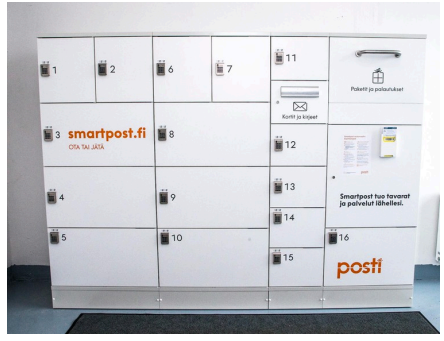
Introduction to Networks

Aalto University
School of Electrical
Engineering

Yu Xiao

17.1.2022

Post Delivery



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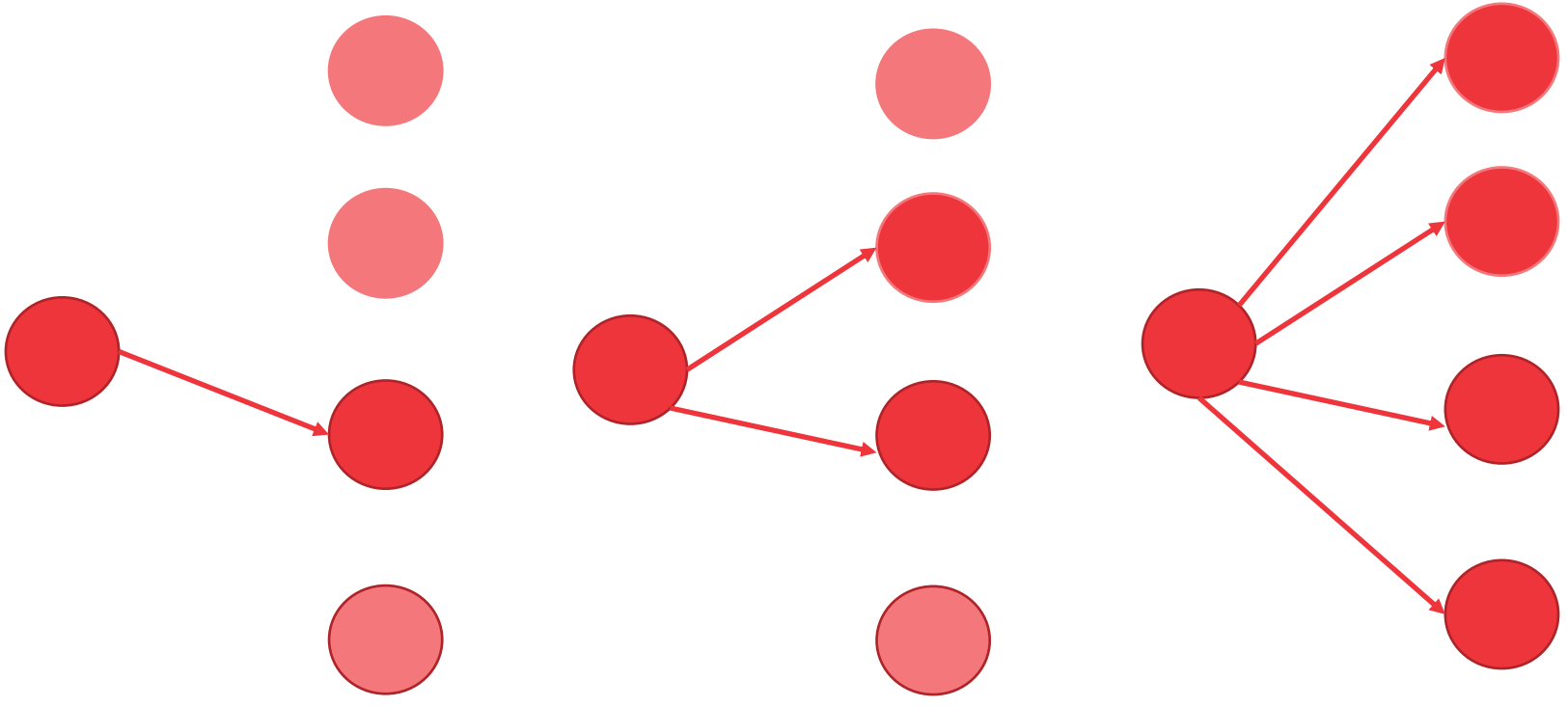
Unicast, Multicast, Broadcast



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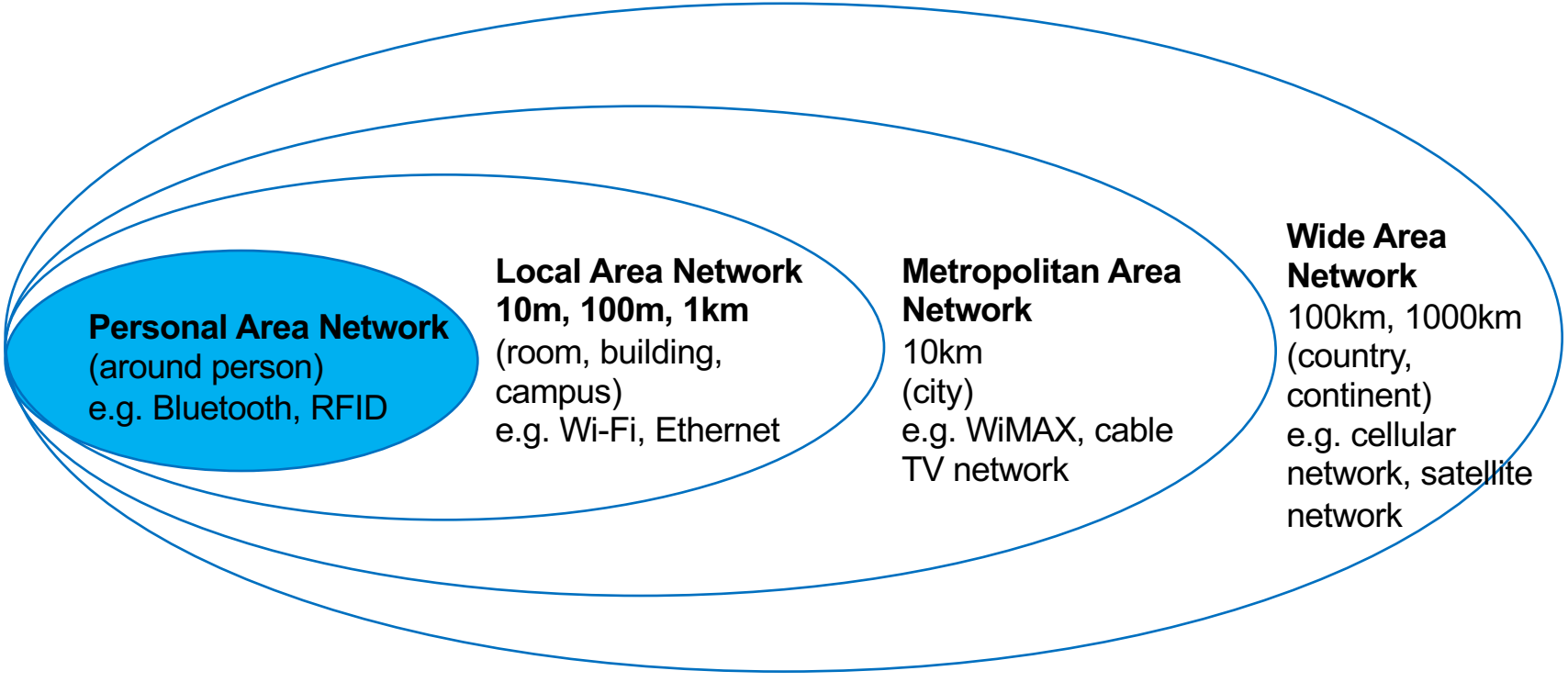
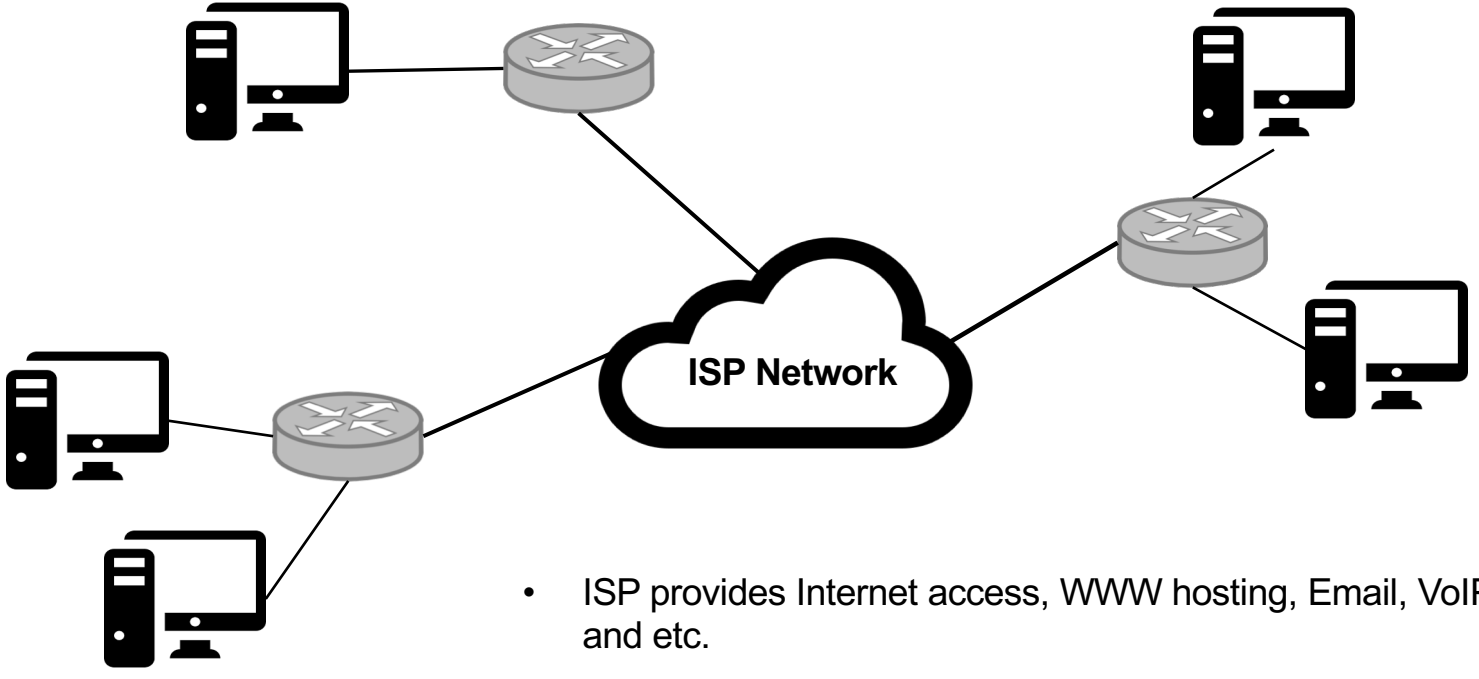
Network Types



