UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa

# FUNDAMENTALS OF INDUSTRIAL WIRELESS COMMUNICATIONS

**MUEI / MUEA / MASE**

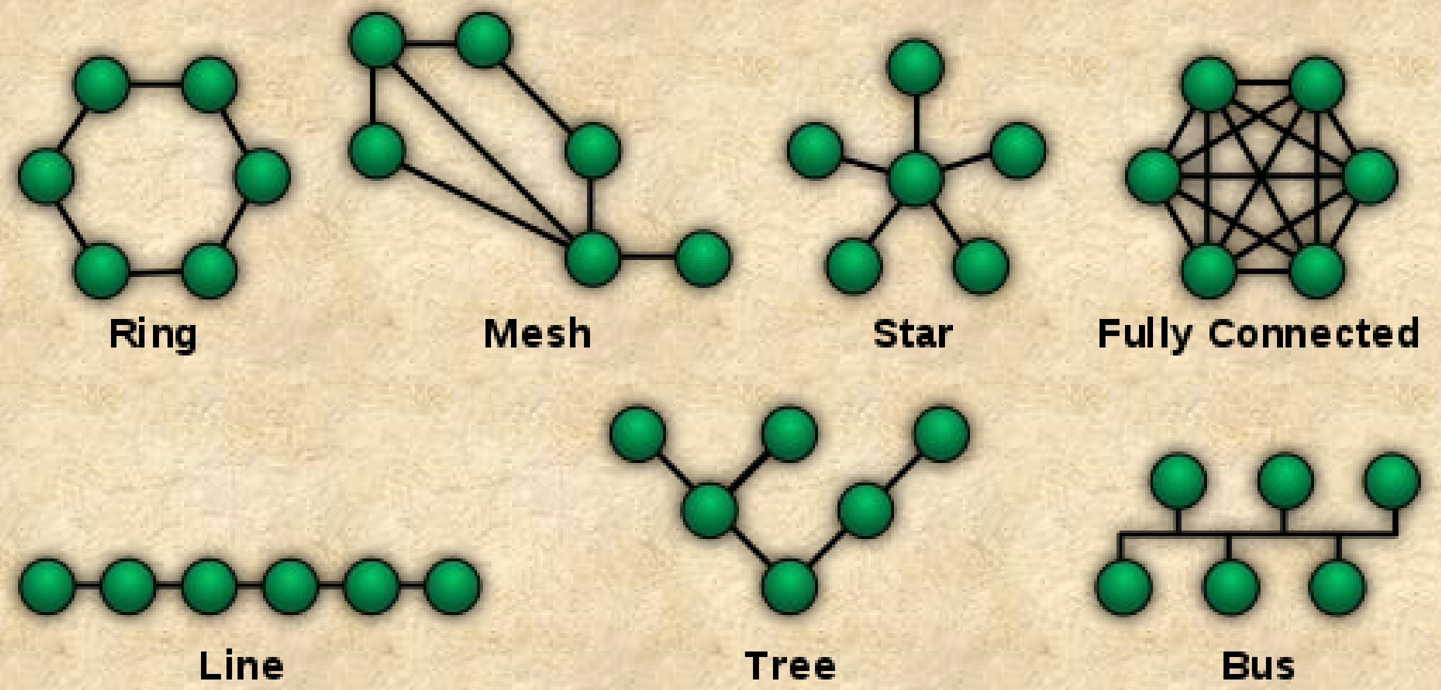
***Eduard Bertran***

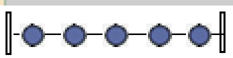
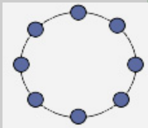
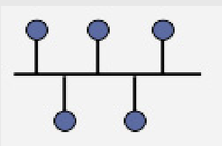
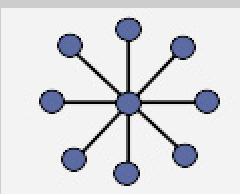
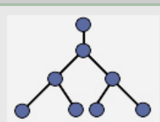
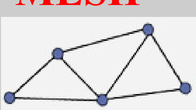
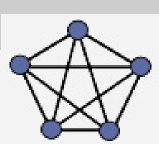
**ESEIAAT. 2n semester, part 1, 2023**

# MODULE 3:  NETWORKS

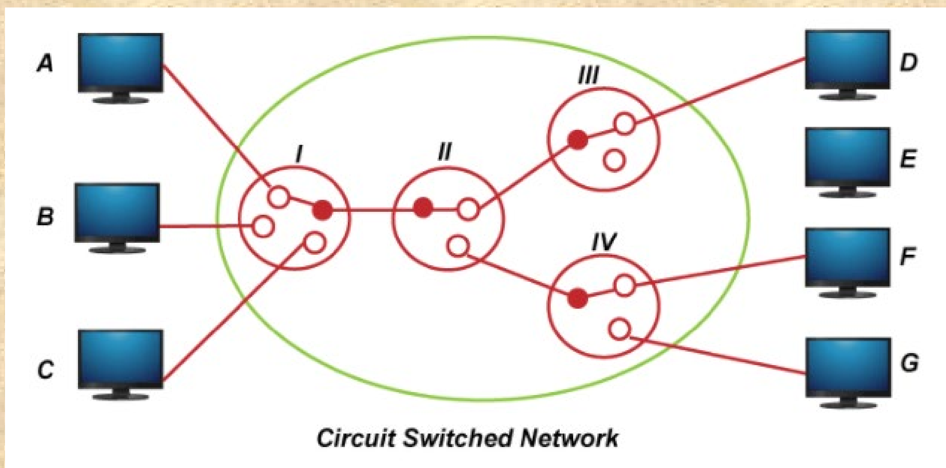
# TOPOLOGIES : links between nodes in a wired network

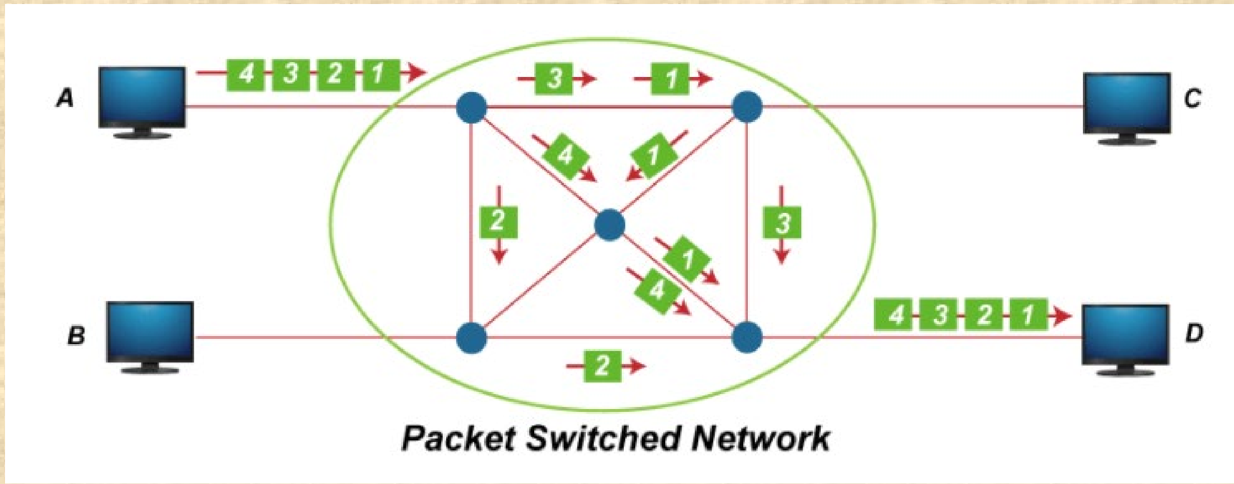
Trade-off:
- velocity
- adaptability (node failure)
- supervisión capacity. Centralization.
- scalability
- traffic congestion.
- cost / wires.



| TOPOLOGY | | PROS | CONS |
|---|---|---|---|
| **LINE / RING (Daisy Chain)**   | Each node retransmits the message until it reaches the destination | Cost-effective<br>Easy to be expanded. | - Risk of collisions: only a node sends data at a time<br>- Nodes has to be monitored: a failure in a node (or in cable) should go down the whole system. |
| **BUS**  | Each node is connected to a single bus cable through some kind of connector, with “terminated” terminals (impedance matched). Uses MAC or IP addresses. | Cost-effective. A failure in a node does not affect the rest of the network<br>Easy to be expanded. | - Risk of collisions: only a node sends data at a time<br>- Failure in the cable requires time to restore the system (impedances) |
| **STAR**  | All traffic on the network passes through the central hub. The hub acts as a signal booster or repeater | Nodes are separately connected to the central hub: a failure in a node does not affect the rest of the network. Easy to be expanded. | Failure in central node (hub). |
| **TREE**  | Hierarchical. Different node levels. | Easy addition of nodes | Failure in a node will disconnect all its branches. |
| **MESH**   | - *fully* mesh (costly)<br>- *partially* (redundancy in selected nodes) | Reliable and stable | Costly (wires and volume) |
| **HIBRID** | | | |

