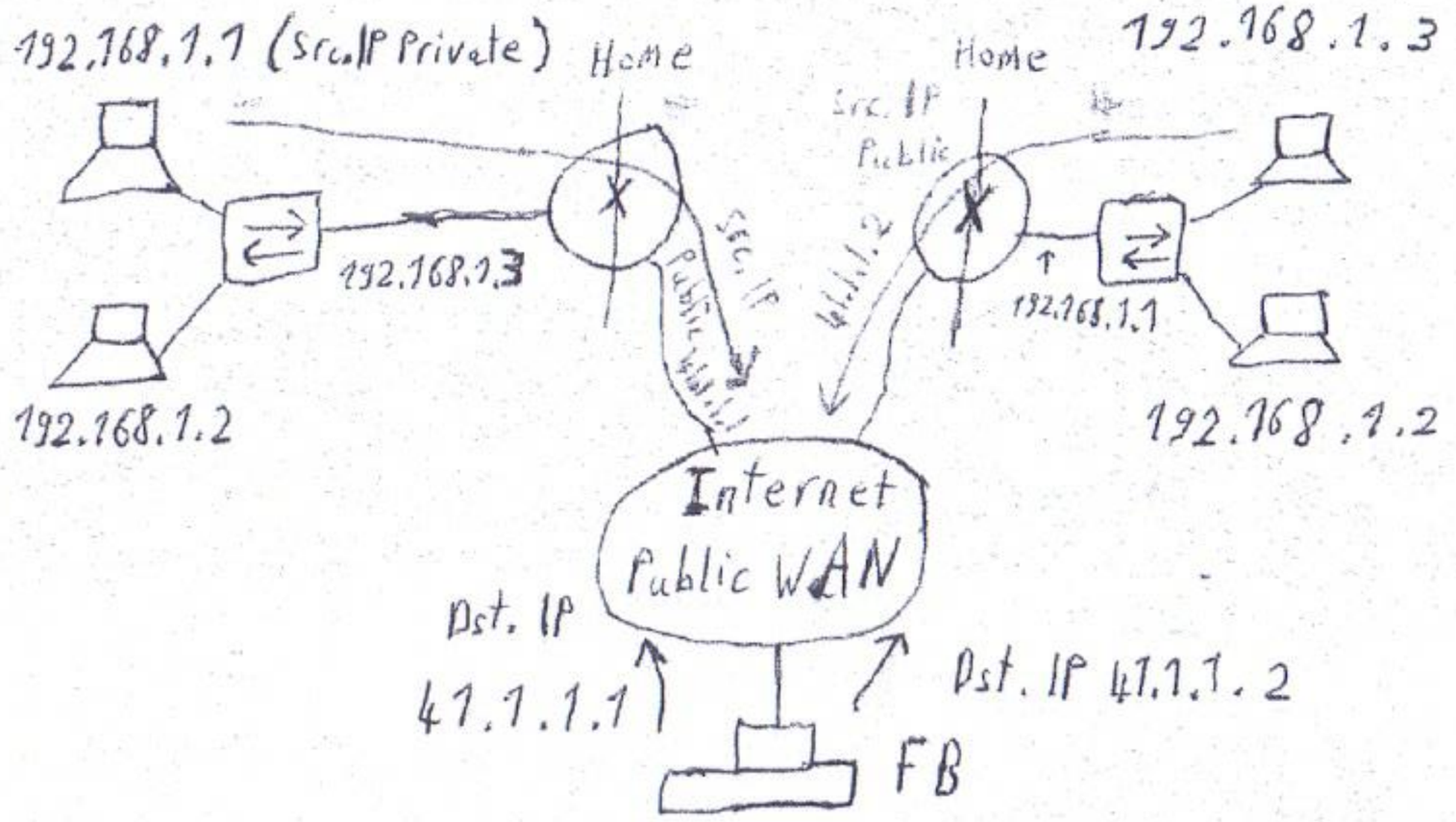


Session 8/4

Private IP: Free IP - Used in Private LANs & WANs

Free IP:
- Class A: 10.X.X.X
- Class B: 172.16.X.X → 172.31.X.X
  → 169.254.X.X → Automatic Private IP Address (APIPA)
- Class C: 192.168.0.X → 192.168.255.X

Public IP = Real IP = Unique IP ⇒ 1 $ per year



NAT ⇒ Network Address Translation
- It converts Private IP → Public IP

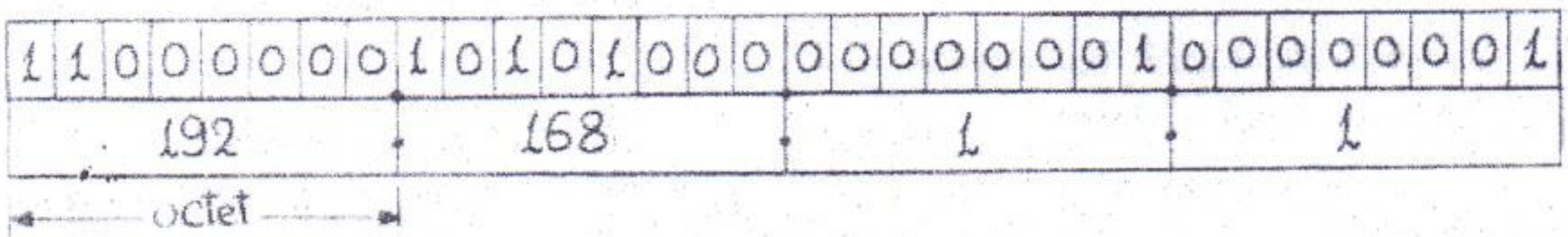
* Class A&B&C Private IP ranges should be used in Private LANs & WANs only in order to not to be conflicted.

Internet Layer / Network Layer :

IPv4 :

Internet Protocol version 4. It is responsible for logical addressing, encapsulating data end-to-end ≡ IPv4 address.

so IPv4 Address : It is 32-bit address. It is represented in dotted decimal octet.



Class A :

First octet: 1-126

Network . Host . Host . Host

H = 24 bit

No. of IPs on each network = $2^H = 2^{24} = 16\,777\,216$ IP.

No. of devices on each network = $2^H - 2 = 16\,777\,214$ device.

Class B :

First octet : 128 - 191

Network . Network . Host . Host

H = 16 bit

No. of IPs on each network = $2^{16} = 65536$ IP.

No. of hosts on each network = $2^{16} - 2 = 65534$ host.

Class C :

First octet : 192 - 223

Network . Network . Network . Host

H = 8 bit

No. of IPs on each network = $2^8 = 256$ IP.

No. of hosts on each network = $2^8 - 2 = 254$ host.

Class D :
First octet : 224 - 239 , Used For multiCast

Class E :
First octet : 240 - 254 , Used For researches & military applications.

Classless IP :
First octet : 0 just use 0.0.0.0 All IPv4 networks.
First octet : 127 just use 127.0.0.1 used For test TCP/IP.
First octet : 255 just use 255.255.255.255 All IPv4 devices.

Broad Cast
local Broad Cast 255.255.255.255 inside LAN only (non routable)
direct Broad Cast X.255.255.255 Can be used on WAN (routable)

IPv4 Shortage :
2^{32} = 4 294 967 296
For example :

Network needs	Class	Wasted IP
6 IP	C	250 IP
536 IP	B	65 000 IP
300 000 IP	A	16477216 IP

IPv4 Shortage Solutions :
1. IPv5 = 64-bit (researches only) .
IPv6 = 128-bit " 2^{128} = 3.4×10^{38} IP " .
2. Subnetting .
3. Private IP + NAT .

=> Private IP + NAT (Network Address Translation):

Free IPs used for private LAN & private WAN :

Class A : 10.X.X.X (1 network).
Class B : 172.16:31.X.X (16 network).
Class C : 192.168.0:255.X (256 network).

} Public IP or Real IP or Unique IP

Another Private IPs is APIPA Automatic Private IP Address
169.254.X.X non routable so used on lan only.

ISP (internet service provider) : Convert Private IP to Real IP ...

Frame ...

Packet ...

Pre-amble	dst MAC	Src MAC	Type
Version	Header length	TOS 1-byte	Total Length
Fragmentation			
TTL 1-byte	Protocol	check SUM	Fixed Header = 20 byte
Source IP 4-byte			
Destination IP 4-byte			
Options ...			
Segment			
CRC			

Session 9 Outlines :

- IPv4 .
- IP shortage solutions.
- Troubleshooting end-to-end data delivery.
- Getting started for end-to-end data delivery.

Session 9/1

IP_{V4} Subnetting: (Subnetworking)

- It is dividing major network to smaller networks called (subnets)

* Major Network
- Class A → 16,777,216 IP (1-126)
- Class B → 65,536 (128-191)
- Class C → 256 (192-223)

- Subnet Mask: Defines # of IPs / Hosts

Subnet Mask	# of IPs - $2^{\#}$	
/32	1 - (2^0)	
/31	2 - (2^1)	
/30	4 - (2^2)	
/29	8 - (2^3)	
/28	16 - (2^4)	
/27	32 - (2^5)	
/26	64 - (2^6)	
/25	128 - (2^7)	
/24	256 - (2^8)	class C
⋮	⋮	
/16	65,536 - (2^{16})	class B
⋮	⋮	
/8	16,777,216 - (2^{24})	class A
⋮	⋮	

/2 → 1,xxx,xxx,xxx (2^{30})
/1 → 2,xxx,xxx,xxx (2^{31})
/0 → 4,xxx,xxx,xxx (2^{32})

200.7.9.X /27

Network Host

200.7.9.0	subnet1
200.7.9.1	32 IP
200.7.9.2	
⋮	
200.7.9.31	
200.7.9.32	subnet 2
200.7.9.33	32 IP
⋮	
200.7.9.63	
200.7.9.64	subnet 3
200.7.9.65	32 IP
⋮	
200.7.9.95	
200.7.9.96	subnet 4
⋮	
200.7.9.255	subnet 8 32 IP

8 subnet x 32 = 256 IP

/27 ⇒ 2^5 = 32

200.7.8.X /26

Network Host

200.7.8.0	subnet1 64 IP
200.7.8.1	
200.7.8.2	
⋮	
200.7.8.63	
200.7.8.64	subnet2 64 IP
200.7.8.65	
⋮	
200.7.8.127	
200.7.8.128	subnet3 64 IP
200.7.8.129	
⋮	
200.7.8.191	
200.7.8.192	subnet 4 64 IP
200.7.8.193	
⋮	
200.7.8.255	

256 IP

4 subnet x 64 = 256 IP

/26 ⇒ 2^6 = 64

* In each subnet there are:

1- Network Address: 1st IP

If all hosts bits = 0, used as entry in Routing Table.