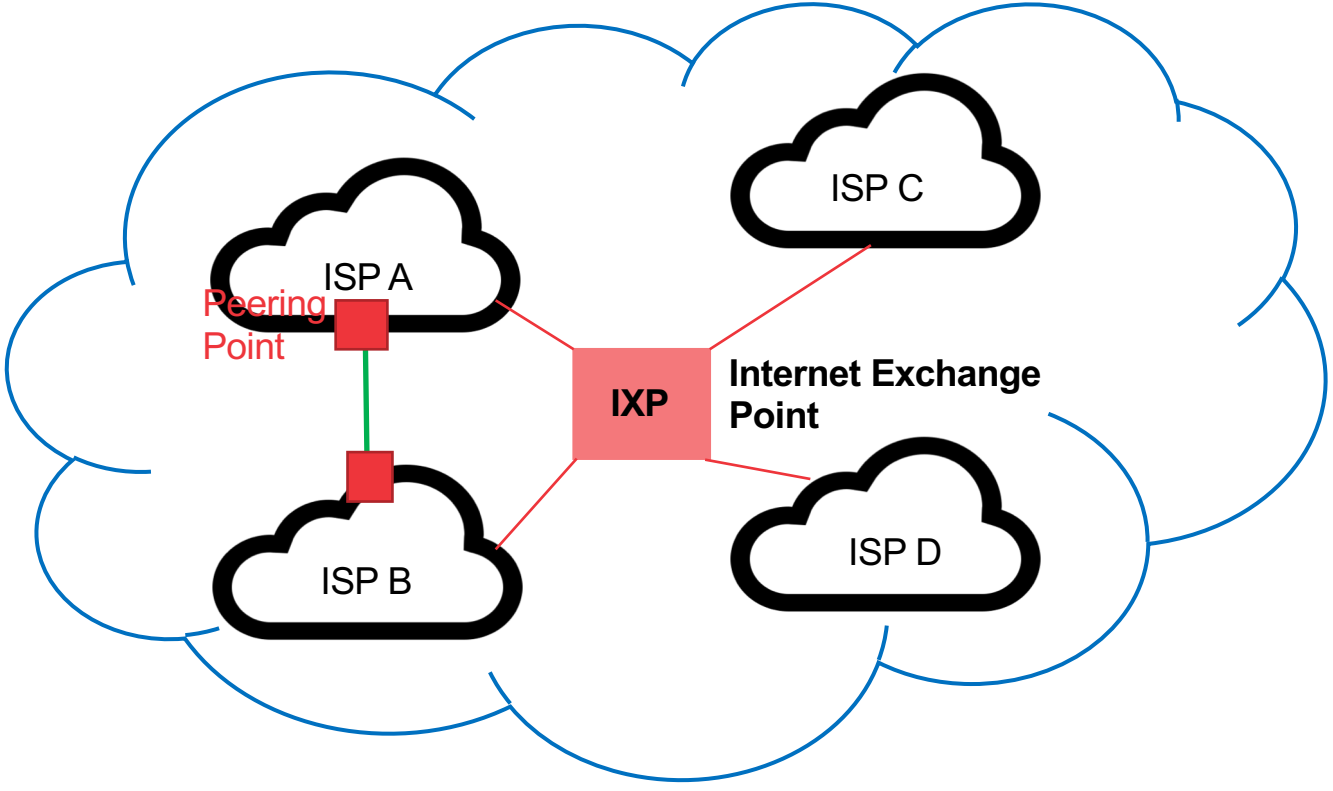
Internet (Interconnected Networks)