# Circuit and packet switching



# CHANNEL ACCESS (wired –bus- or <u>wireless</u> networks)

**A- Random Access Protocol:** No station has more priority than another station.

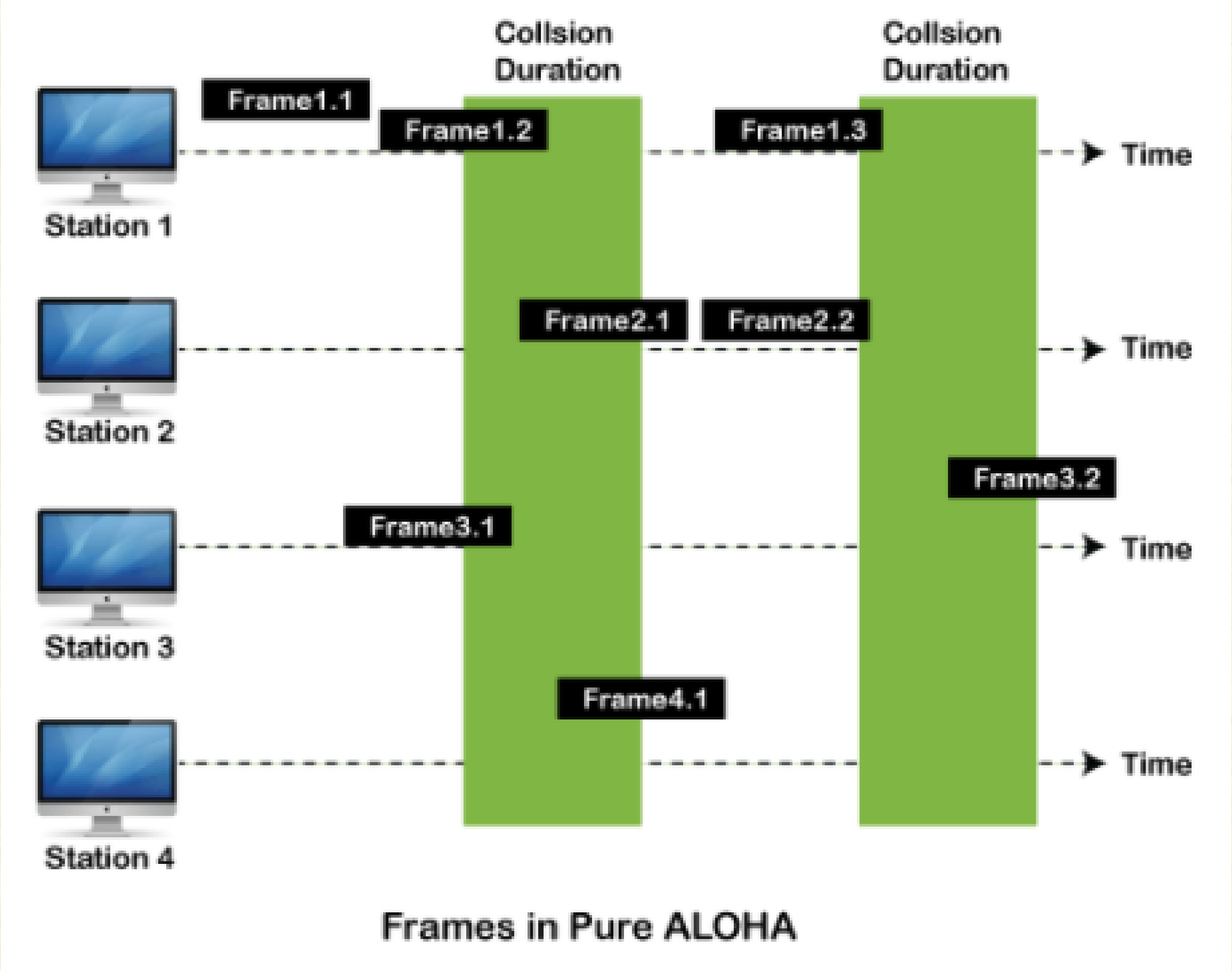
- **ALOHA**: (older) May be <u>pure</u> or <u>slotted</u>. Wireless packets may collide at a receiver if they are transmitted simultaneously. If an acknowledgment is not received timely enough, then the data packet is re-sent at a later instant determined,

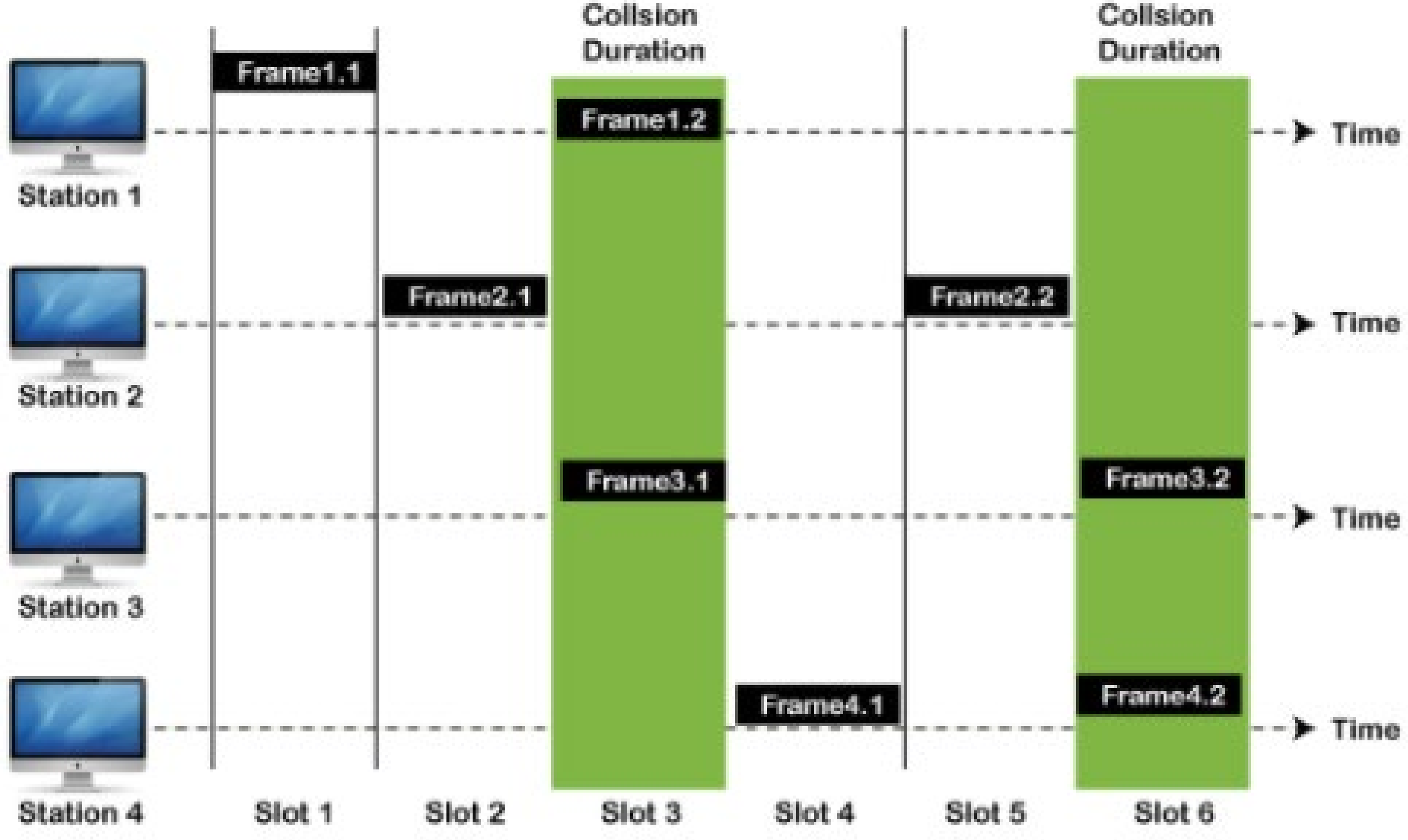
- **CSMA –** Carrier Sense Multiple Access. Wireless nodes <u>first sense the wireless medium</u> (difference with ALOHA) before transmitting their data packets. Some kinds:

  - **Persistent:** The node senses the channel, if idle it sends the data, otherwise it continuously keeps on checking and transmits unconditionally as soon as the channel gets idle. (P-persistent, etc….)
  - **Non-Persistent:** The same, but the node checks the channel after a random time (not continuously).

  - **CSMA/CD –** Carrier sense multiple access with collision detection. Stations can terminate transmission of data ***after*** a <u>collision is detected</u>. CSMA CD immediately sends a jam signal to stop transmission and waits for a random time before transmitting another packet. Frame transmission time should be at least twice the maximum propagation time, which can be deduced when the distance between the two stations involved in a collision is maximum. Preference in wired networks.

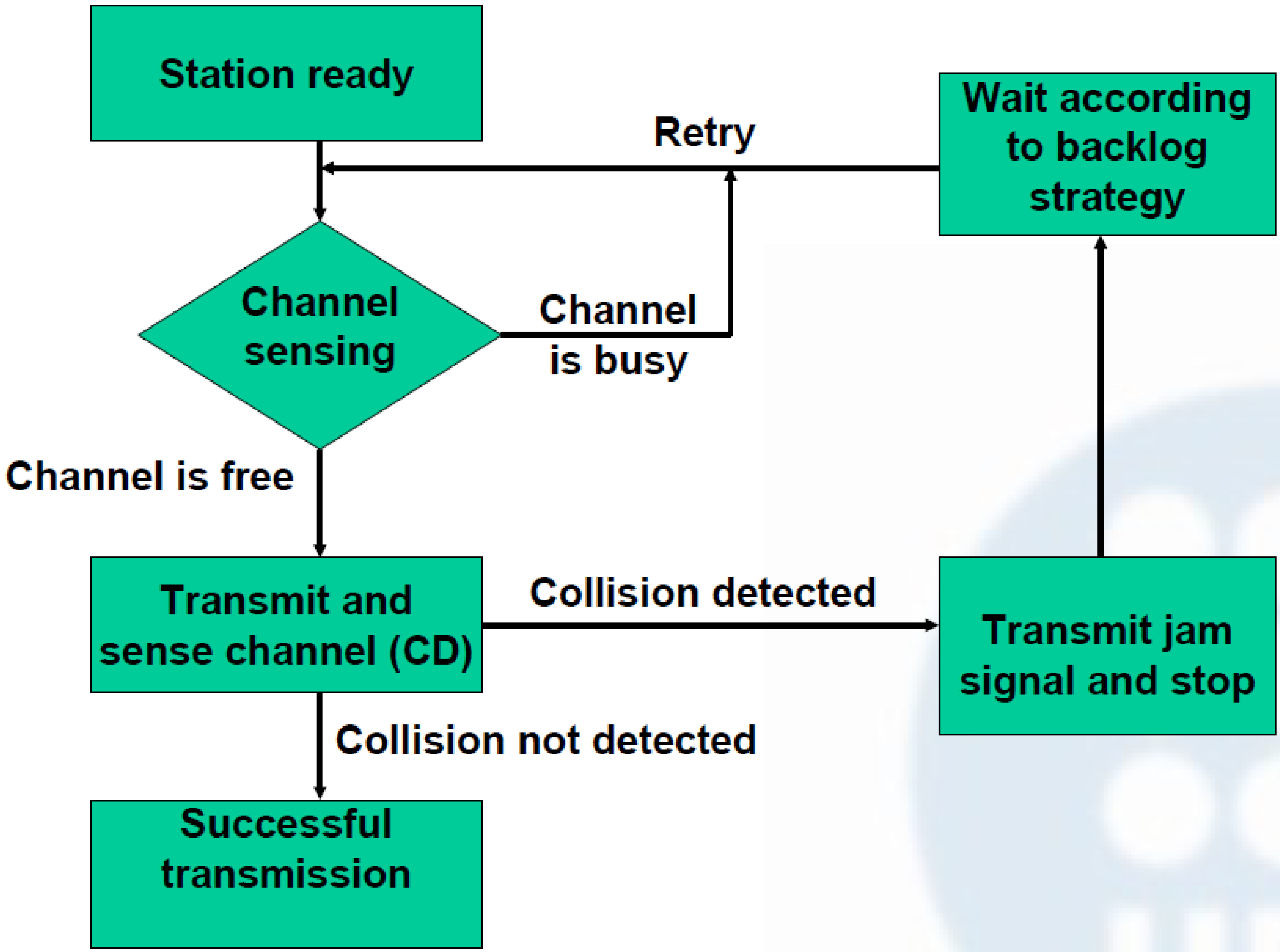
  - **CSMA/CA –** Carrier sense multiple access with collision avoidance. Preference in wireless. The sender receives <u>acknowledgement</u> signals (transmits ***before*** collisions). **Slots reservation**. If there is just one signal (its own) then the data is successfully sent but if there are two signals (its own and the one with which it has collided) then it means a collision has occurred. RTS/CTS) – 802.11


Collsion Duration
Collsion Duration
Frame1.1
Frame1.2
Frame1.3
Time
Station 1
Frame2.1
Frame2.2
Time
Station 2
Frame3.2
Frame3.1
Time
Station 3
Frame4.1
Time
Station 4
Frames in Pure ALOHA