2- Direct Broadcast Address: Last IP

If all hosts bits = 1, used for protocols & application,

3- Host Address:

If all hosts bits ≠ 0 ≠ 1, used for DTEs.

No. IPs/subnet = $2^{32 - \text{mask}}$
No. Subnets = $2^{\text{new mask} - \text{old mask}}$

Ex: you are given a major network 197.2.5.0 /24 (256 IP)

we need to divide it using new subnet mask (/25)

Find: • no. IPs/subnet
• no. subnets

Network 197.2.5.0 — 1st subnet
197.2.5.1
197.2.5.2
|
Broadcast 197.2.5.127
(256 IP)

Network 197.2.5.128 — 2nd subnet
197.2.5.129
|
Broadcast 197.2.5.255

• no. IPs = 2^{32-25}
$= 2^7 = 128$
(128 IPs/subnet)

• no. subnets = $2^{25-24} = 2^1 = 2$
(2 subnets)

Ex: you're given 200.5.6.0 / 24 (256 IP)

we need to divide it using new subnet mask (/28)

Find: no. IPs/subnet & no. subnets

no. IPs/subnet
$2^{32-28} = 2^4$
= 16 IPs/subnet

no. subnets
$2^{28-24} = 2^4$
= 16 subnets

Ex: you are given 173.15.0.0 / 16 [65,536 IP]

we need to divide it using new subnet mask

Find: no. IPs/subnet & no. subnets (/23)

no. IPs/subnet
$2^{32-23} = 2^9$
= 512 IP/subnet

no. subnet
$2^{23-16} = 2^7$
= 128 subnets

173.15.0.0 — Network
173.15.0.1
173.15.0.2
|
173.15.0.255
173.15.1.0 — 1st subnet
173.15.1.1 — 512 IP
|
173.15.1.255 — Broadcast
|
173.15.255.255

Session 9/3

Subnet mask: It's a 32 bit mask

- Starts with 1's and ends with 0's

(/#) = (Network bits) (Host bits)
N H

Default mask:

/8 → 1111 1111.0000 0000.0000 0000.0000 0000 — 255.0.0.0
ClassA — Network Bits = 8 — Host Bits = 24

/16 → 1111 1111.1111 1111.0000 0000.0000 0000 — 255.255.0.0
Class B — Network Bits = 16 — Host Bits = 16

/24 → 1111 1111.1111 1111.1111 1111.0000 0000 — 255.255.255.0
Class C — Network Bits = 24 — Host = 8

Ex: 10.7.8.9 → class A - /8
N H

mask = 1111 1111.0000 0000.0000 0000.0000 0000 — 255.0.0.0

Ex: 172.16.5.80 → class B - /16
N H

mask = 1111 1111.1111 1111.0000 0000.0000 0000

255.255.0.0

Ex: 192.168.1.1 → class C - /24
N H

mask = 1111 1111.1111 1111.1111 1111.0000 0000

255.255.255.0 / No. IPs = 1.1.1.256 = 256

> No. IPs = 256 - Mask (Dotted Decimal) & multiply
>
> Subnet Mask (Dotted Decimal) = 255.255.0.0

Ex: 255.255.255.252 /30

IP = 256 - (255.255.255.252) = 1.1.1.4

1x1x1x4 = 4 IPs

Ex: 255.255.255.224 & multiply

IP = 256 - (255.255.255.224) = 1.1.1.32 = 32 IPs

Ex: 255.255.255.128 — 128 IPs

No IPs = 256 - (255.255.255.128) = 1.1.1.128

Ex: 255.255.254.0 /23

No. IPs = 1.1.2.256 = 512 IPs

Ex: Mask is 255.255.252.0

No. IPs = 1.1.4.256 = 1024 IPs

Session 9/4

IP_{V4} (Internet Protocol version 4)

↓ End to End Protocol

↘ Layer End to End

It is responsible for:

1. Logical Addressing: (Final End Address)
   - subnetting
   - 32 bit classes
   - new version
   - private/public
2. End to End Encapsulation:

IP_{V4} Header [H | H | H | Data Part | T]

segment

Frame: packet

Source IP (4 byte)

Destination (4 byte)

TOS (Type of Service) (8 bit)

- Used for QOS (Quality of Service) = give priority
- Reflects the Priority of data (highest is best)
- only used 3 bit xxx { 000 = 0 ... 111 = 7 }

0, 1, 2, 3 → (Downloading, Browsing, Mail, ...)

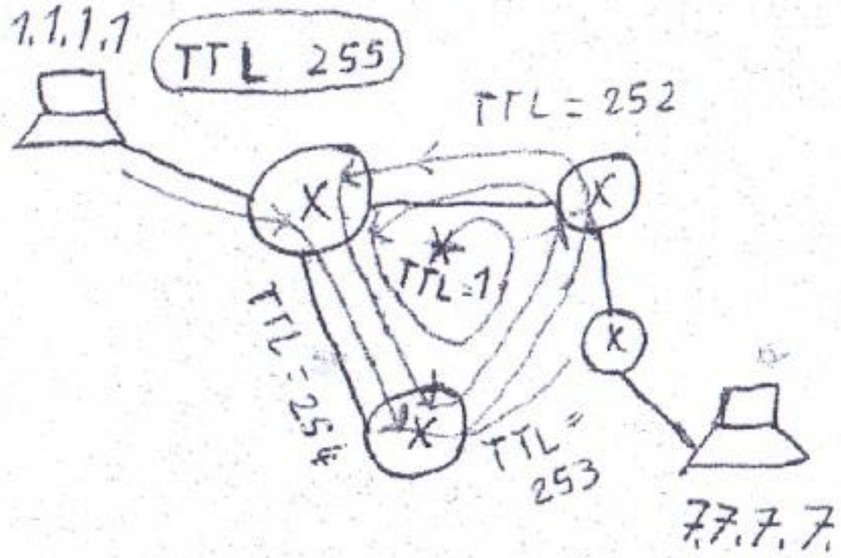
4 → (Video) 6 → Router Protocols

5 → (Voice) 7 → Switch Protocols

* TTL (Time To Live)

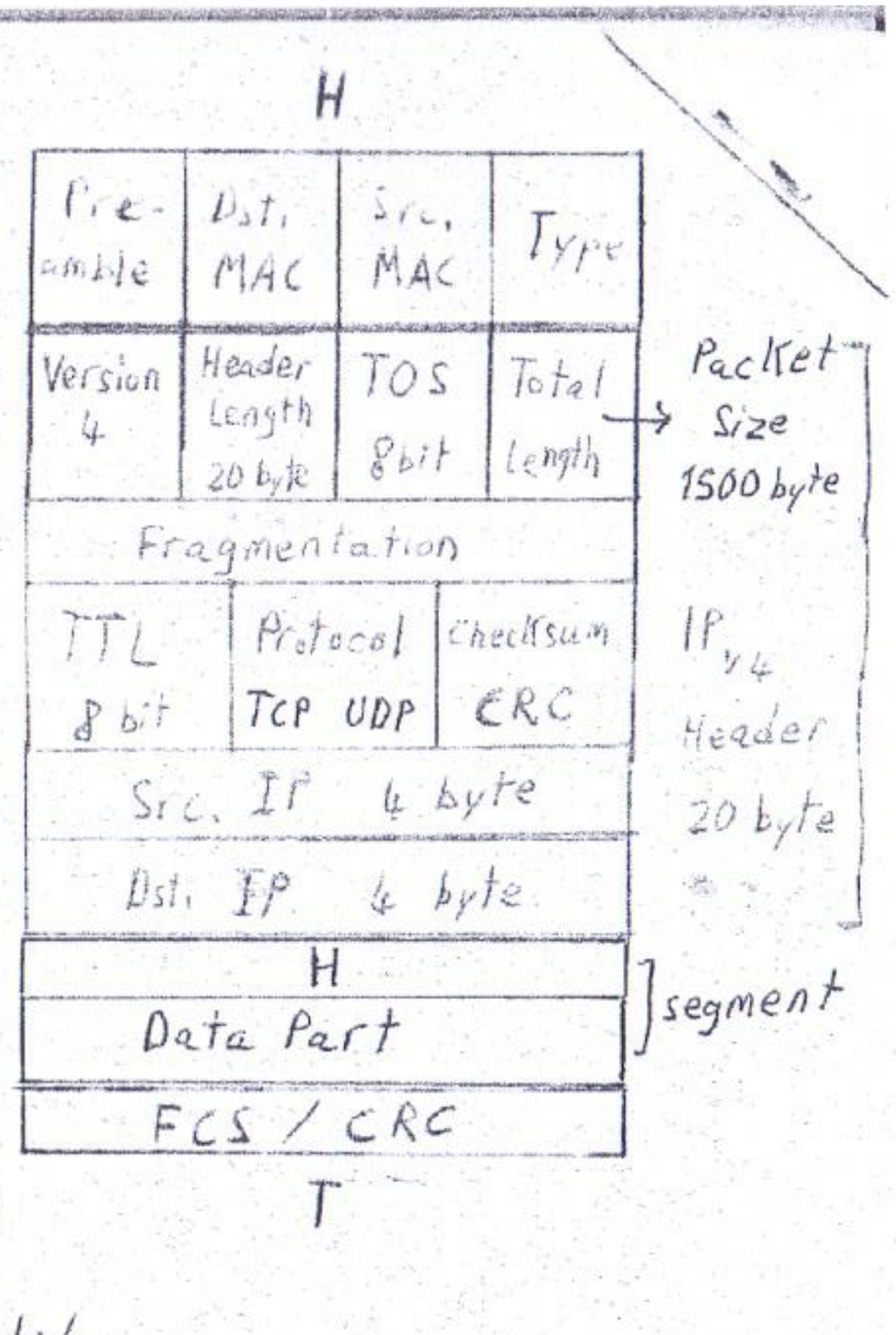
- Removes Layer 3 Loops

8 bit (0 - 255)



- A Value in (IP) packet that tells a network router (whether or not) the packet has been in the network too long and should be discarded,
- Each router receives the packet & subtracts its count by 1, then forwards it.