- **Internet Service Provider (ISP), e.g. Elisa, DNA, Telia**

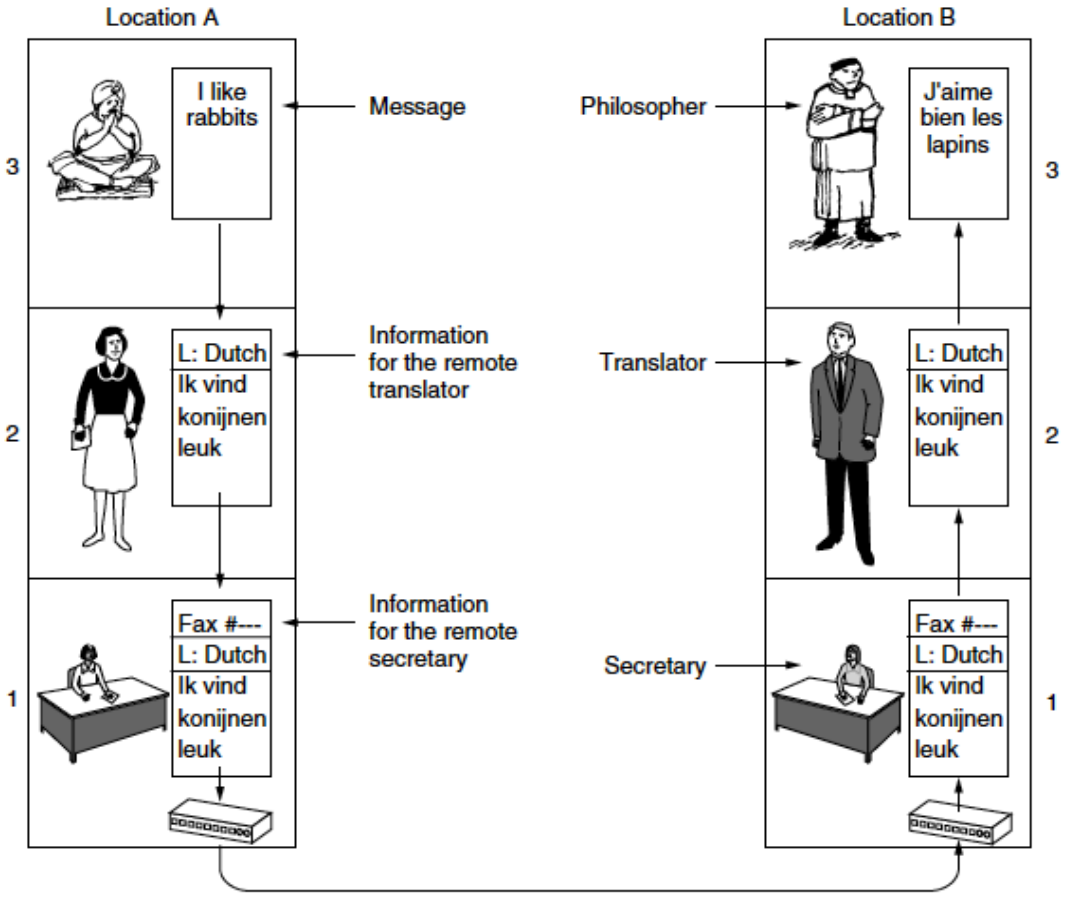


- ISP provides Internet access, WWW hosting, Email, VoIP and etc.

Internet

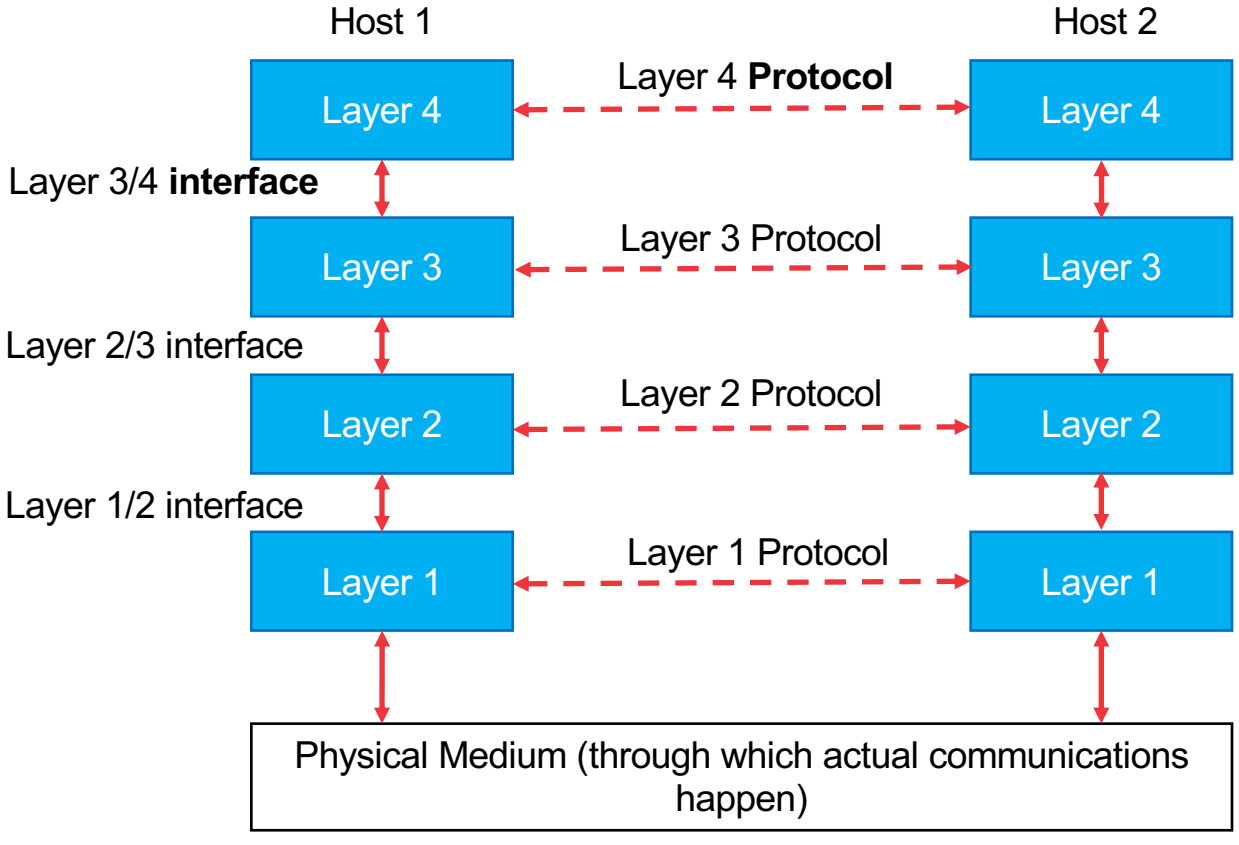

ISP C
ISP A
Peering
Point
IXP
Internet Exchange
Point
ISP B
ISP D

Multilayer Communications



Source: Tanenbaum and Wetherall. Computer Networks.

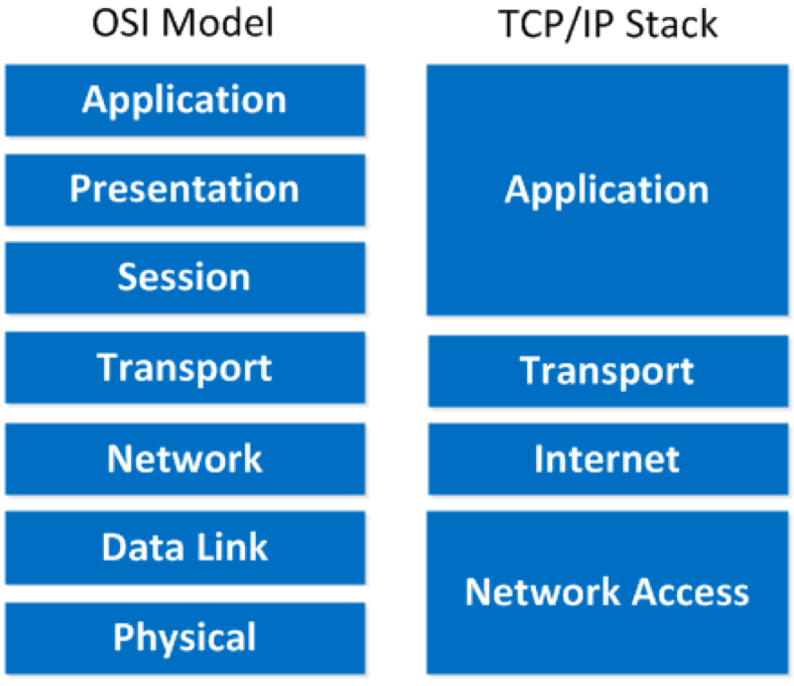
Network Hierarchies



A **protocol** is an agreement between the communicating parties on how communication is to proceed.

The **interface** defines which primitive operations and services the lower layer makes available to the upper one.