Frames in Slotted ALOHA

# CSMA/CD flow diagram

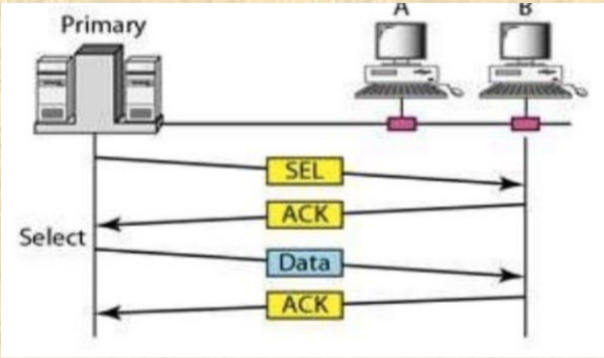


# CHANNEL ACCESS (wired or wireless networks)

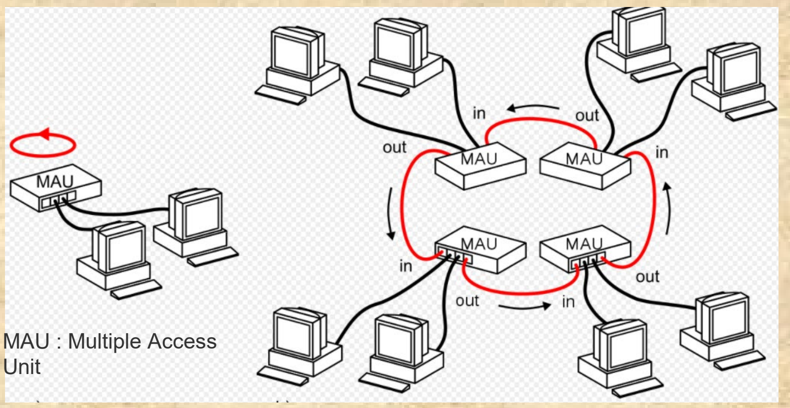
## B- Controlled-Access Methods:

1. **Reservation** (slots reservation): The stations which have reserved their slots transfer their frames in that order. After data transmission period, next reservation interval begins.

2. **Polling** (BUS, STAR structure)



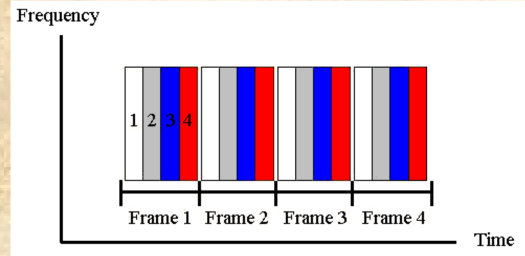

3. **Token Passing** (RING structure): Empty information frames are continuously circulated on the ring. When a node has a message to send, it seizes the token, and then It is able to send the frame.



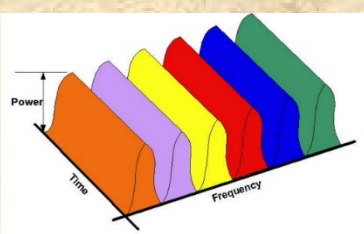
# CHANNEL ACCESS (wired or wireless networks)

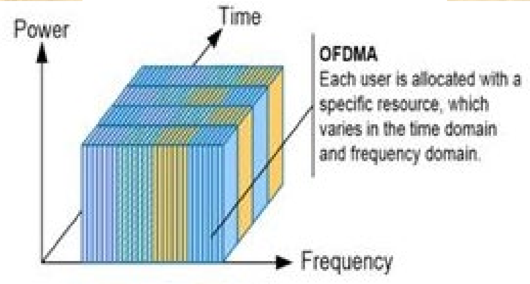
C- Channelization

- **TDMA (Time Division Multiple Access)**

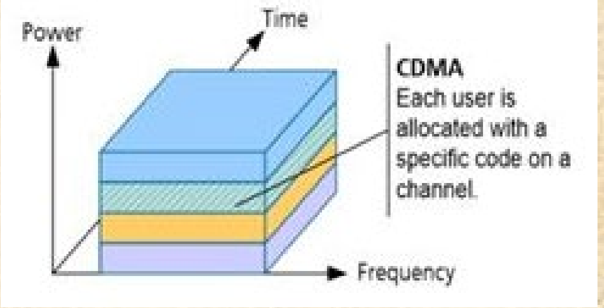



- **FDMA / OFDMA**
**(Frequency Division Multiple Access / Orthogonal …. )**

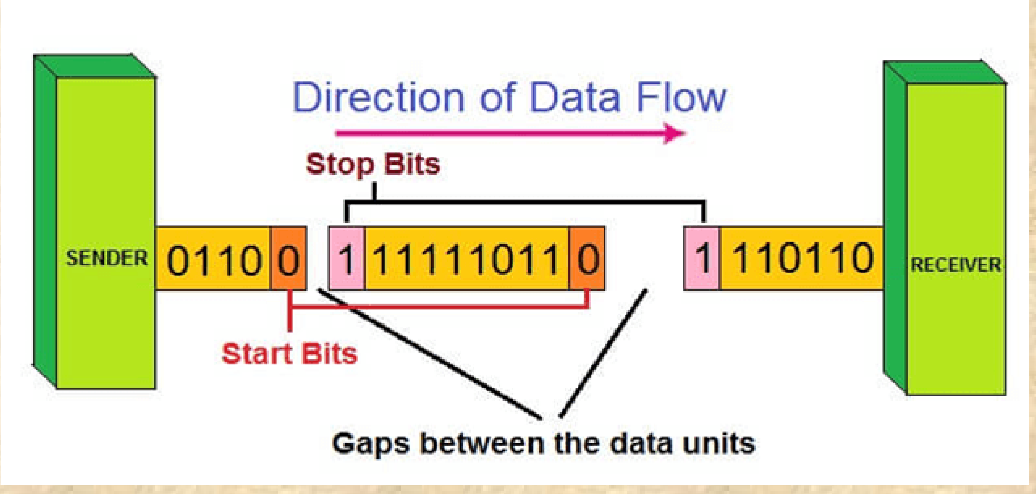


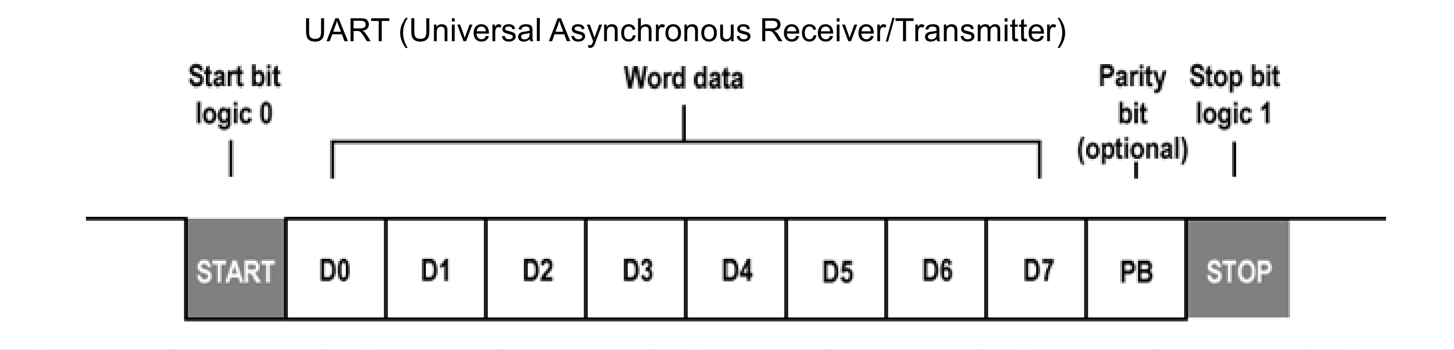




- **CDMA (Code Division Multiple Access)**



# Synchronous & Asynchronous Frame Transmission: Asynchronous




- Slower transmission, due to the extra bits and the gaps
- Cheap and easy to implement = no clock sharing
- Can transmit when ready

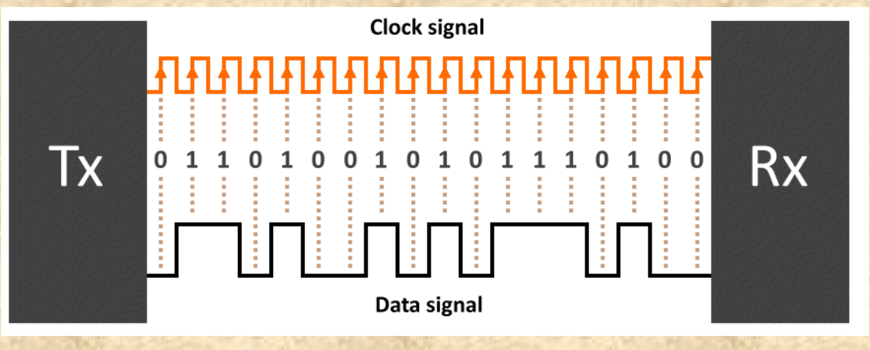
- Asynchronous transmission is used when data is sent sporadically, e.g. via a mouse or keyboard

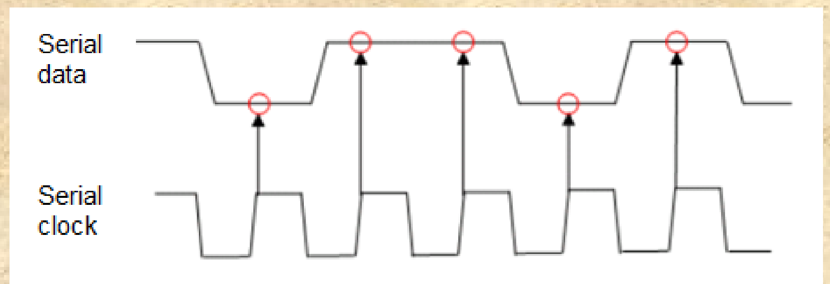
Parity bit

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | Odd parity (odd number of ones) |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | One bit flipped - error detected |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | Two bits flipped - error not detected |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | Odd parity (even number of ones) |
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | One bit flipped - error detected |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | Two bits flipped - error not detected |

# Synchronous & Asynchronous Transmission: Synchronous

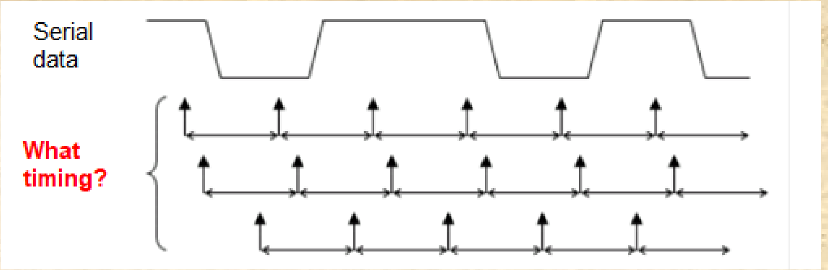


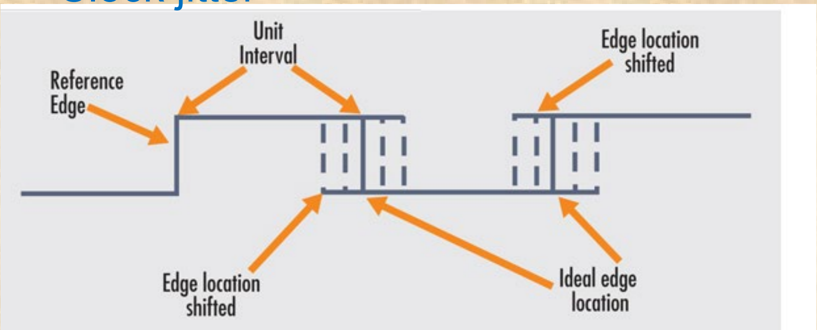

- Fast transmission
- Needs a common clock signal, or some way of sharing it
- May have to wait briefly until data can be sent