* When TTL = 1, The router will drop the data & will stop the loops (Undeliverable packets)



Inside each subnet there are:

1. Network Address :

If all host bits = 0 .

Used as entry in Routing Table.

2. Direct broadcast Address :

If all host bits = 1 .

Used for protocals & applications.

3. Host Address :

If all host bits ≠ 0 , ≠ 1 .

Used for DTEs.

IPv4 Shortage Solutions :

⇒ Subnetting :

It is dividing major network into smaller networks called Subnets . It is browing part of host bits & give them network.

256
65 536
16 777 216
} Major Network
Class A,B,C

2 X 128 IP
4 X 64 IP
8 X 32 IP
} Subnet Network

$$\text{No. of IPs} = 2^{32 - \text{Mask}}$$

$$\text{No. of Subnets} = 2^{\text{New mask} - \text{old mask}}$$

⇒ Subnet Mask :

No. of IPs	Subnet mask	No. of IPs	Subnet mask
4,294,967,296	/0	0.0.0.0	32,768	/17	255.255.128.0
2,147,483,648	/1	128.0.0.0	16,384	/18	255.255.192.0
1,073,741,824	/2	192.0.0.0	8,192	/19	255.255.224.0
536,870,912	/3	224.0.0.0	4,096	/20	255.255.240.0
268,435,456	/4	240.0.0.0	2,048	/21	255.255.248.0
134,217,728	/5	248.0.0.0	1024	/22	255.255.252.0
67,108,864	/6	252.0.0.0	512	/23	255.255.254.0
33,554,432	/7	254.0.0.0	256	/24	255.255.255.0
16,777,216	/8	255.0.0.0	128	/25	255.255.255.128
8,388,608	/9	255.128.0.0	64	/26	255.255.255.192
4,194,304	/10	255.192.0.0	32	/27	255.255.255.224
2,097,152	/11	255.224.0.0	16	/28	255.255.255.240
1,048,576	/12	255.240.0.0	8	/29	255.255.255.248
524,288	/13	255.248.0.0	4	/30	255.255.255.252
262,144	/14	255.252.0.0	2	/31	255.255.255.254
131,072	/15	255.254.0.0	1	/32	255.255.255.255
65,536	/16	255.255.0.0			

⇒ IPv4 examples :

ex.1 : For the given major network : 202.7.7.0/24. we need to divide it using subnet mask /25 . Find :

a. No. of IPs / subnet = $2^{32-25} = 2^7 = 128$ IPs / subnet

b. No. of hosts / subnet = $2^7 - 2 = 126$ host / subnet

c. No. of subnet = $2^{25-24} = 2^1 = 2$ subnet ...

ex.2: For the given major network: 197.20.30.0/24. If we will divide it using subnet mask /27. Find:

1. No. of IPs/Subnet.
2. No. of Subnet.

→ 197.20.30.0/24

No. of IPs/subnet = $2^{32-24} = 2^8 = 256$ IP/subnet & 254 host.

No. of subnets = $2^{24-24} = 2^0 = 1$ subnet.

→ 197.20.30.0/27

No. of IPs/sub net = $2^{32-27} = 2^5 = 32$ IP/subnet & 30 host.

No. of subnets = $2^{27-24} = 2^3 = 8$ subnet.

---

ex.3: You are give a major network: 197.F.F.0/24. We need to divide using new subnet mask /29. Find:

(a) No. of IPs/subnet.

(b) No. of subnets.

→ 197.F.F.0/24

No. of IPs/subnet = $2^{32-24} = 2^8 = 256$ IPs/subnet & 254 host.

→ 197.F.F.0/29

No. of IPs/subnet = $2^{32-29} = 2^3 = 8$ IPs/subnet & 6 host.

No. of subnets = $2^{29-24} = 2^5 = 32$ subnets.

---

ex.4: You are give a major network: 173.15.0.0/16. We need to divide using new subnet mask /23. Find:

(a) No. of IPs/subnet.

(b) No. of subnets.

→ 173.15.0.0/16

No. of IPs/subnet = $2^{32-16} = 2^{16} = 65536$ IPs/subnet & 65534 host.

→ 173.15.0.0/23

No. of IPs/subnet = $2^{32-23} = 2^9 = 512$ IPs/subnet & 510 hosts.

No. of subnet = $2^{23-16} = 2^7 = 128$ subnet.

⇒ Private IP + NAT (Network Address Translation):

Free IPs used for private LAN & private WAN.

Class A : 10.X.X.X (1 network).
Class B : 172.16:31.X.X (16 network).
Class C : 192.168.0:255.X (256 network).

} Public IP or Real IP or Unique IP

Anothe Private IPs is APIPA Automatic Private IP Address
169.254.X.X non routable so used on lan only.

ISP (internet service provider) : Convert Private IP to Real IP ...

Frame ...

Pre-amble	dst MAC	Src MAC	Type
Version	Header length	TOS 1-byte	Total Length
Fragmentation			
TTL 1-byte	Protocol	check SUM	
Source IP 4-byte			
Destination IP 4-byte			
Options ...			
Segment			
CRC			

Packet..

Fixed Header = 20 byte

→ Source IP is 4-byte.

→ Destination IP is 4-byte.

→ TOS (Type of service) is 1-byte used 3-bit only. Used for QOS (Quality of service): Reflect priority (highest is best).
ex: Data " Torent 0, Down/Upload 1, Browsing 2, e-mail 3".
Video 4, Voice 5, Router protocols 6, Switch protocal 7.

→ TTL (Time to live) is 1-byte used 8bit only. Used for remove layer 3 loops (Maximum number of hop between 2 ends = 30).
every hop sub 1 from TTL. then drops.

10 &

Session 11 Outlines :

. DNS .

. ARP .

. Commands .

. Add IP & DNS manual .

. Layer 4 - Transport layer.

Session 10/1

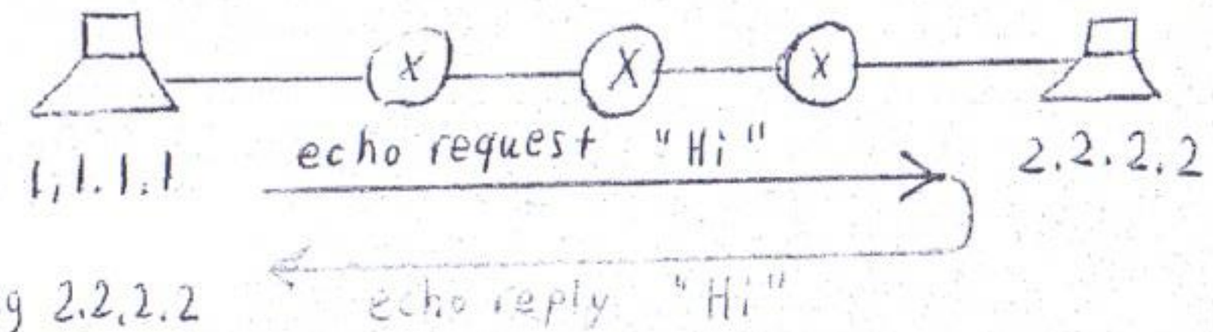
Internet Layer Protocols:

IP_{V4} : send data end to end

ICMP : Internet Control Messaging Protocol
(Troubleshoot end to end connectivity)

Internet : Internet Layer (end to end)

Control : handling troubles

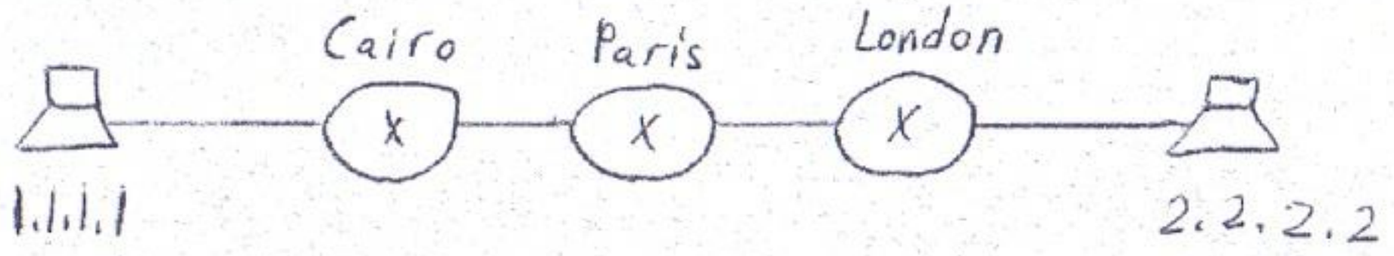


ping
- windows → 4 echo
- linux → ∞ echos
- Ios → 5 echo

[1] Echo Request & Echo Reply msg. : (Ping)

* checks if a particular IP Address is accessible or not.