OSI Model and TCP/IP Stack

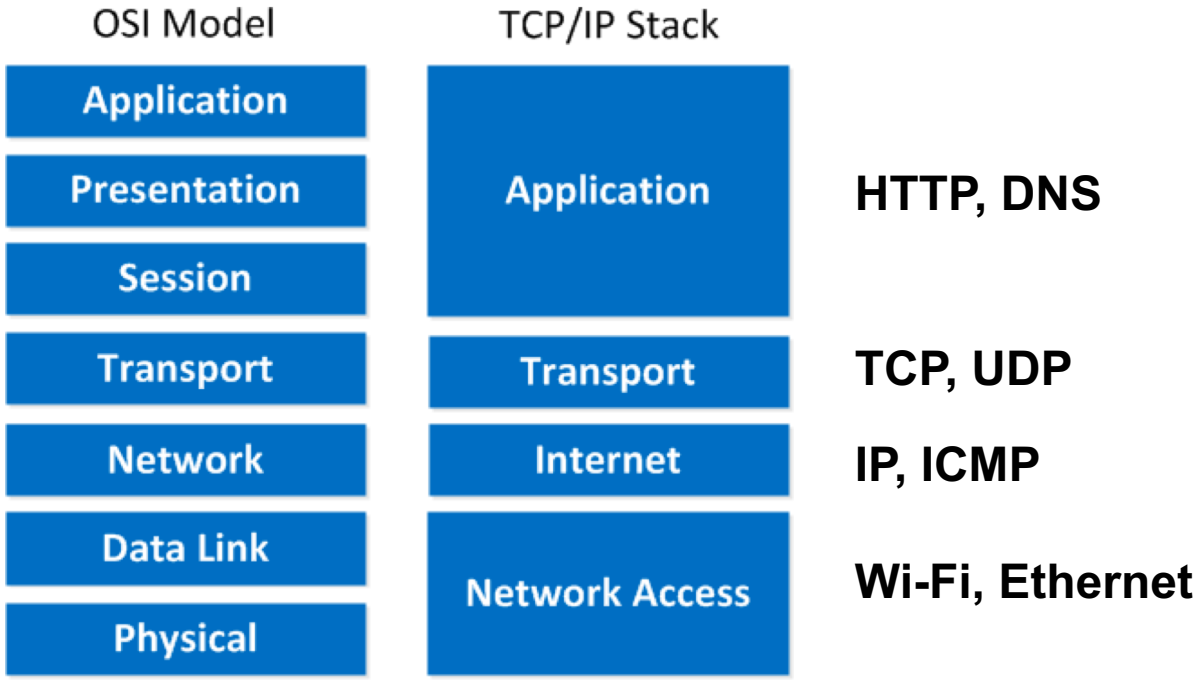


Open Systems Interconnection (OSI)

OSI Model

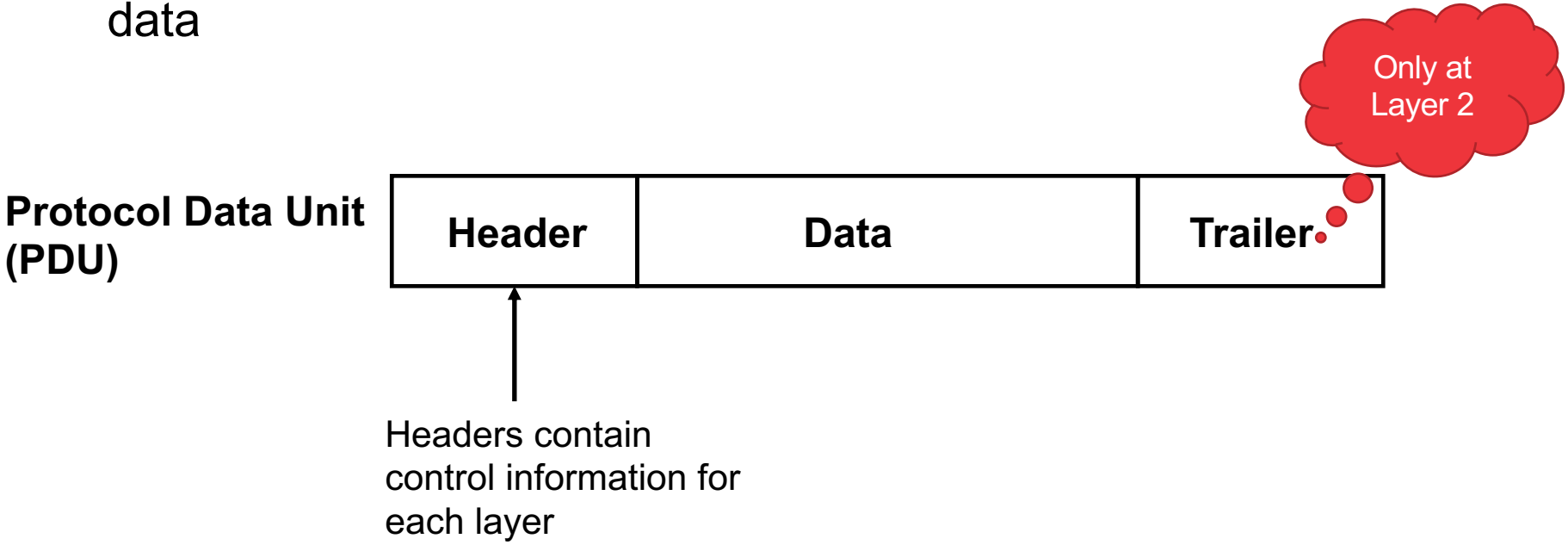
7 Application	Serves as the window for users and application processes to access the network services.	Data
6 Presentation	Formats the data to be presented to the Application layer. It can be viewed as the “Translator” for the network.	Data
5 Session	Allows session establishment between processes running on different hosts	Data
4 Transport	Ensures that messages are delivered error-free, in sequence, and with no losses or duplications	Segments
3 Network	Determine how packets are routed from source to destination	Packets
2 Data Link	Provides error-free transfer of data frames from one node to another over the Physical Layer.	Frames
1 Physical	Transmission and reception of the unstructured raw bit stream over the physical medium.	Bits

Example Protocols

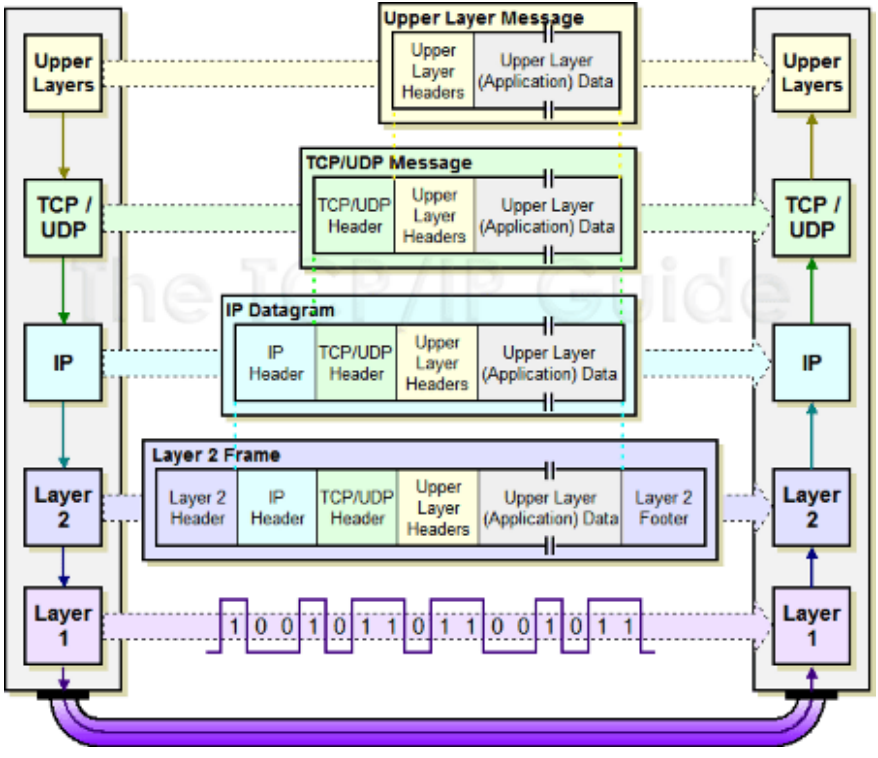


Data Encapsulation

- **Encapsulation:** The process of adding headers and trailers to data



Data Encapsulation



Source: https://buildingautomationmonthly.com/what-is-the-tcp-ip-stack/

Why do we need the model?

Why do we need the model?