- Almost all parallel transmission is synchronous

## Clock drift




## Clock jitter



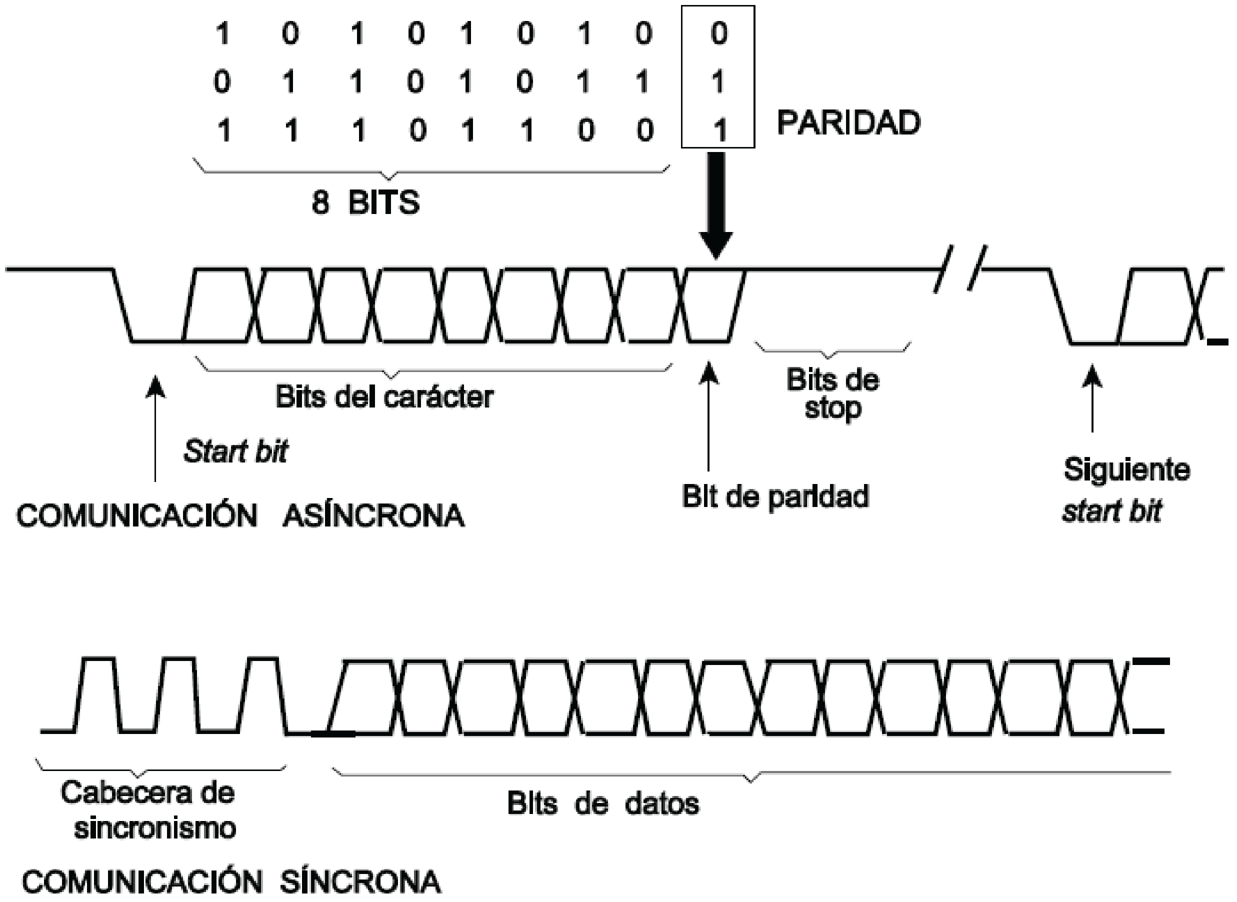
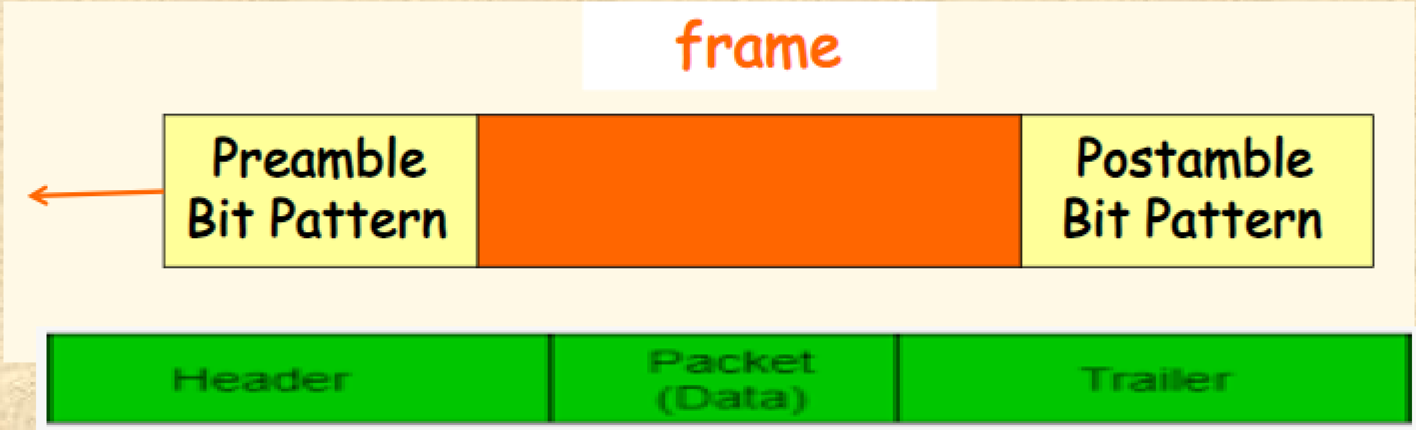



*Fig. 4.89. Comunicaciones asíncrona y síncrona*

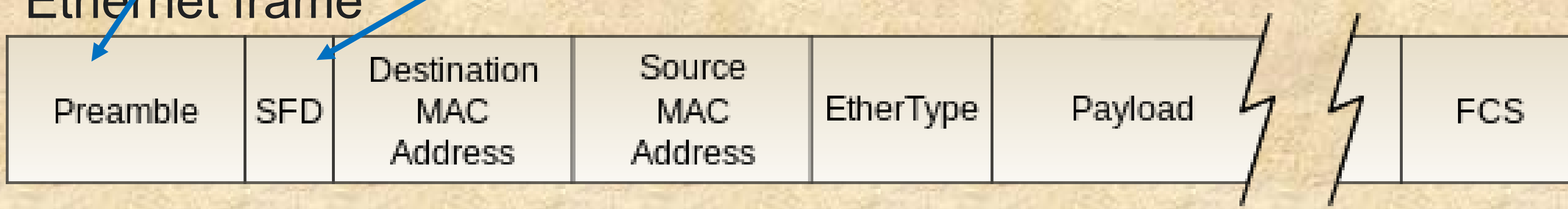
# Frames




To synchronize the receiver clock, providing bit-level synchronization

byte-level synchronization: to mark a new incoming frame

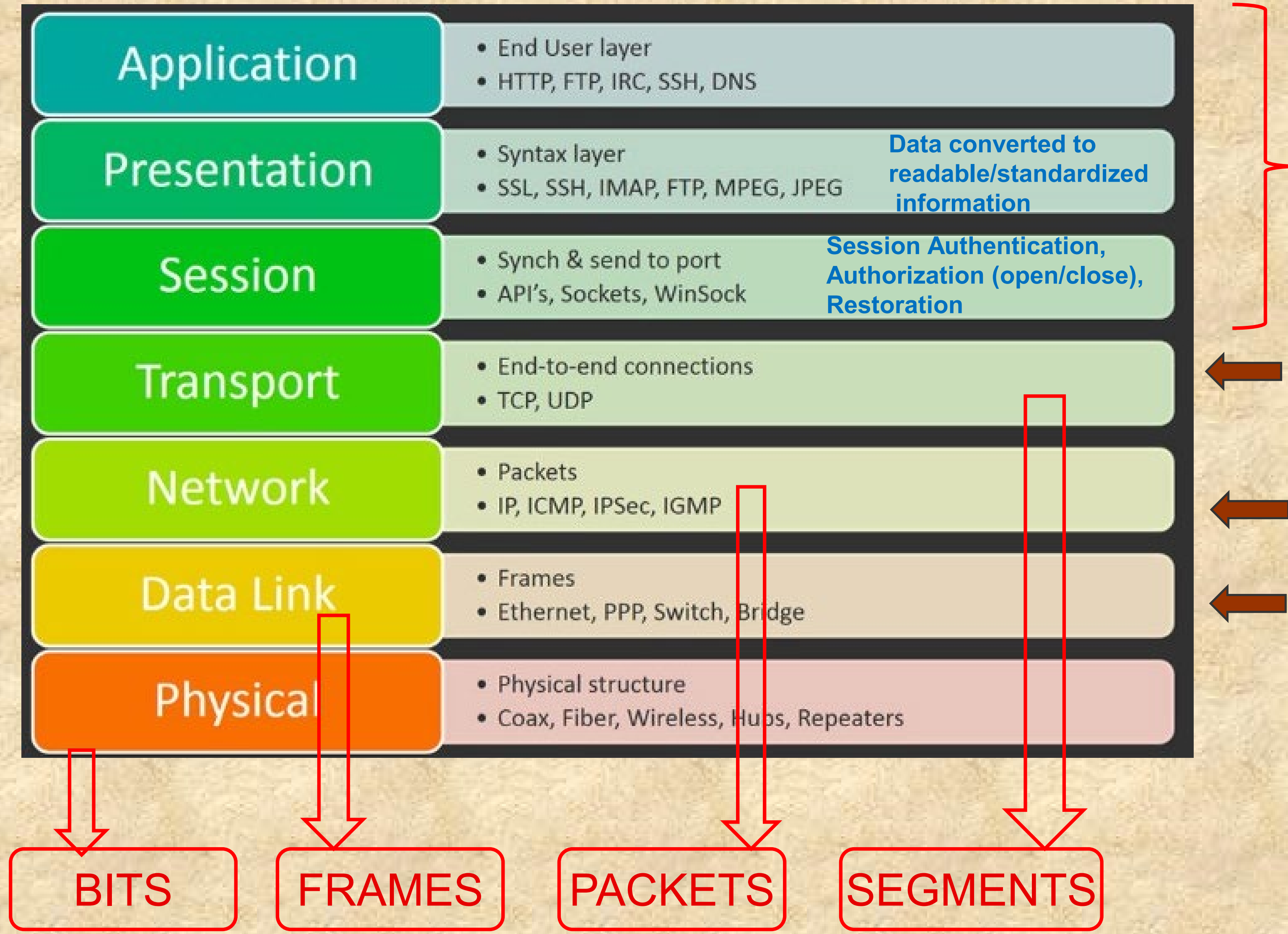
Ethernet frame




SFD: Start frame delimiter
FCS: Frame check sequence (32-bit CRC)