[2] Trace: (Traceroute)



(Traceroute)
All Operating Systems

1. Cairo
2. Paris
3. London
4. 2.2.2.2

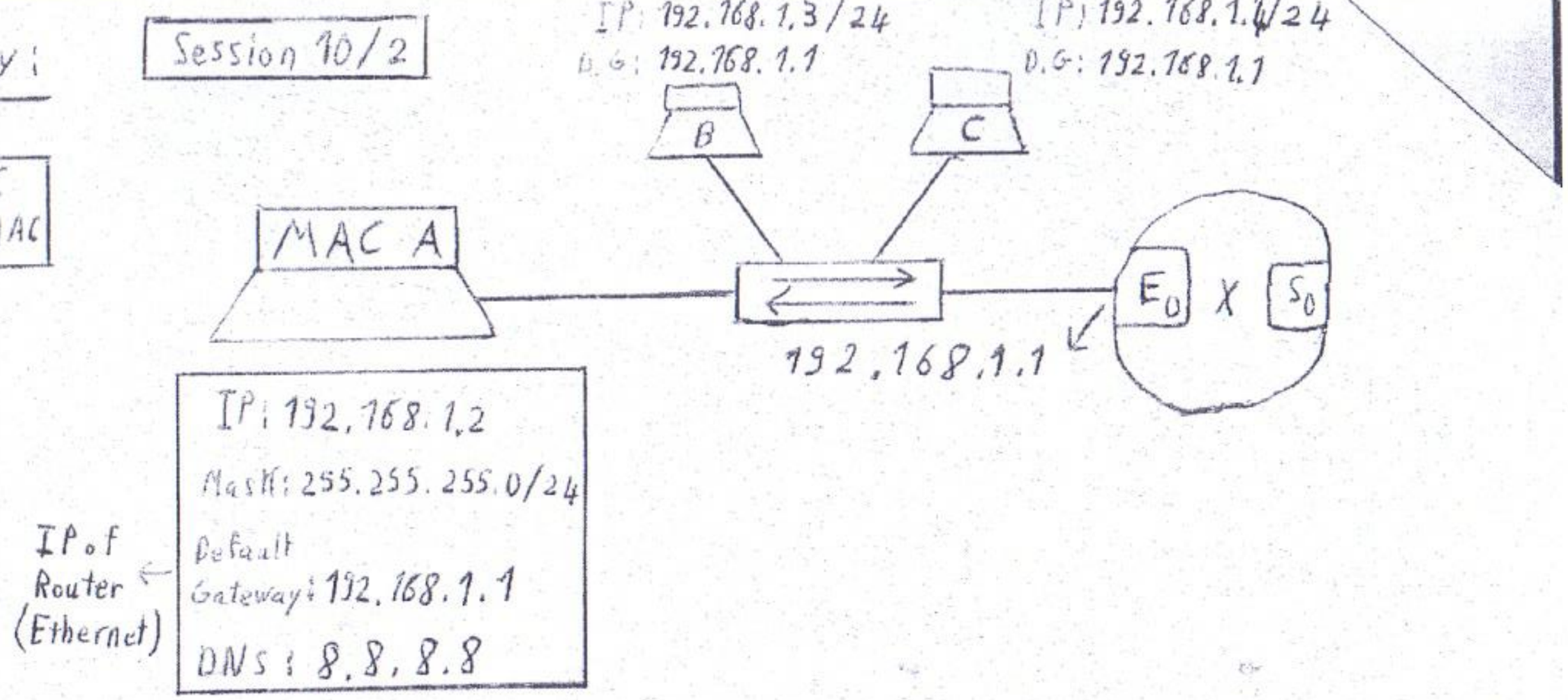
(Tracert)
Windows only

* Trace tests hop to hop connectivity till final end.

Getting started for end to end data delivery:

Session 10/2

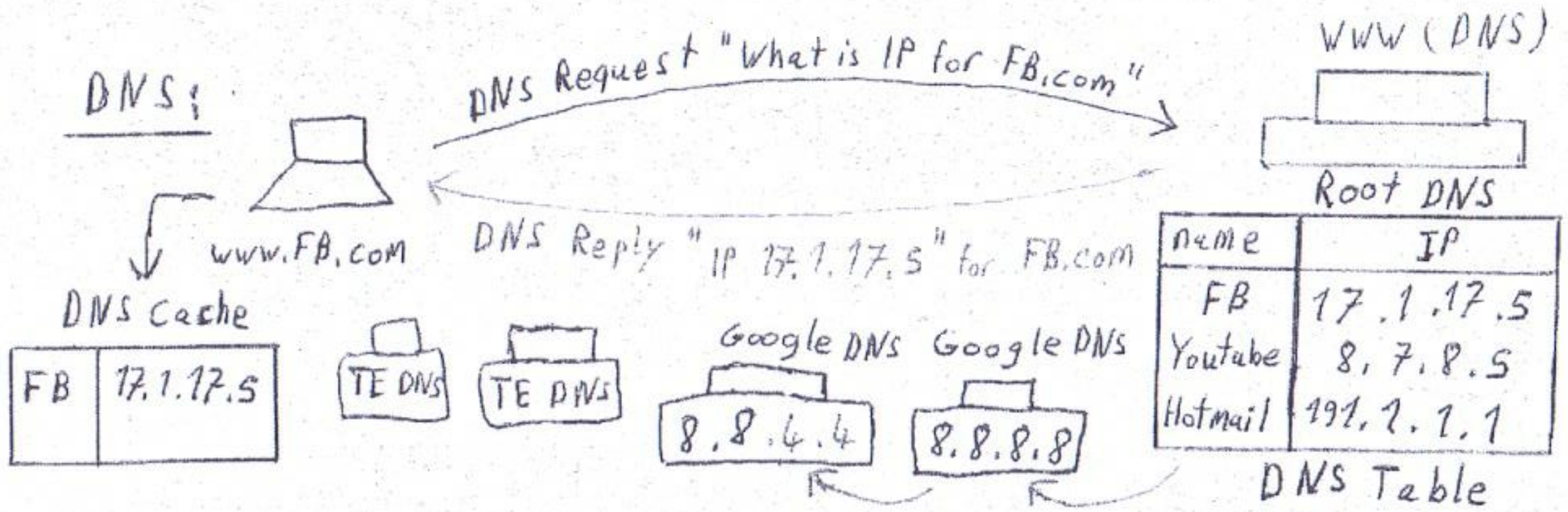
Source MAC	Source IP	Dst. IP	Dst. MAC next hop MAC
Burnt on ROM of DTE's NIC	• Manual • Automatic	DNS	ARP
Physical / H/W Address			

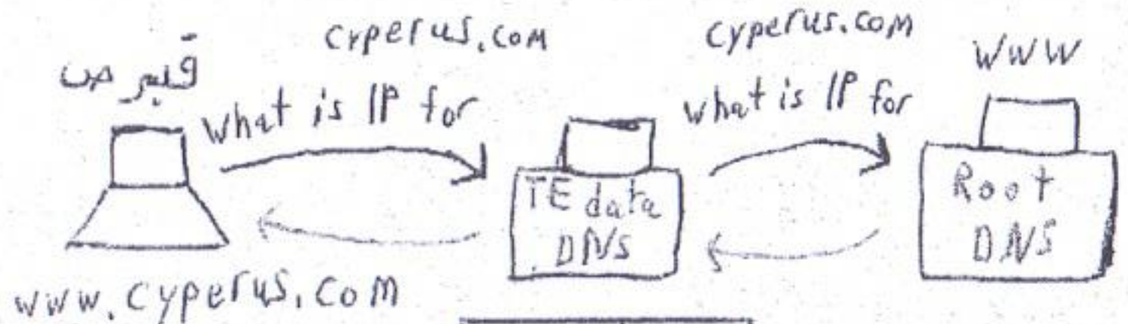


Source IP → (Manual / static) IP, Subnet Mask, Default Gateway, DNS.

Dst: IP → DNS = Domain Name Service
= Domain Name Server
= Domain Name System

DNS: Connects URLs with their IP Addresses.





WWW → name

IANA → IP

* TE Data DNS will flush inaccessible websites after 24 hours.

Name	IP
Cyperus	....

⇒ TE Data DNS

Session 10/3

Source IP: (Automatic)