- Enables different vendor equipment to work together
- Creates industry standards
- Divides a complicated process into smaller, more easily understood components
- Makes development easier

Ethernet

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Learning Outcomes

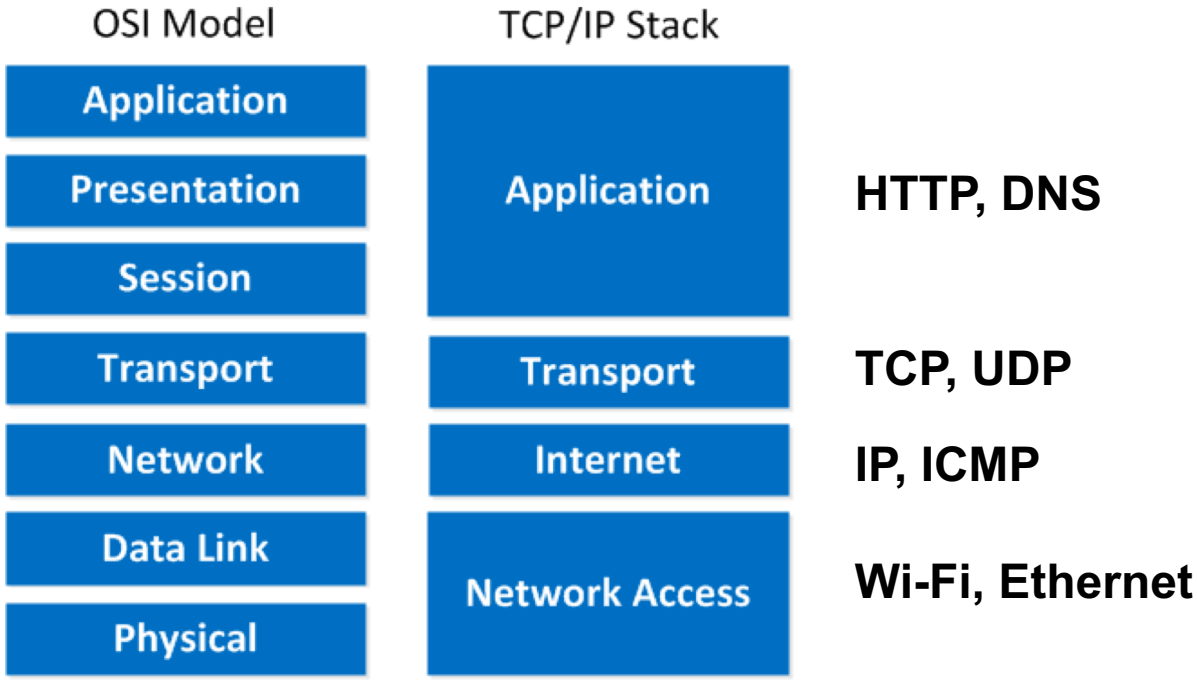
By the end of this lecture, you will be able to

- **Understand packet-based data transmission at the data link layer**

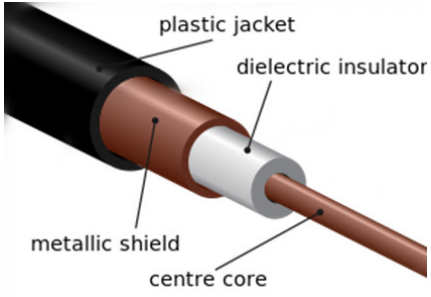
Network Access Layer (Layer 1& 2 in OSI Model)

e.g. 802.3 Ethernet, 802.11 Wi-Fi, 802.15.4 ZigBee

Example Protocols



Hardware



Coaxial Cable

- Easy to install
- Relatively resistant to interference
- Bulky and just ideal for short length, due to high attenuation
- Expensive for long distance comm.

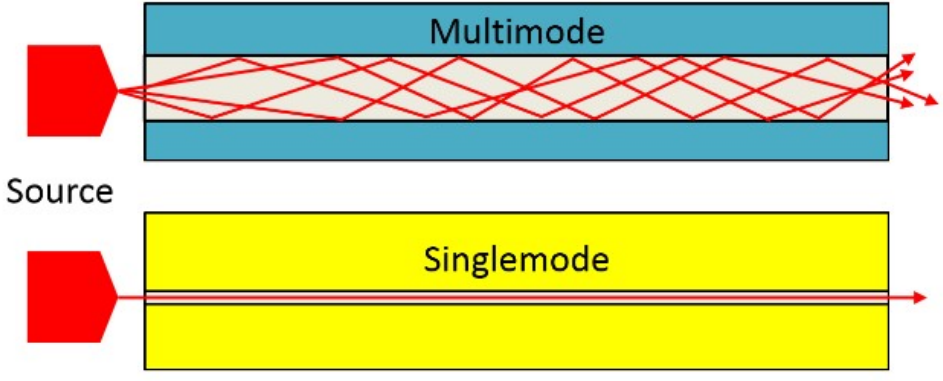
Unshielded/Shielded Twisted Pair Cables

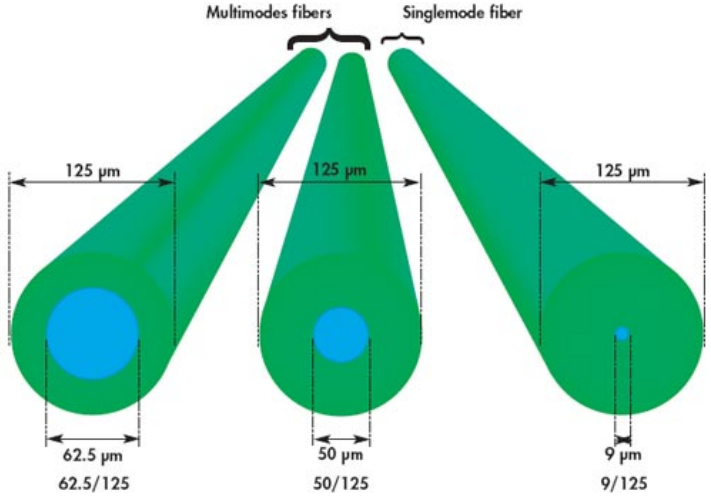
- UTP is commonly used in Ethernet networks and STP in Token Ring networks
- Cheap, easy to install and operate
- Relatively low bandwidth, due to attenuation
- Susceptible to interference and noises

Fiber Optic Cables

- Small in size and light in weight
- Immune to electromagnetic interference
- Transmit a big amount of data with low loss at high speeds over long distance
- Difficult to install, expensive in short run

Multimode vs. Single Mode Fiber





Multimode:

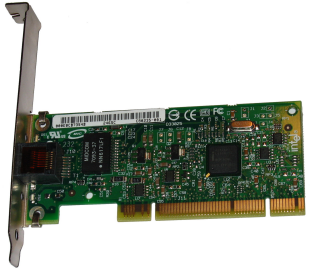
- Light waves are dispersed into numerous paths, or modes.
- May cause signal distortion at the receiving end in long cable runs.
- Used in short distance communications (up to 2KM)

Single Mode:

- Carry a single ray of light
- Small core
- Higher bandwidth
- Uses as backbone and long distance communications (hundred kilometers)
- More expensive

Gigabit Ethernet

- Gigabit Ethernet refers to technologies for transmitting Ethernet frames at a rate of a gigabit per second, as defined by the IEEE 802.3-2008 standard. (source: Wikipedia)
- E.g. 1000BASE-T is a standard for Gigabit Ethernet over copper wiring, and 1000BASE-X for optical fiber



Intel Pro/1000 GT PCI Network interface controller

Small Form-factor Pluggable (SFP) - transceiver

NETGEAR 5-Port Gigabit Ethernet Unmanaged Switch

PCI: Peripheral Component Interconnect

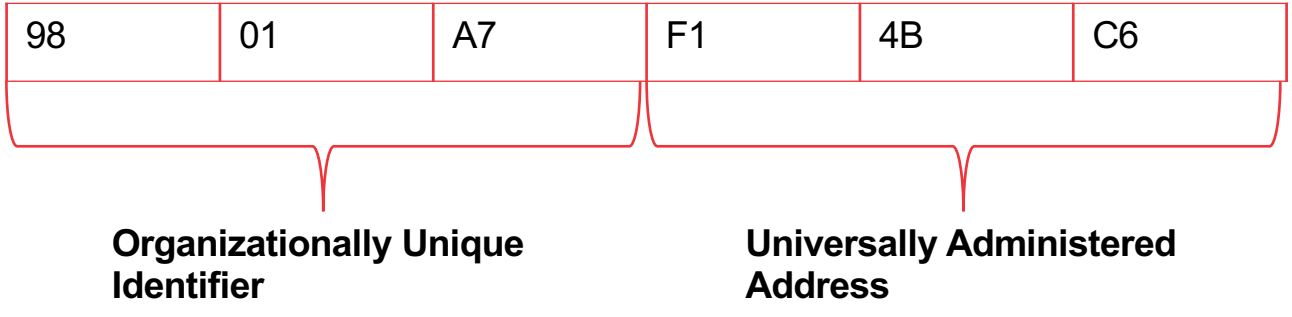
Data Link Layer (Layer 2) has two sub-layers.