# OSI Model (Open Systems Interconnection): 7 layers

(ISO: International Organization for Standardization)




DATA

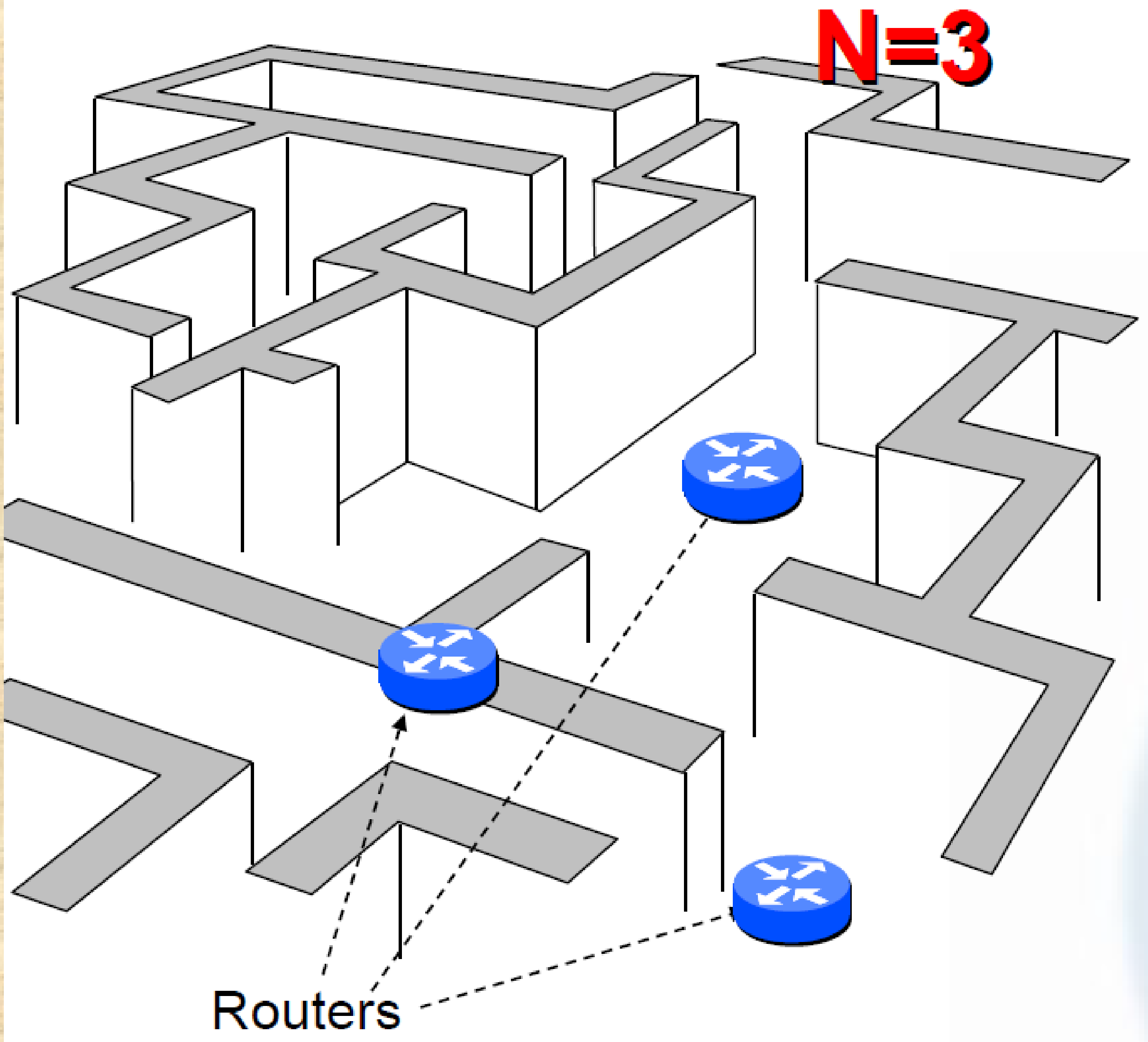
Establishment and control of connection between client and server

Manages devices addressing
Moves data to delivery address

Topology
Flow control, congestion, errors: signal lost, timing…

**MAC sub-layer** (Media Access Control) and **LLC sub-layer** (Logical Link Control)

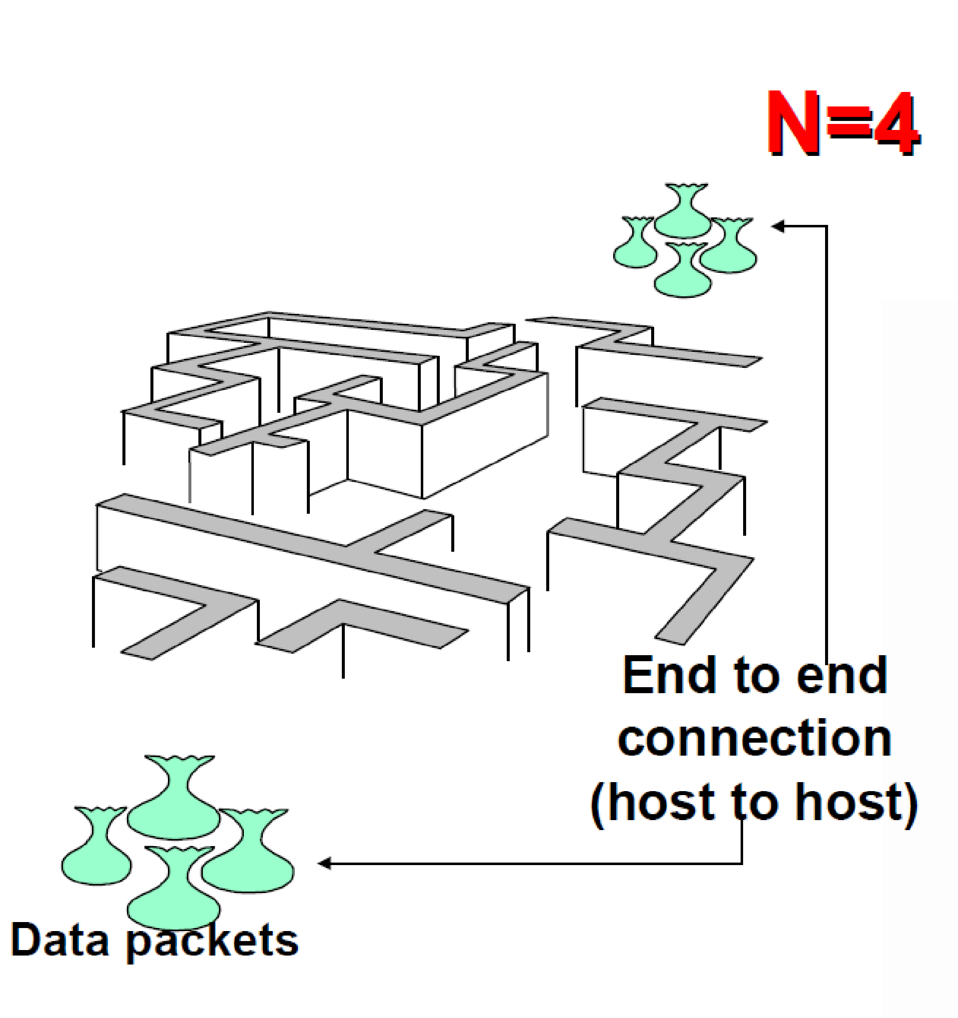
# Network layer




**Provides information about the route that packets must follow:**

- addressing
- route optimization

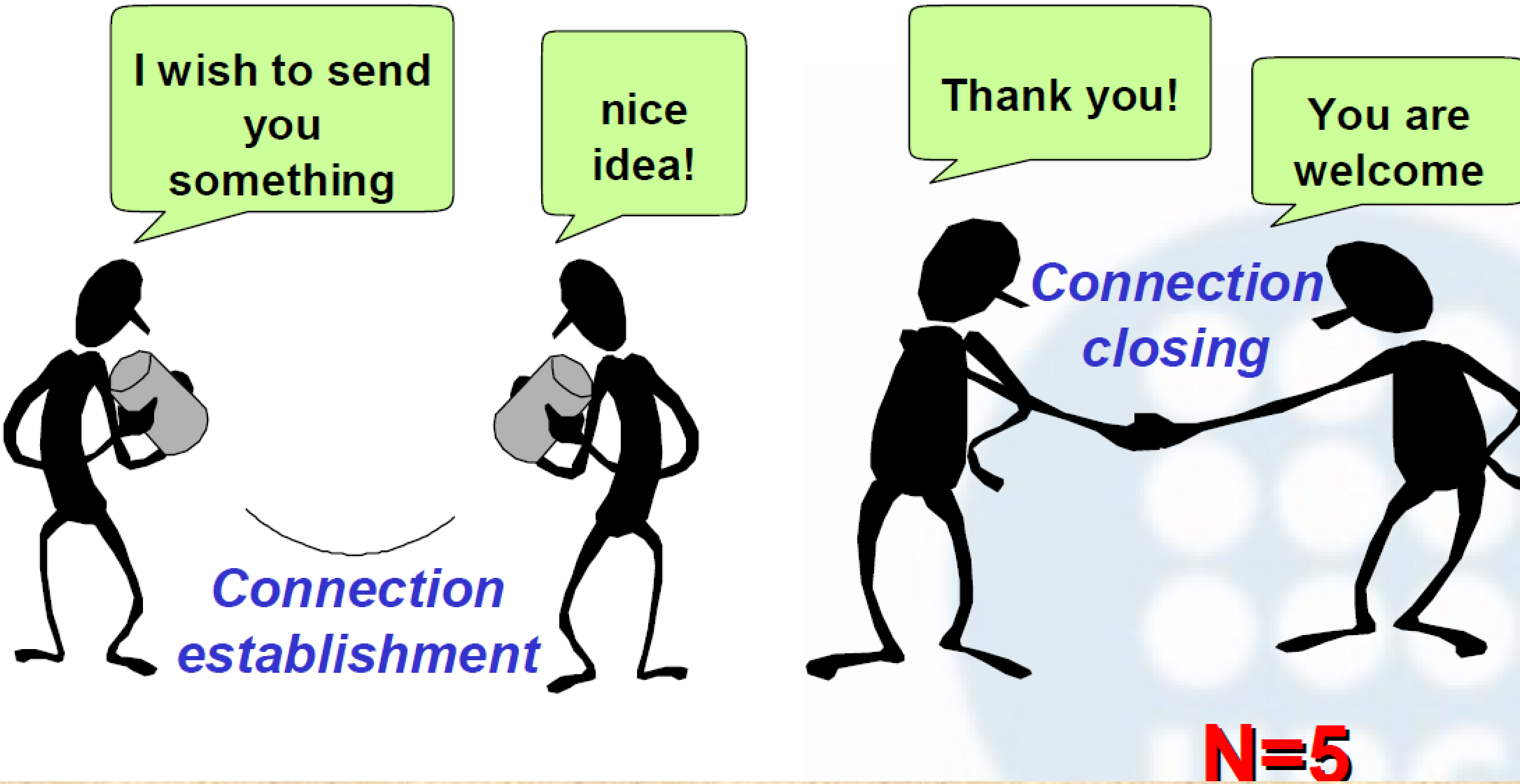
# Transport layer




- Verifies that packets are correctly received end-to-end
- possible fragmentation and reassembly