- DHCP: Dynamic Host Configuration Protocol

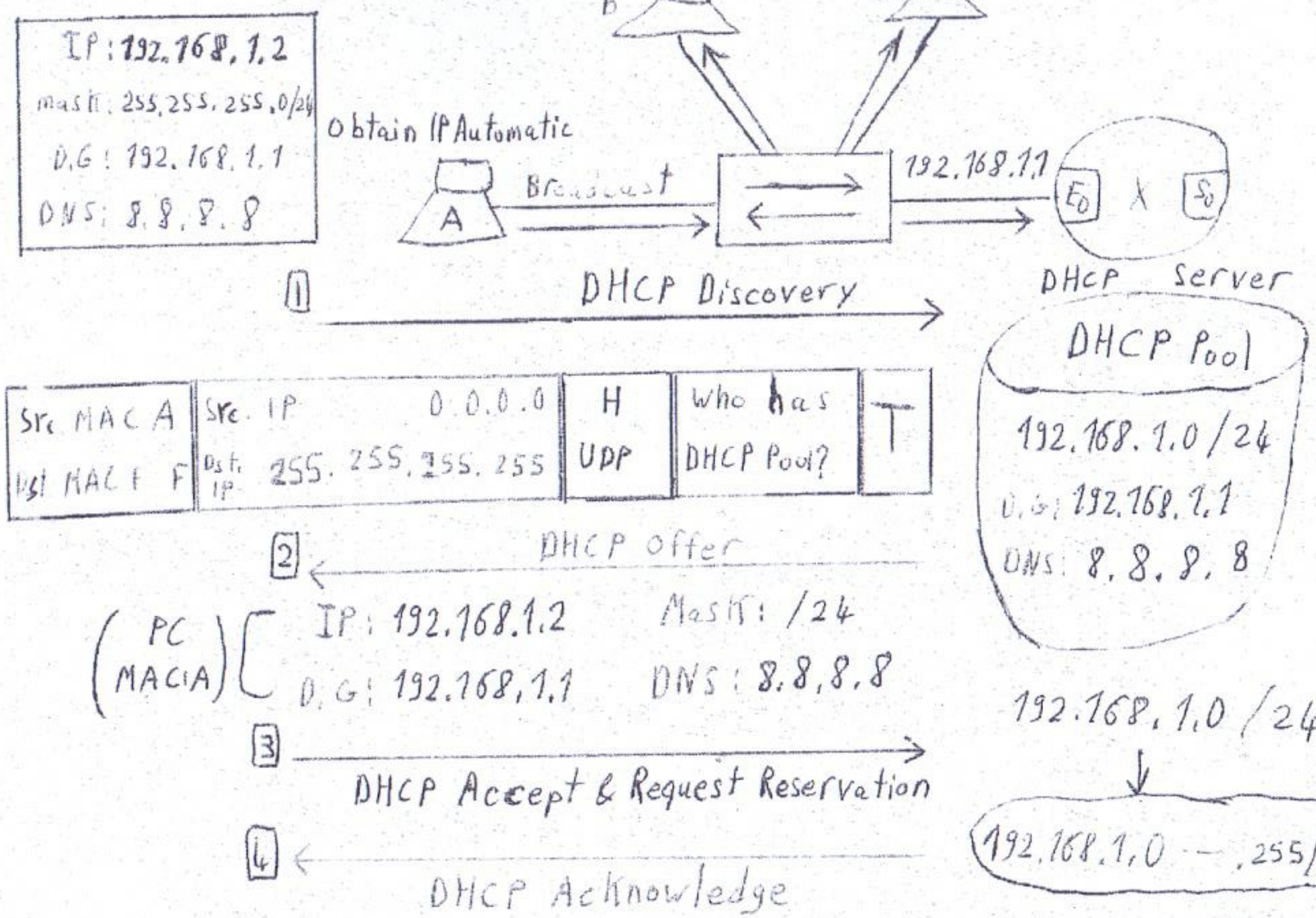
A network protocol that enables a server to automatically assign (IP Address, DNS, Default Gateway, subnet mask) to each host from a defined range of numbers configured for a given network.

* When the user is unable to contact the DHCP server because it is unavailable, APIPA will be activated.

- APIPA: Automatic Private IP Address

Enables a host to automatically assign itself an IP Address (Private) from a range of addresses (169.254.X.X/16)

* APIPA Addresses are invalid on the Internet, so that the hosts with these addresses can communicate on LAN only. (no DNS, no default gateway)
(IP Address & SubnetMask only)

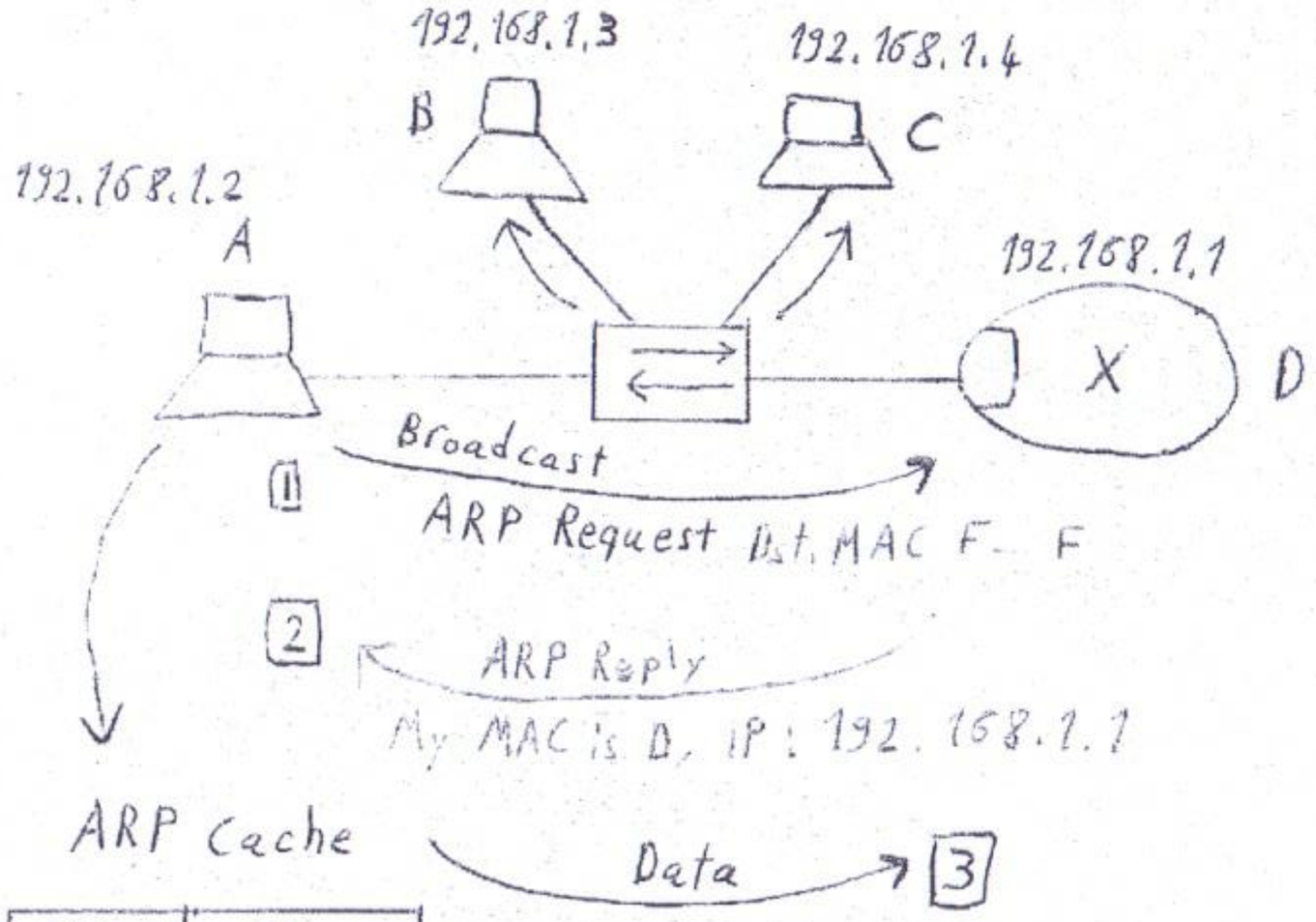


Session 10/4

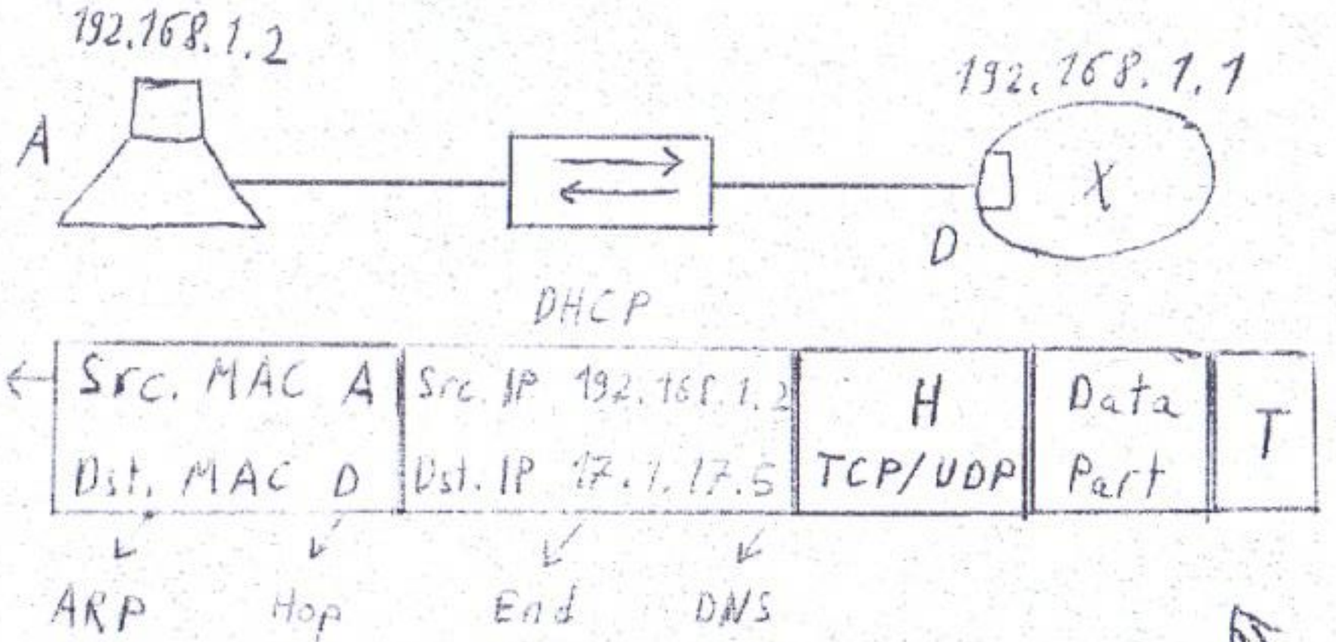
D.t. MAC (next hop MAC) → ARP

• ARP : Address Resolution Protocol

Resolve unKnown MAC Address, finding an address of a computer at a networK.



MAC	IP
B	192.168.1.3
C	192.168.1.4
D	192.168.1.1 → Default Gateway



=> Troubleshooting end-to-end data delivery:

Using ICMP (Internet Control Messaging Protocal)

1. Echo request / echo reply message:

Ping IP address

Command to test end to end connectivity ...