- IEEE 802.2 Logical Link Control (LLC)
- **IEEE 802.3 Media Access Control (MAC)**

IEEE stands for Institute of Electrical and Electronics Engineers

MAC Address

- A MAC address is a **unique identifier** assigned to a network interface controller (NIC) by manufacturer
- Used for communications at the data link layer
- Ethernet addresses are 6 bytes long



Hexadecimal (base 16)

0-9, A-F

0000 0000 0x00

1111 1111 0xFF

98	01	A7	F1	4B	C6

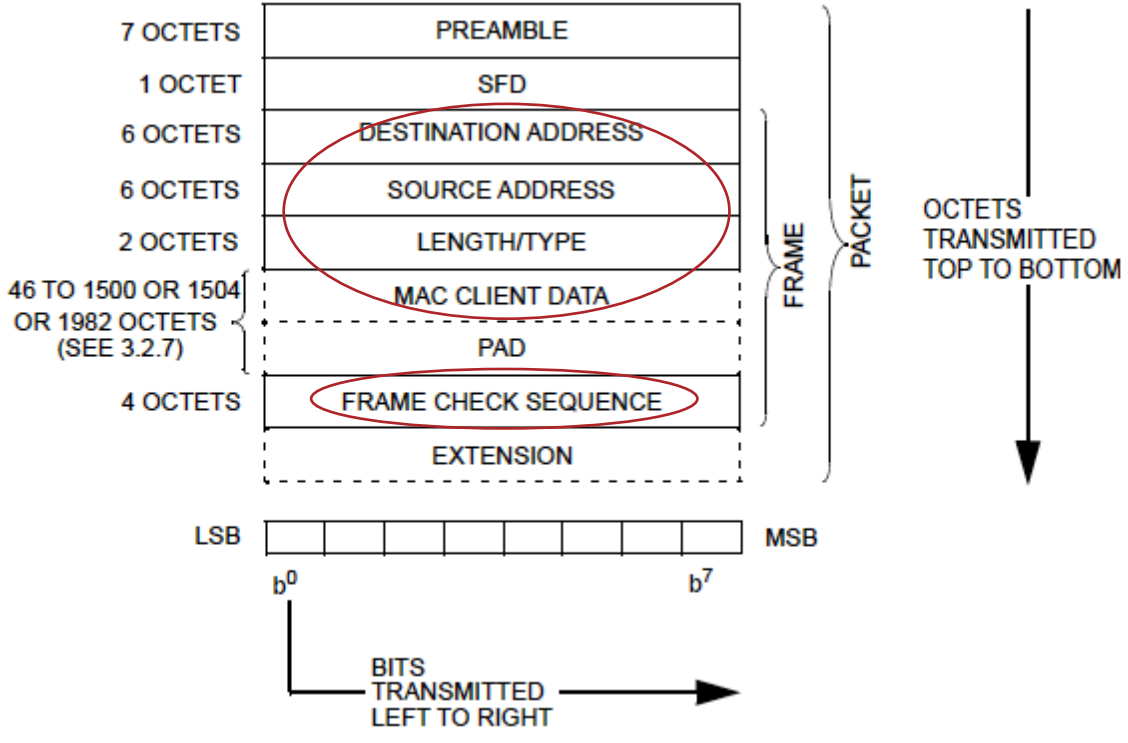
98:01:A7:F1:4B:C6

Decimal	Hex	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

You can check the MAC address of your computer and phone

Packet-based Data Transmission

- Ethernet is commonly described as being a packet delivery system



Source: IEEE 802.3-2018

Ethernet Packet

- **Preamble** is a bit sequence used for physical medium stabilization and synchronization.

10101010 10101010 10101010 10101010 10101010 10101010 10101010

- The **Start Frame Delimiter (SFD)** field is the sequence 10101011. It immediately follows the preamble pattern. A MAC frame starts immediately after the SFD.
- Note: 100 and 1000 Mb/s Ethernet systems signal constantly and do not need preamble or start frame delimiter fields.

Ethernet Frame

- **Source and Destination Addresses (48 bits each)**

I/G = 0 INDIVIDUAL ADDRESS
I/G = 1 GROUP ADDRESS
U/L = 0 GLOBALLY ADMINISTERED ADDRESS
U/L = 1 LOCALLY ADMINISTERED ADDRESS

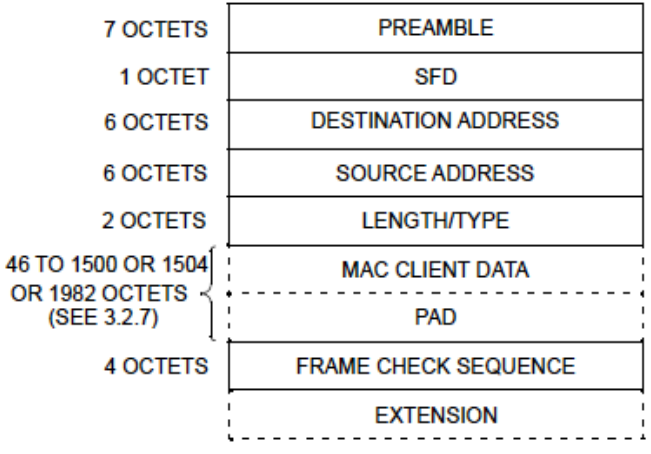
- **Broadcast MAC address is FF:FF:FF:FF:FF:FF**

Ethernet Frame

- **Length/Type Field:**
  - the number of MAC client data octets contained in the following MAC Client Data field, if the field value < or = 1500 decimal
  - Otherwise, the Ethertype of the MAC client protocol (e.g. 1500 basic frames, 1504 Q-tagged frames, 1982 envelop frames)
- **PAD field**
  - A minimum MAC frame size is required for correct CSMA/CD protocol operation
  - The length of PAD is max [0, minFrameSize – (clientDatasize + 2x addressSize + 48)] bits. minFrameSize is typically 64 octets

Ethernet Frame

- **Frame Check Sequence (FCS)** contains a 4-octet CRC (cyclic redundancy check) value.
  - The CRC value is computed as a function of the contents of the protected fields of the MAC frame (from destination address to Pad)
- An **Extension Field** is added, if required (for 1000Mb/s half duplex operation only)



Invalid MAC Frame

A MAC frame is invalid when it meets at least one of the following conditions:

- The frame length is inconsistent with a length value specified in the length/type field
- It is not an integral number of octets in length
- The bits of the incoming frame (exclusive of the FCS field itself) do not generate a CRC value identical to the one received

Invalid frames should not be passed to the LLC or MAC sublayers.

Two Operating Modes of MAC Sub-Layer

- **Half Duplex: A host can only send or receive at one time**
  - CSMA/CD
- **Full Duplex: A host can send and receive simultaneously. No collision.**
- **Duplex configuration: either manually set or auto negotiated by connected devices**
- **Duplex mismatch → poor performance**

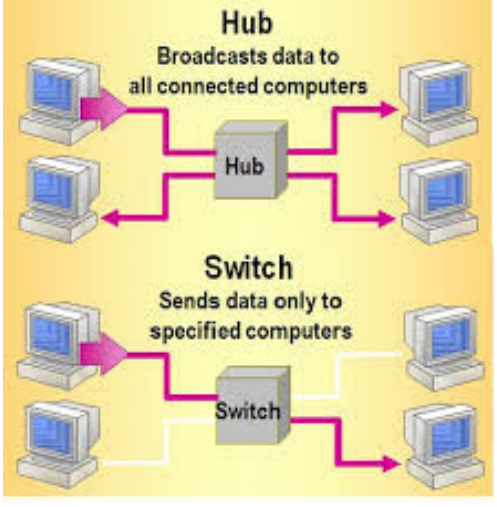
Hubs vs. Switches

Hubs

- Every station that is attached can see the traffic sent between all the other computers
- Use **CSMA/CD** to schedule transmission

Switches

- Traffic is forwarded only to the ports where it is destined.
- Multiple frames can be sent simultaneously by different stations
- Queueing: when multiple frames are sent to the same output port at the same time. Once the queue is full, packets will be dropped.