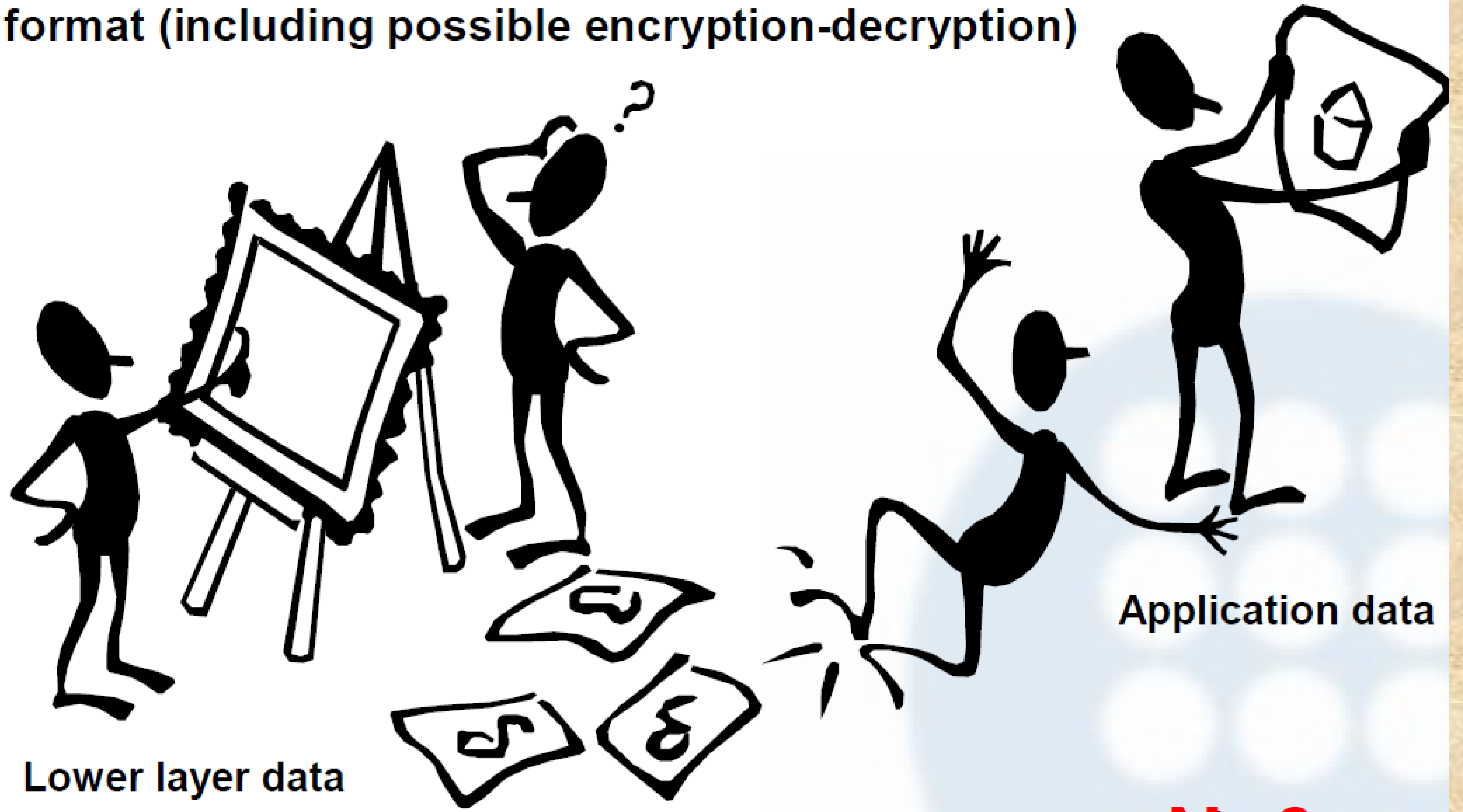
# Session layer

**Synchronizes data interchange between lower and higher layers**



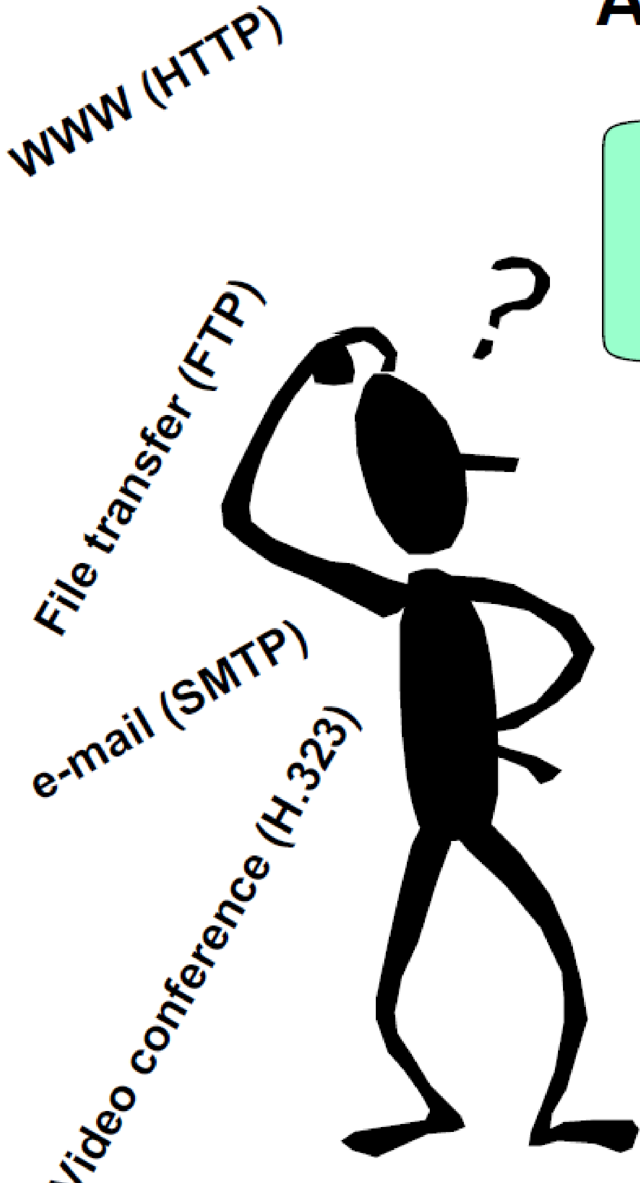
# Presentation layer

**Translates network data into the application format (including possible encryption-decryption)**




**N=6**

# Application layer

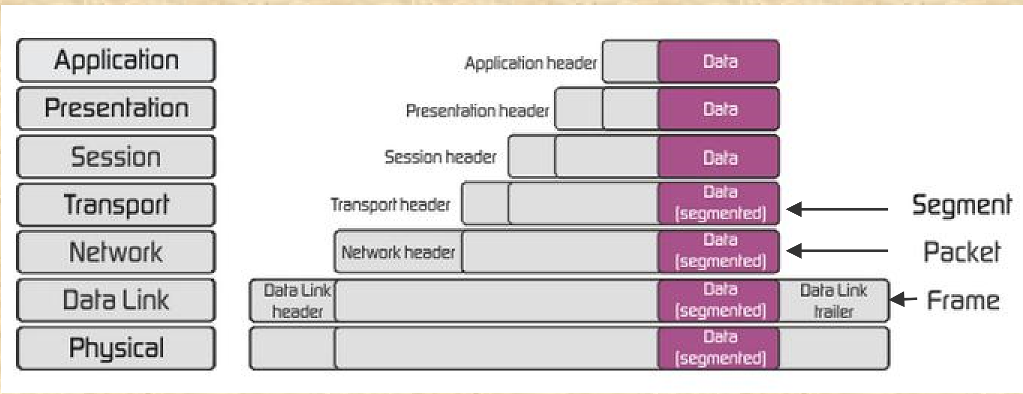


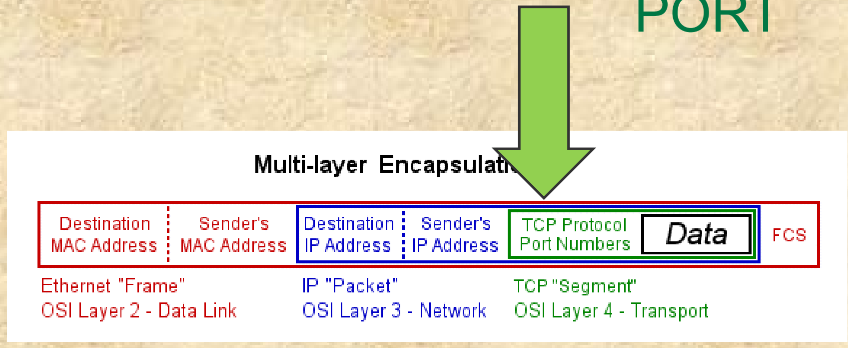

**¿What do I want to send?**

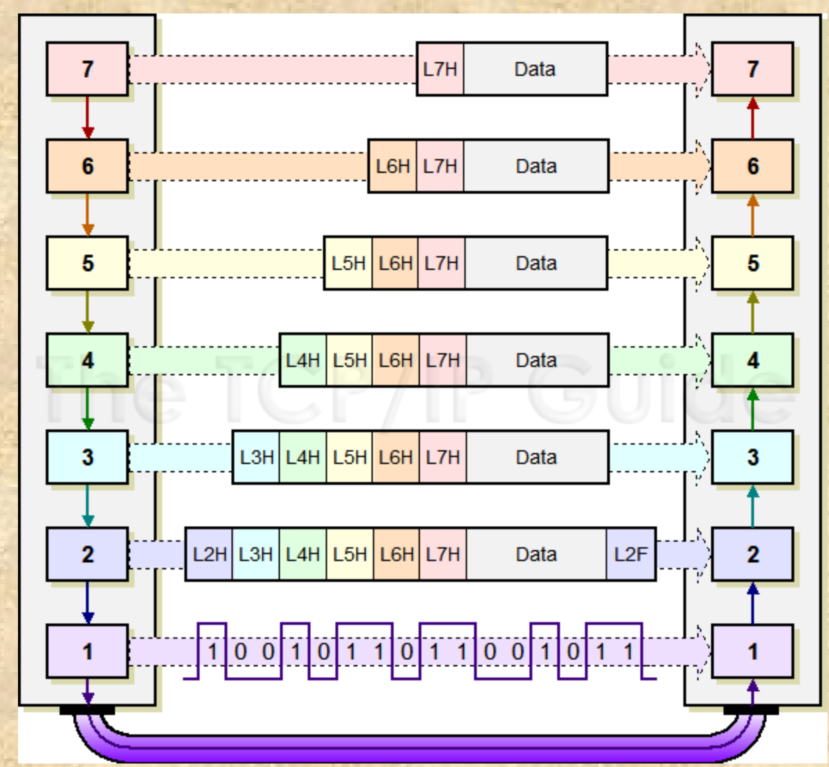
- Interface to the final user
- Shows received information
- All applications fall into this layer
- Sends user data to remote application by using lower layers services.