* windows : 4-echo . add (-t) windows : ∞-echo
* linux : ∞-echo . "Press ctrl+C to stop"
* IOS : 5-echo (Apple, Android).

2. TTL expired:

Tracert
Traceroute IP Address { windows / linux, IOS

Command to Identify the path hop-to-hop ...

=> Getting started for end-to-end data delivery:

Source MAC	Source IP	dst IP	dst MAC

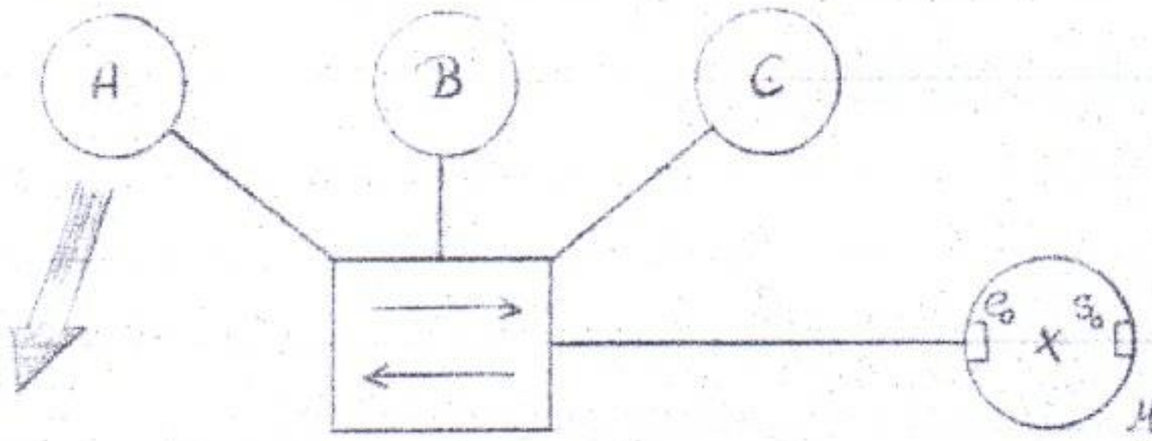
Source MAC: Burnt on ROM of NIC

Source IP:
- Manual : (static) IP, Mask, Default gateway, DNS
- Automatic : RARP (Reverse ARP), Boot P (Booting Protocal) DHCP (Dynamic Host Configuation Protocal), APIPA.

dst IP: DNS

dst MAC: ARP

DHCP :



SrC MAC : A dst MAC : FF..F	SrC IP: 0.0.0.0 dst IP: 255.255.255.255	Header UDP	who is DHCP server?	T

DHCP Discovery →

DHCP Pool

DHCP Offer

IP: 192.168.1.2 D.G: 192.168.1.1

Mask: /24 DNS: 8.8.8.8

DHCP Accept & Request Reservation →

DHCP Acknowledgement

DNS - Domain Name" Server, Service, System" :

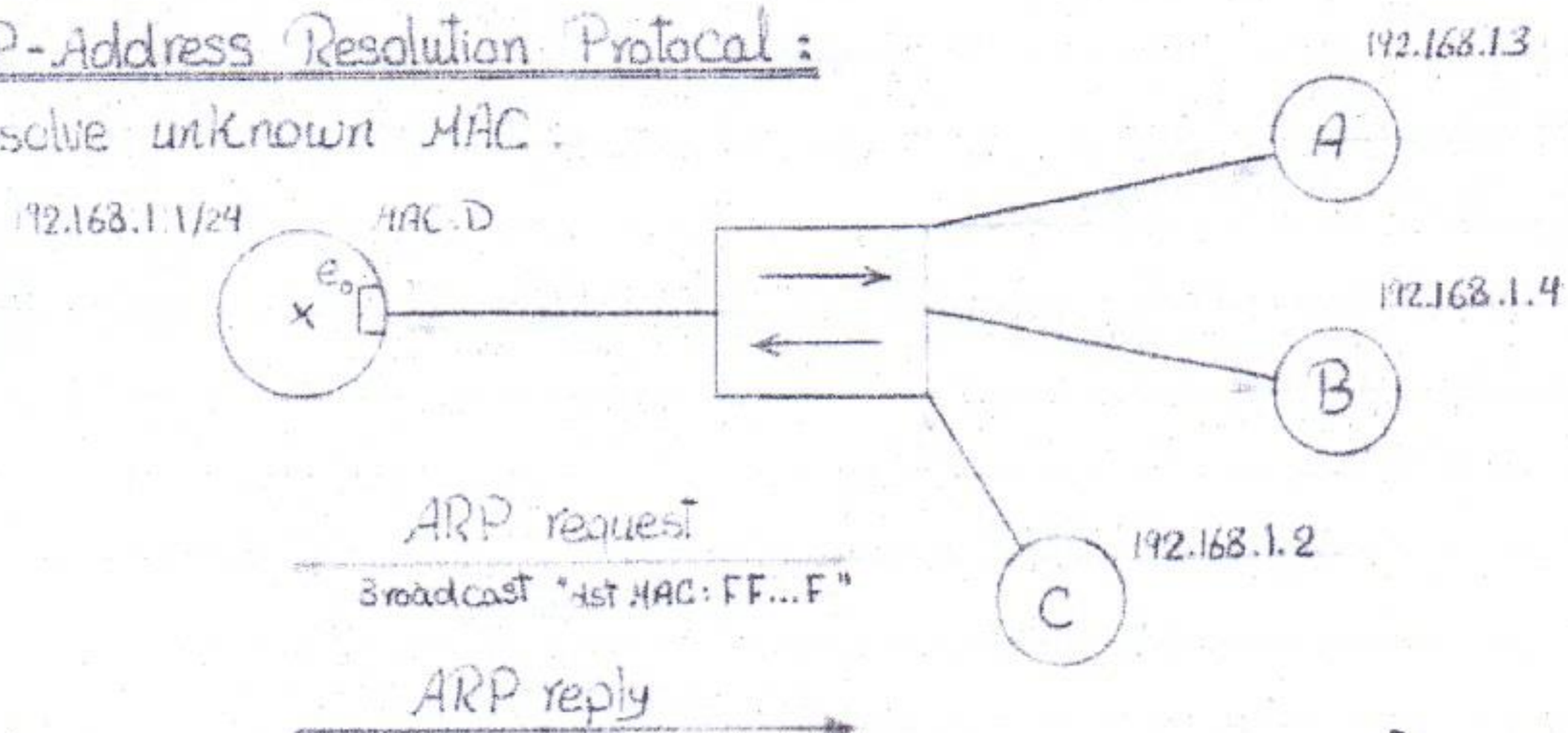
Resolve destination IP.

- world wide web ... Root DNS ...
- Service Provider :

TE-Data DNS	163.121.128.134,	163.121.128.135
Google DNS	8.8.8.8 ,	8.8.4.4

ARP - Address Resolution Protocal :

Resolve unknown MAC :



IP Address	MAC Address
192.168.1.3	A
192.168.1.4	B
192.168.1.1	D

ARP Cache
any DTE make this table ...
to display it :
Command in CMD : arp -a

All Commands :

- To open CMD
  - Start menu → Run → CMD
  - Windows + R → CMD
- getmac
  - MAC Address

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- For the given host 197.3.4.130/25

Find subnet address & direct broadcast,

197 ⟶ Class C

$2^{32-25} = 2^7 = 128$ IP

197.3.4.0 / 25 ⎤
| ⎦ subnet
197.3.4.127/25

197.3.4.128/25 ⎤
| ⎦ subnet
197.3.4.255/25

Another Solution

variable, host = 7

197.3.4.130/25 197.3.4.1000 0010/25

Fixed, network = 25

H=0 : 197.3.4.1000 0000 = 197.3.4.128

H=1 : 197.3.4.1111 1111 = 197.3.4.255

X X X X x x x x
128 64 32 16 8 4 2 1

- For the given host address 200.7.8.65/26

Find subnet Address & Direct Broadcast Address

200.7.8.65/26 200.7.8.0100 0001/26

n = 26 h = 6

H=0 : 200.7.8.0100 0000 = 200.7.8.64

H=1 : 200.7.8.0111 1111 = 200.7.8.127

- For the given host address 173.15.5.0/23

Find Subnet Address & Direct Broadcast Address

173.15.00000101.00000000

n = 23 n = 9

H=0 : 173.15.0000 0100.0000 0000 = 173.15.4.0

H=1 : 173.15.00000101.1111 1111 = 173.15.5.255

173.15.4.0 ⎤
| ⎦ 256 IP
173.15.4.255 ⎤
173.15.5.0 ⎦ 512 IP
| ⎤
173.15.5.255 ⎦ 256 IP

Session 11/2

L4: Transport Layer PDU = Segment

It is responsible for end to end delivery control (error control)

1- Segmentation: Divide data into smaller parts
1460 byte

2- Error Detection: Using CRC 2 byte

3- Addressing: Using S/W Port no.
16 bit = (0 - 65,535)

0 - 1023
Well Known / Registered
Ports & used by [servers]

20, 21 → FTP
23 → Telnet
25 → SMTP
53 → DNS
22 → SSH (Secure Shell)
Encrypted Telnet