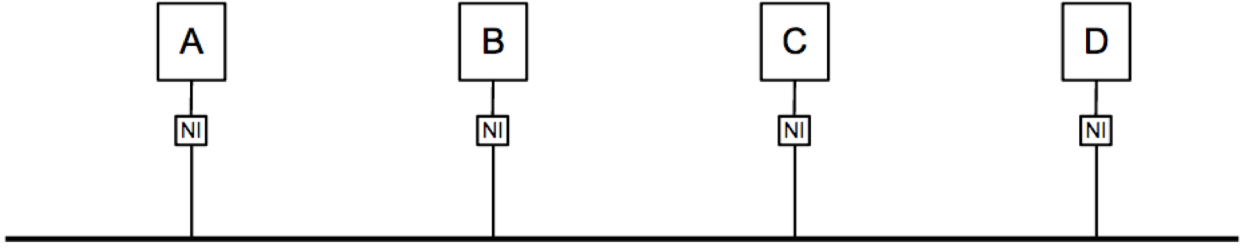
Source: hinditechy.com

5 Ports

- Modern Ethernet networks, built with switches and full-duplex, no longer need CSMA/CD.

CSMA/CD

- **Carrier Sense Multiple Access with Collision Detection (CSMA/CD)** defines how Ethernet frames get onto an Ethernet network
- CSMA/CD is designed to allow fair access by all transmission devices to shared network channels.



CSMA/CD

- The Physical Layer performs the task of generating the signals on the medium that represent the bits of the frame. **Only one signal at a time can be transmitted on an Ethernet network**
- Simultaneously, the Physical Layer monitors the medium and generates the collision detect signal, which in the contention-free case, remains off for the duration of the frame.
- Whenever two stations transmitted at the same time, the signals would **collide**; frames that collide must be retransmitted.

CSMA/CD

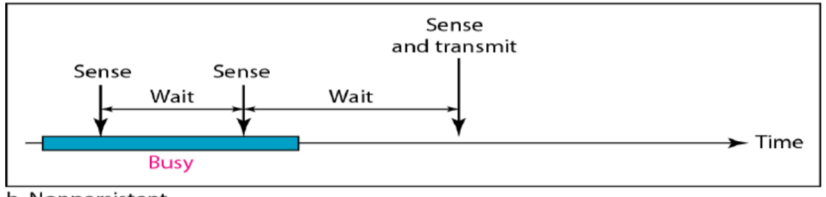
In order to minimize collision loss, each station implemented the following:

- Every Ethernet device listens to hear if another device is already transmitting**.** When the medium is clear, frame transmission is initiated (after a brief interframe delay).
- While transmitting, continually monitor the carrier sense signal provided by the physical layer to detect collisions; if a collision is detected, cease transmitting
- If a collision occurs, use a backoff-and-retransmit strategy

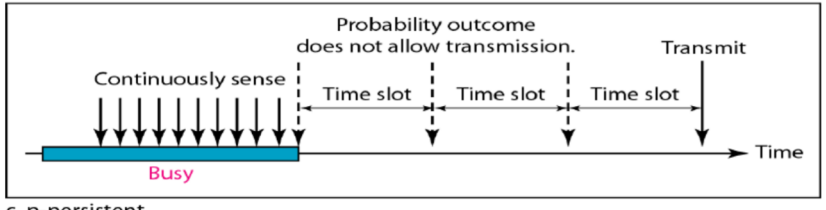
CSMA/CD

P-persistent: when the line is free the sender will transmit frame with probability p. If the medium is busy, it will wait until the line is free before sending the packet with probability p.

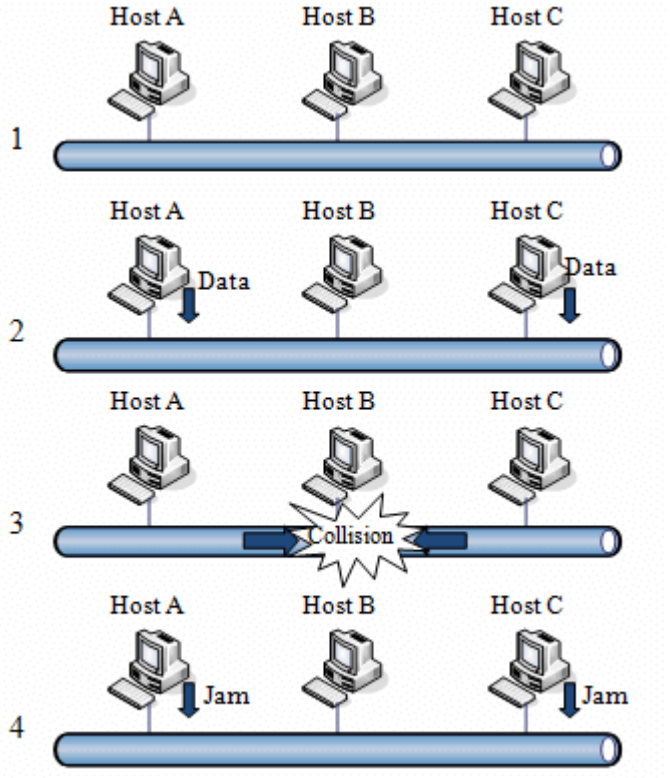
a. 1-persistent



b. Nonpersistent



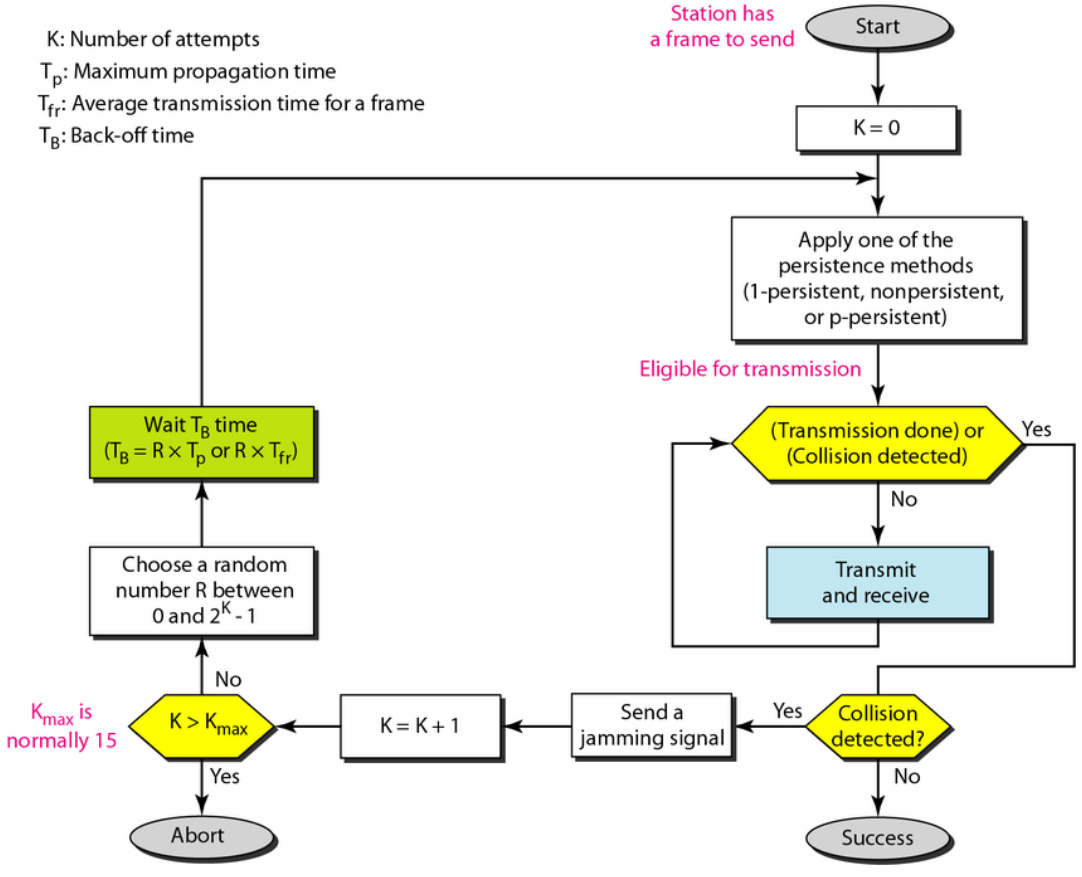
c. p-persistent



Non-persistent: Station will sent immediately if the line is idle or the station will have to wait for a random amount of time and then sense the line again to check its status.