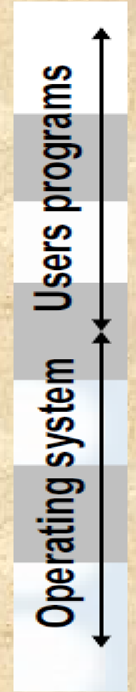
**N=7**

PORT


Application
Presentation
Session
Transport
Network
Data Link
Physical
Application header
Presentation header
Session header
Transport header
Network header
Data Link header
Data Link trailer
Data
Data (segmented)
Segment
Packet
Frame

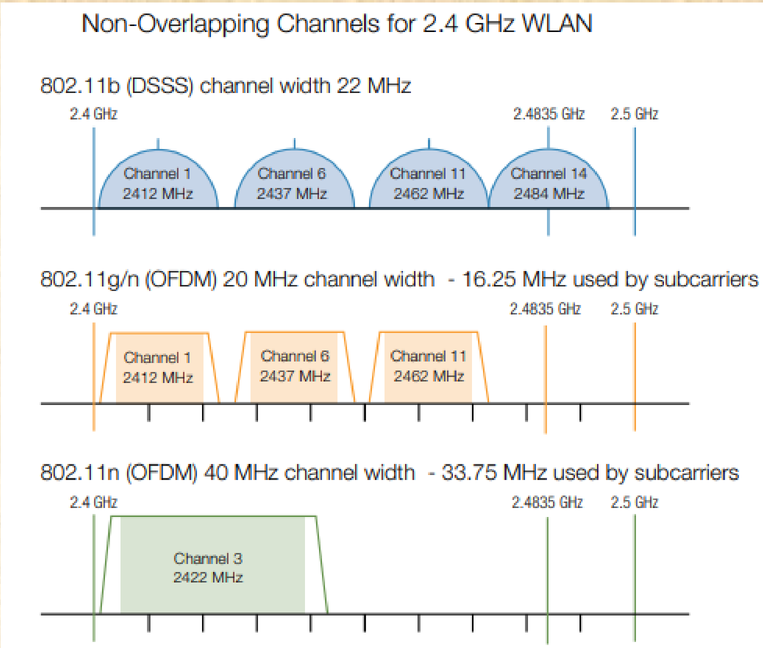

Multi-layer Encapsulation
Destination MAC Address
Sender's MAC Address
Destination IP Address
Sender's IP Address
TCP Protocol Port Numbers
Data
FCS
Ethernet "Frame"
OSI Layer 2 - Data Link
IP "Packet"
OSI Layer 3 - Network
TCP "Segment"
OSI Layer 4 - Transport

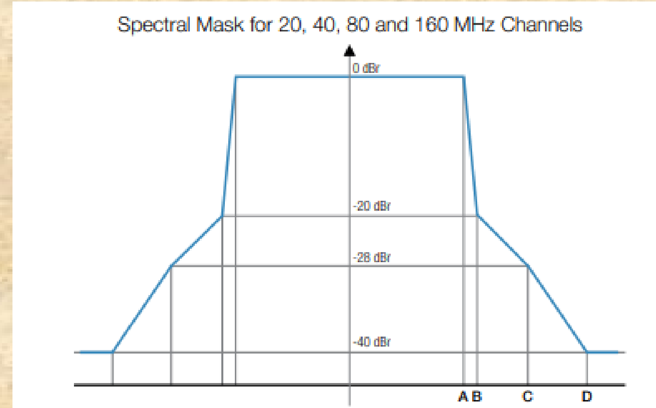

7
6
5
4
3
2
1
L7H Data
L6H L7H Data
L5H L6H L7H Data
L4H L5H L6H L7H Data
L3H L4H L5H L6H L7H Data
L2H L3H L4H L5H L6H L7H Data L2F
1 0 0 1 0 1 1 0 1 1 0 0 1 0 1 1


Users programs
Operating system

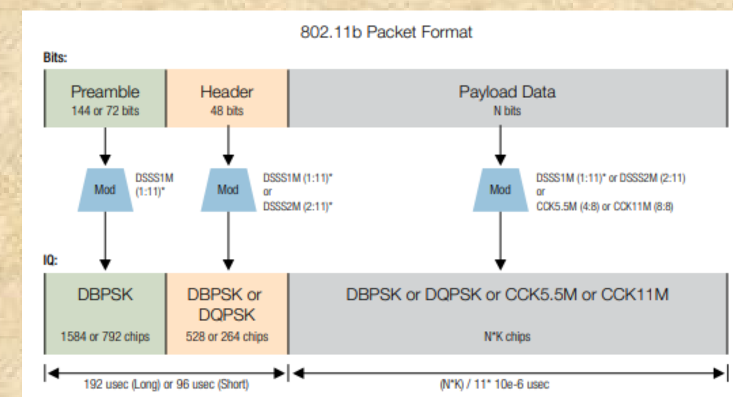
# - **Physical Layer** "responsibilities"

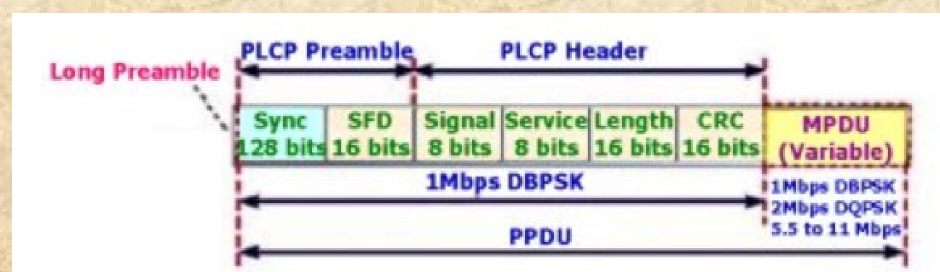
## Ex. IEEE 802.11 b



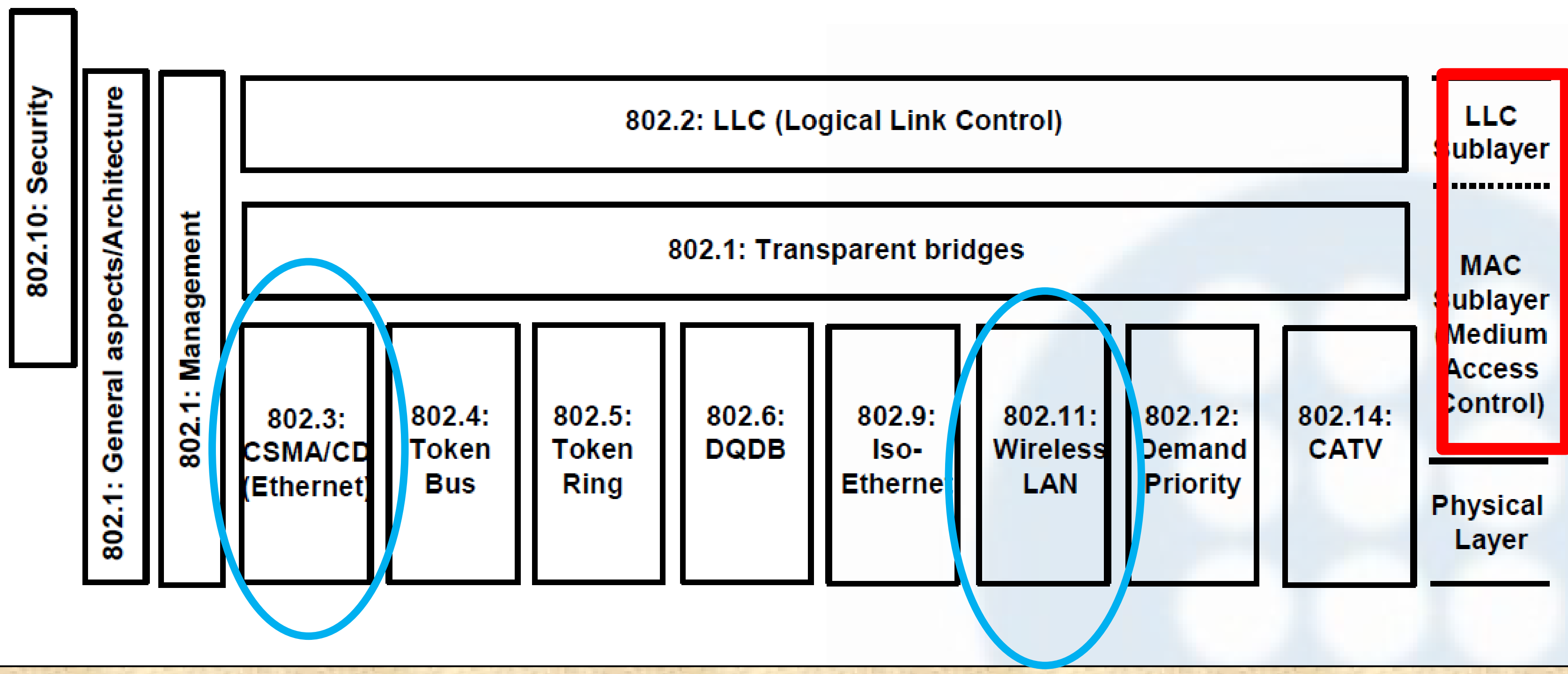




| Channel Size | A | B | C | D |
|---|---|---|---|---|
| 20 MHz | 9 MHz | 11 MHz | 20 MHz | 30 MHz |
| 40 MHz | 19 MHz | 21 MHz | 40 MHz | 60 MHz |
| 80 MHz | 39 MHz | 41 MHz | 80 MHz | 120 MHz |
| 160 MHz | 79 MHz | 81 MHz | 160 MHz | 240 MHz |