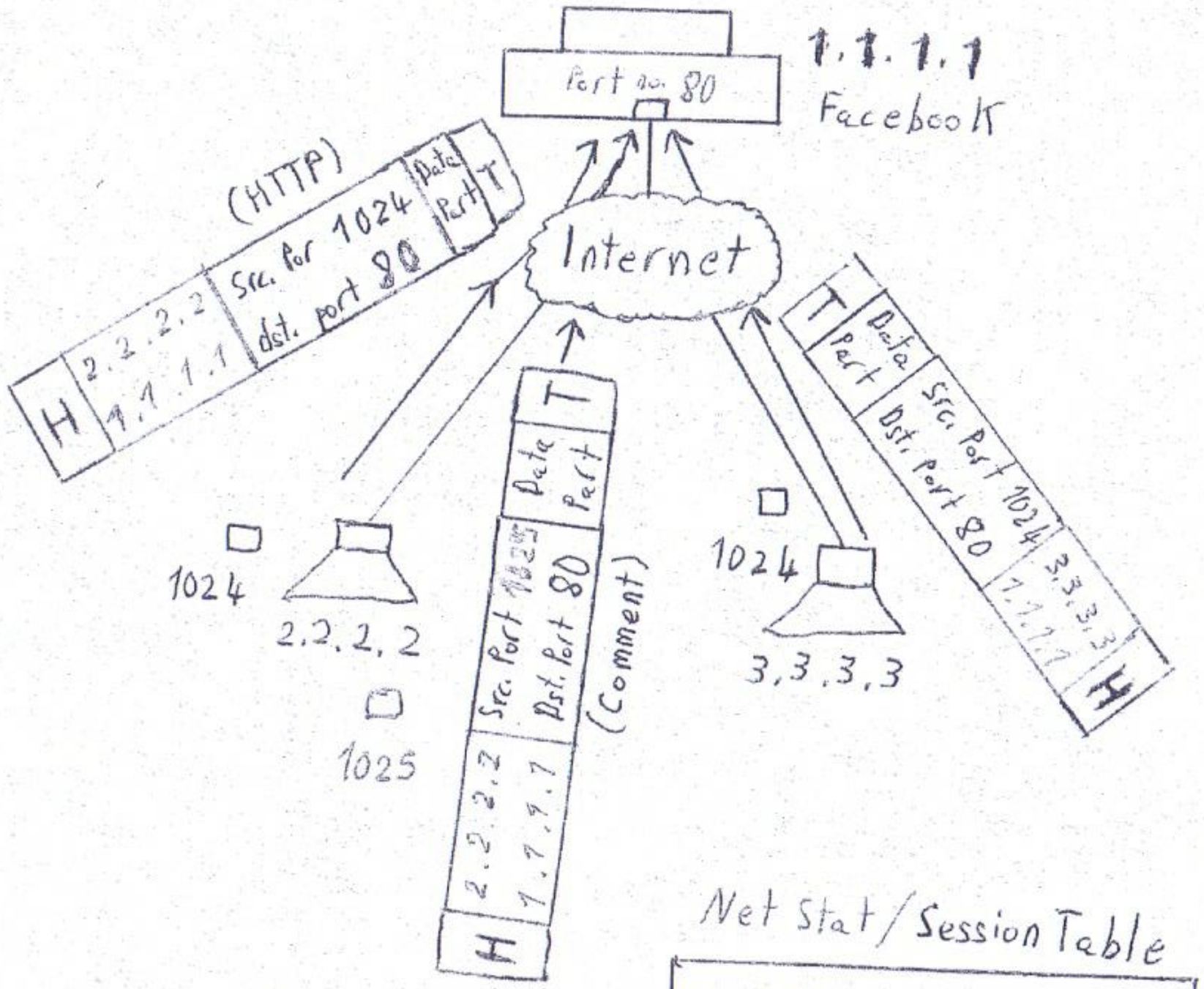
1024 - 65,535
UnKnown / Unregistered
Ports & used by [users]

as session no. =

src. port : Host's window

Well Known ports:

67, 68 → DHCP 110 → POP 3
80 → HTTP 443 → HTTPs Encrypted HTTP



IP : Port
32 bit : 16 bit

Socket no. = Session id

Net Stat / Session Table

1- 2.2.2.2 : 1024 → Session 1
2- 2.2.2.2 : 1025 → Session 2
3- 3.3.3.3 : 1024 → Session 3

Session 11/3

L4: Transport Layer

1- Segmentation

2- Error Detection

3- Addressing:

1024 – 65,535

UnKnown Ports

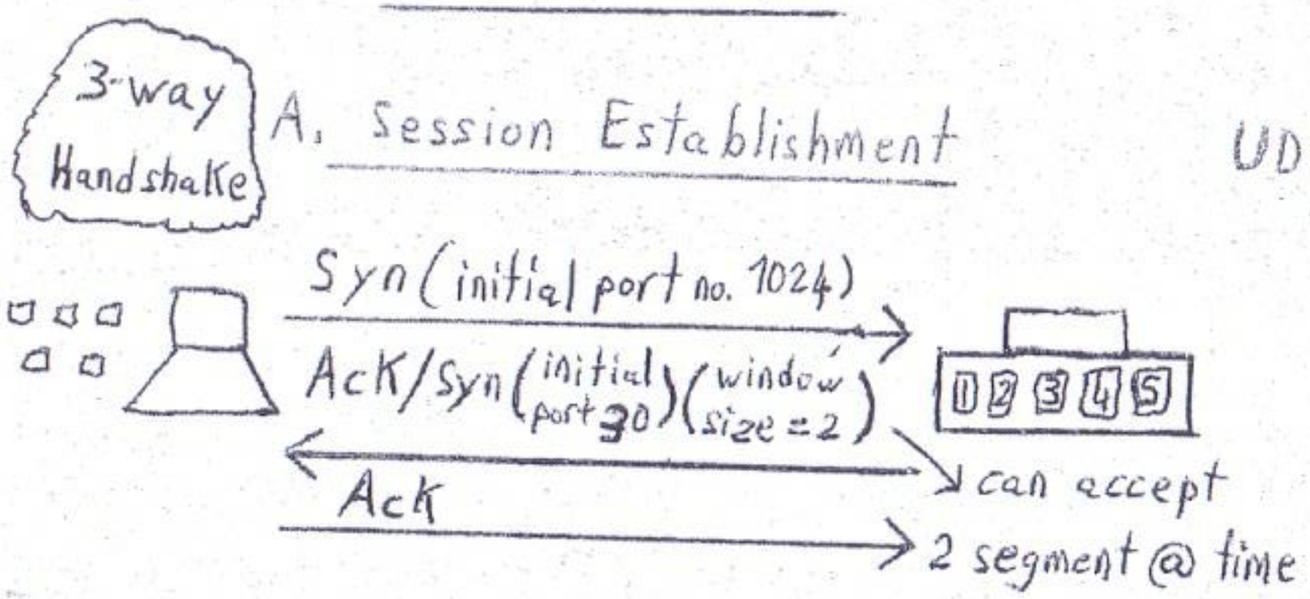
UDP Header (8 byte)

Src. Port 2 byte	Dst. Port 2 byte
Length 2 byte	CRC 2 byte
Data Part	

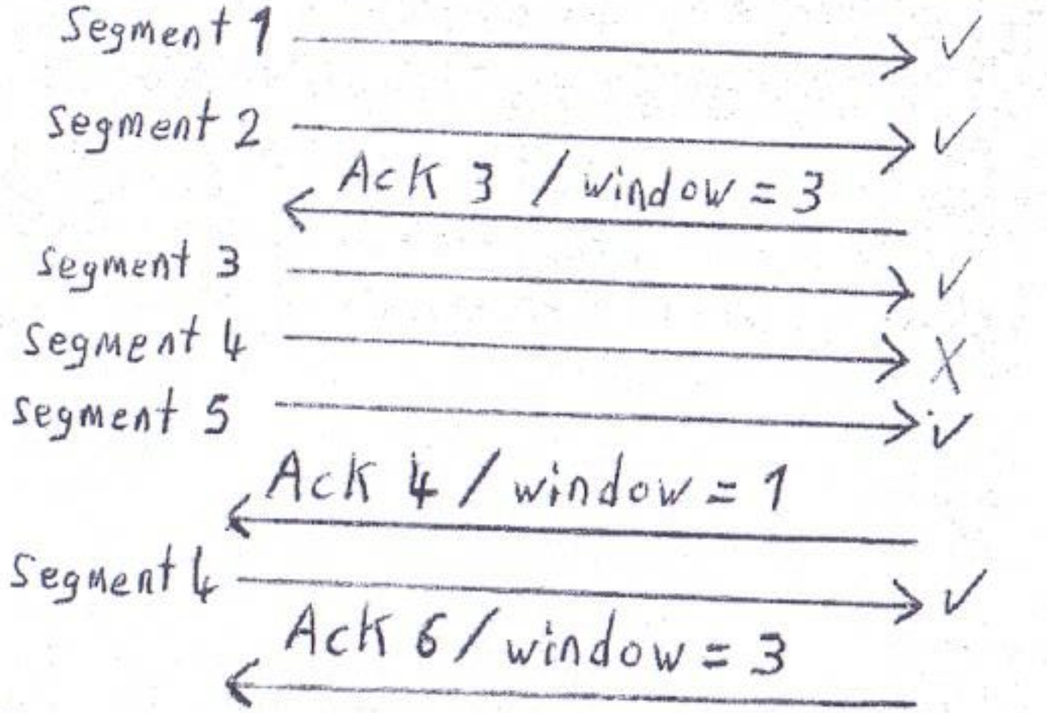
Length = Data Length

4- For TCP only:

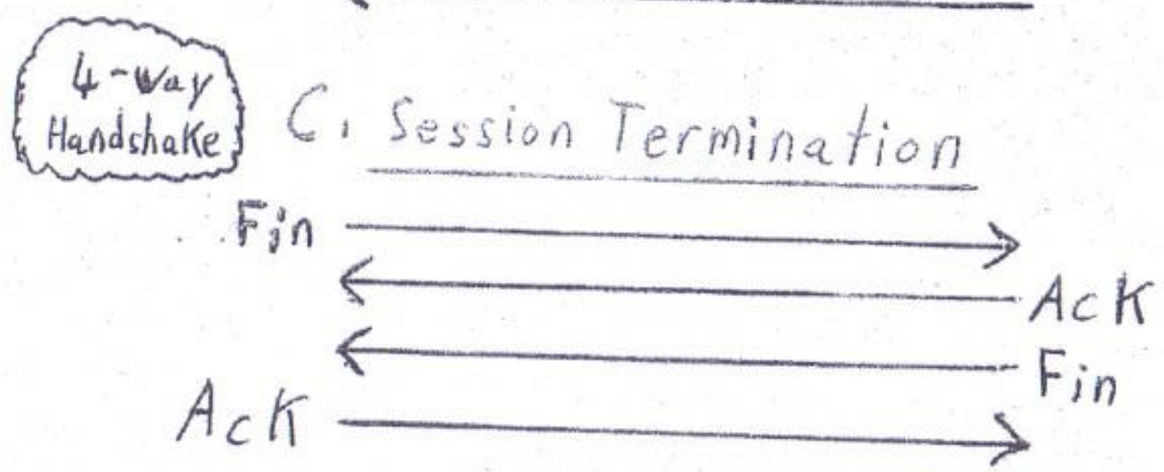
A. Session Establishment



B. Session Management & Control



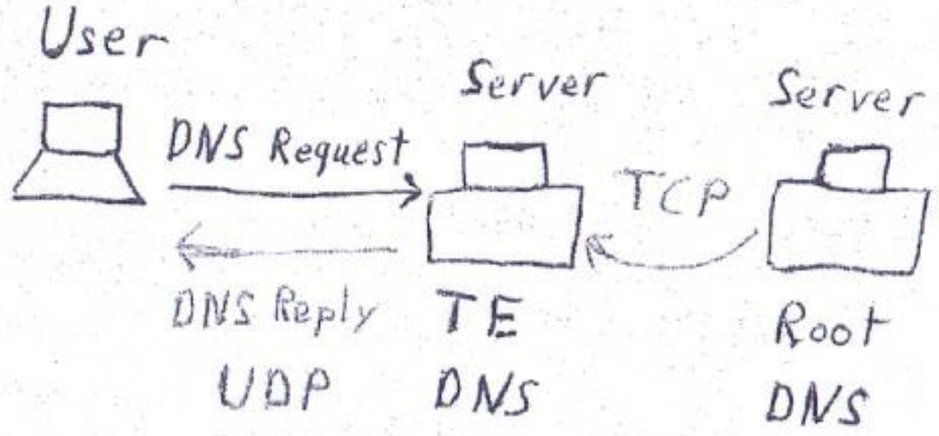
C. Session Termination



TCP → HTTP - SMTP - POP3 - FTP - Telnet - HTTPs

UDP → RTP - DHCP

* DNS
- TCP → Server
- UDP → User



TCP → Accuracy

UDP → Achievement

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Routed Protocol

It is protocol that carry user data traffic from end to end,

By providing:

- Logical Addressing < IP address, Port no. > socket no.
- Encapsulation from end to end
  - IP_{V4} Header
  - TCP/UDP Header

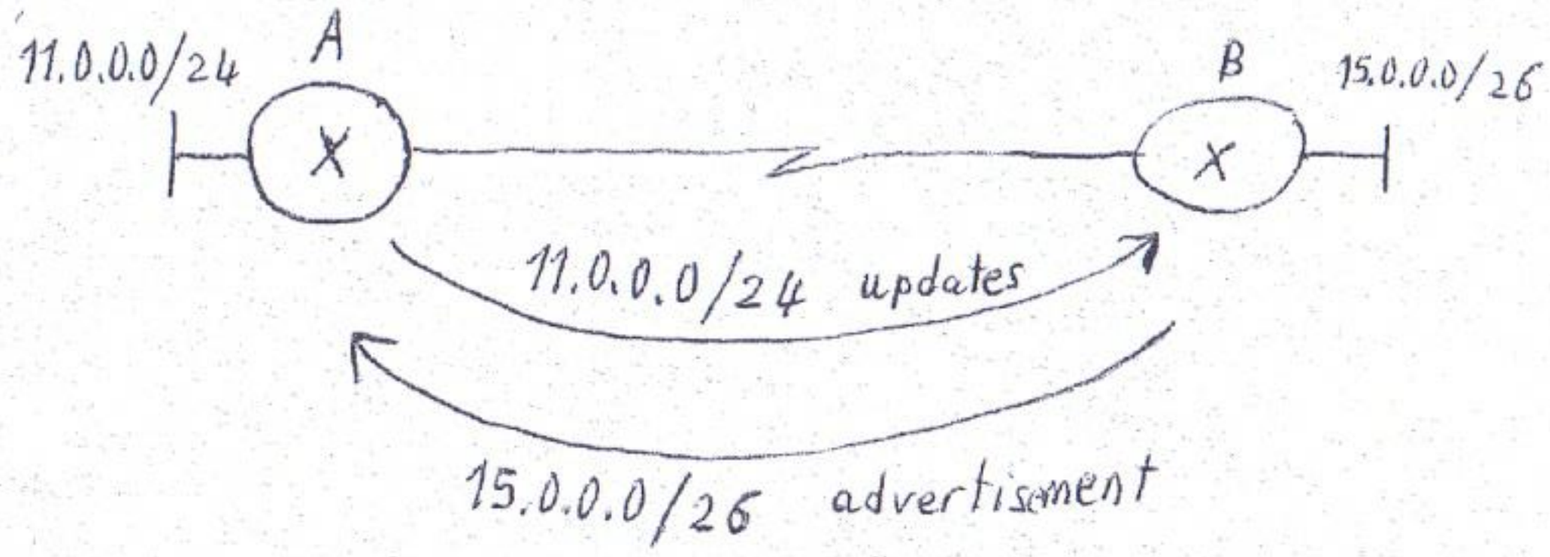
Ex: IP_{V4} , IP_{V6}

IPX, APPle TalK

TCP & UDP

Routing Protocol

It is exchange of information between Routers, so as each router tell others about networks it can reach,



Advertisement = Updates

& Protocols

RIP_{V1}	IGRP	ISIS	EGP	→ old
RIP_{V2}	EIGRP	OSPF	BGP	→ new

- RIP_{V1}: no subnetting, classfull (A, B, C)
- RIP_{V2}: Knows subnetting, Classless
- EIGRP: Enhanced

- ipConfig
  IP Address, Subnet mask, and Default getway.
- ipConfig /all
  IP Address, Subnet mask, Default getway, MAC Address, and DNS.
- 127.0.0.1
  Test TCP/IP model.
- 127.0.0.1 -t
  Continue ping press Contral + C to Cancel ping.

- Add IP & DNS manual:
  There is an icon which Consist of 2-Computers in the toolbar & double click on TCP/IP.

OR

- Start menu → Contral panel → Network & Internet → Network & Sharing Center → Change adapter Settings → right click on any icon then Properties → double click on TCP/IPv4.

Layer 4 - Transport layer:
It is responsible for end-to-end delivery Contral. PDU: Segment.

1. Segmentation:
   Dividing data into smaller parts.
2. Error detection:
   Using CRC.
3. Session Addressing:
   Using Software port Numbers (16-bits).
   - 0-1023: well Know ports used by servers
   - 1024-65535: Unregistered ports used by user as session no.

Number of Ports used by servers :

Protocal	Port No.
File Transfer Protocal (FTP)	20/21
Secure Shell (SSH)	22
Telnet	23
Simple Mail Transfer Protocal (SHTP)	25
Domain Name System (DNS)	53
Dynamic Host Configuration Protocal (DHCP)	67/68
Trivial File Transfer Protocal (TFTP)	69
Hypertext Transfer Protocal (HTTP)	80
Post Office Protocal (POP) version 3	110
Simple Network Management Protocal (SNMP)	161/162
Border Gateway Protocal (BGP)	179
Hypertext Transfer Protocal over SSL/TLS (HTTPS)	443
Open Shortest Path First (OSPF)	89
Enhanced Interior Gateway Routing Protocal (EIGRP)	88
Routing Information Protocal version 2 (RIPv2)	520

Command in CMD :
netstat
To display session table.

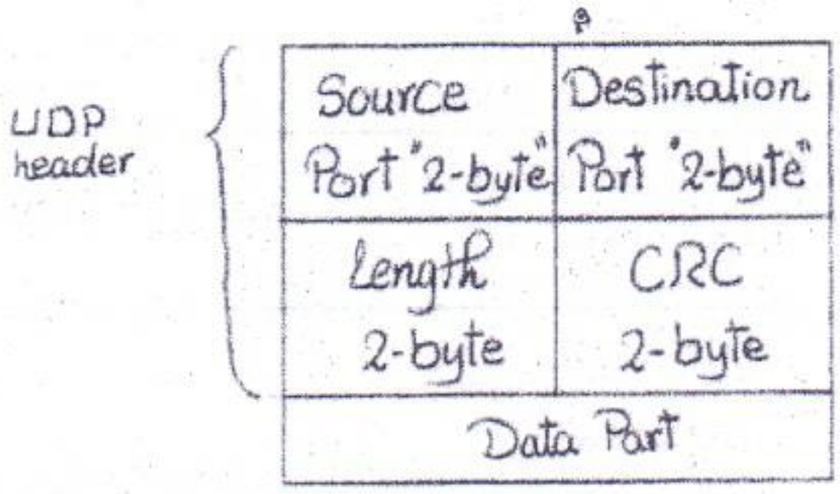
Layer 4 - Transport Layer:

User Datagram Protocal (UDP):

Header is 8-byte. It is high Speed & Low accuracy. (4 way handshake).

Applications:

DHCP, RTP, Boot P, TFTP, SNMP...



Transmission Contral Protocal (TCP):

Header is 20-byte. It is high accuracy & low Speed. (7 way hand shake).

Applications:

HTTP, HTTPs, FTP, SMTP, POP3, Telnet, SSH ...

For TCP only (Connection Oriented):