Source: Anna malai, Saravanan. (2012). INTRODUCTION TO NETWORKING.

Workflow of CSMA/CD



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Source: Anna malai, Saravanan. (2012). INTRODUCTION TO NETWORKING.

Backoff-and-retransmit

- Transmit Media Access Management component of the MAC sublayer **enforces the collision by transmitting a bit sequence called jam**.
- Terminate the transmission and **schedule another transmission attempt after a randomly selected time interval**.
- In case of repeated collision, adjust the medium load by **backing off (voluntarily delaying its own retransmission to reduce its load on the medium).**

Let’s play a game

Students count out loud from 1 to 20 or higher in random order. Each group member offers one number at a time. If two persons say a number at the same time, students can make another attempt from where it stops after a randomly selected time interval.

- **What do you think are the advantages and disadvantages of CSMA/CD?**

Hubs vs. Switches

Hubs

- Every station that is attached can see the traffic sent between all the other computers
- Use **CSMA/CD** to schedule transmission

Switches

- Traffic is forwarded only to the ports where it is destined.
- Multiple frames can be sent simultaneously by different stations
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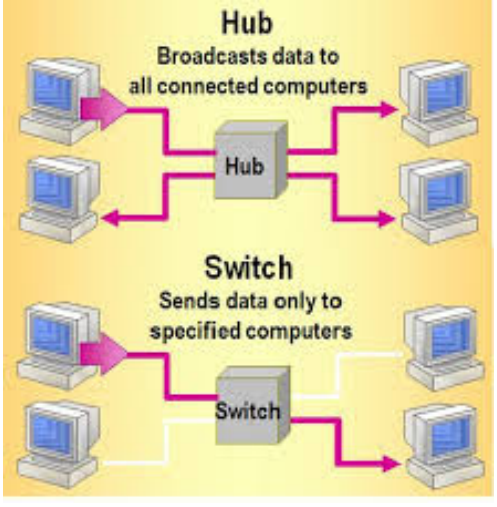


Source: hinditechy.com

5 Ports

- Modern Ethernet networks, built with switches and full-duplex, no longer need CSMA/CD.

Is a Hub half duplex or full-duplex?

Can switches support full-duplex?

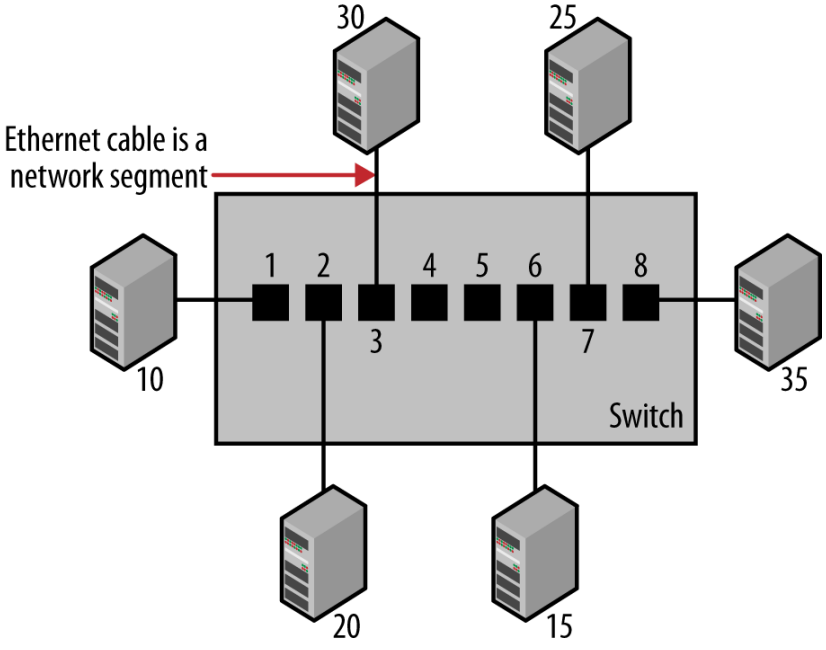
Datagram Forwarding

Header: destination address

Forwarding Table

<destination, next_hop>

Address Learning



Port	Station
1	10
2	20
3	30
4	No station
5	No station
6	15
7	25
8	35

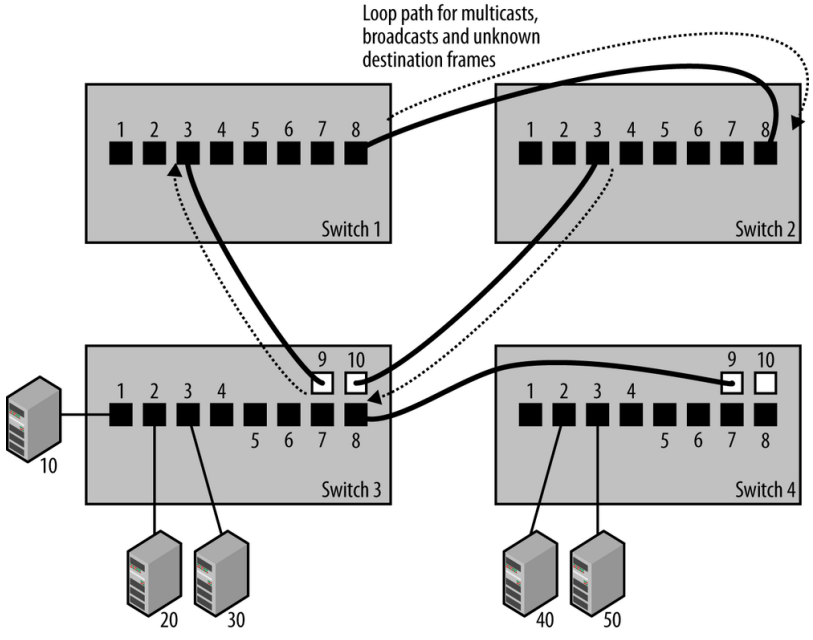
Address Learning

- A station's MAC address is entered into a switch's forwarding table when a packet from that station is first received.
- Switches automatically age out entries in their forwarding database after a period of time (e.g. 5 min), if they do not see any frames from a station.
- **Frame Flooding:**
  - The switch forwards the frame destined for an unknown station out all switch ports other than the one it was received on, thus *flooding* the frame to all other stations.
  - When the unknown device responds with return traffic, the switch will automatically learn which port the device is on, and will no longer flood traffic destined to that device.

Charles E. Spurgeon, Joann Zimmerman. Ethernet Switches. O'Reilly. 2013.

Forwarding Loop Between Switches

- **Tree structure** which consists of multiple switches branching off of a central switch
- In a sufficiently complex network, switches with multiple inter-switch connections can create loop paths in the network



Self-test

- Unicast vs. Multicast vs. Broadcast
- Can you remember the name of each layer in the OSI model?
- What is MAC address?
- Full duplex vs. Half duplex
- Hub vs. Switches
- How does CSMA/CD work?
- How to create a switch’s forwarding table?

Reading Tasks

An Introduction to Computer Networks.

Chapter 3.7 Wi-Fi

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