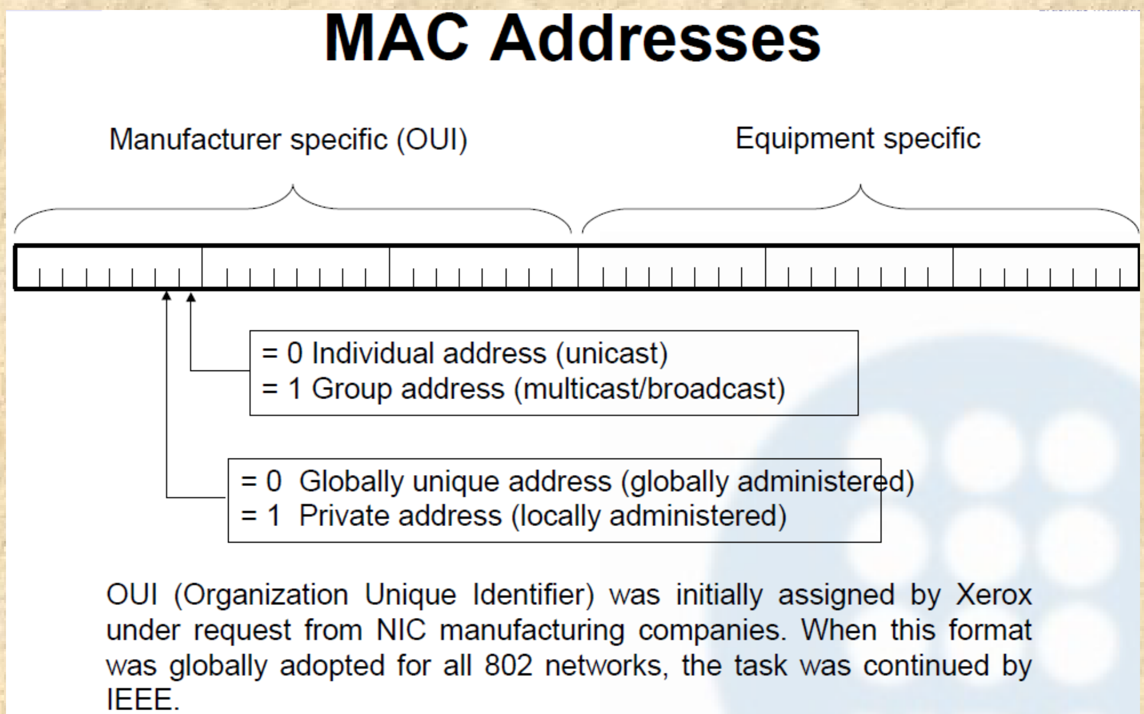


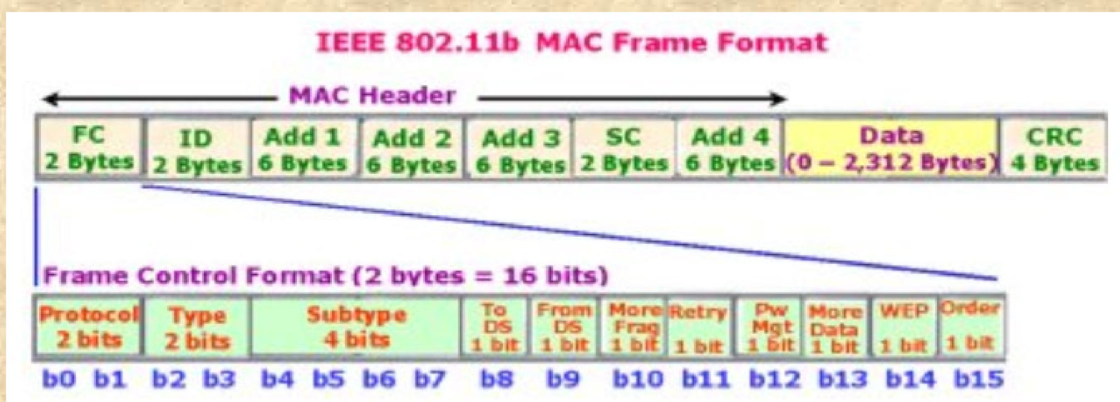



# IEEE 802 standards



# MAC (Medium Access Control) sub-layer




# LINK LAYER: Some link level protocols:

***HDLC:*** High-Level Data Link Control *(ISO standard)*

***Point to point communications. Synchronous or asynchronous***

**HDLC frame format**

| Bits → | 8 | 8 | 8 | ≥0 | 16 ó 32 | 8 |
|---|---|---|---|---|---|---|
| | 01111110 (flag) | Address | **Control** | Data | CRC | 01111110 (flag) |

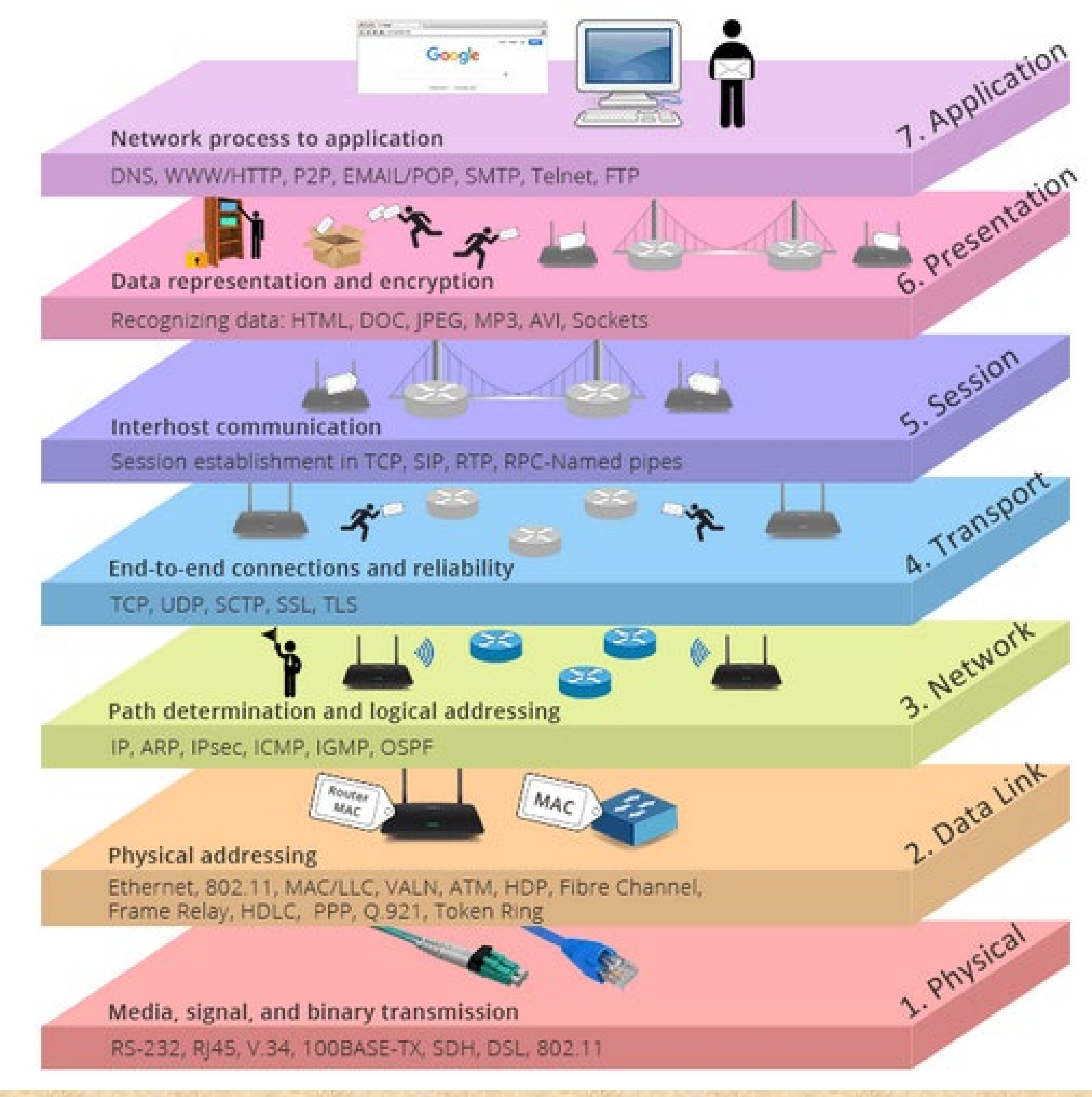
SUBSETS of HDLC:

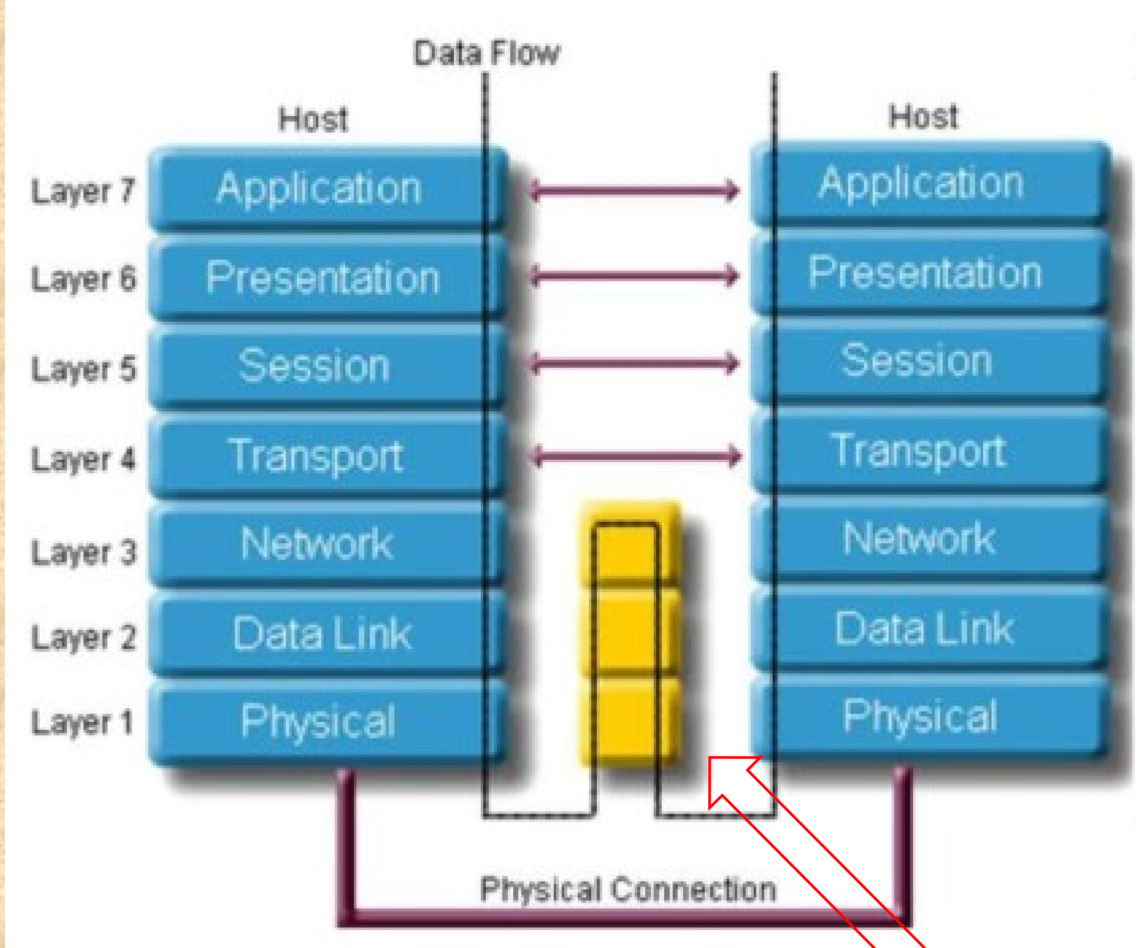
- PPP: Internet
- LAP-B: X.25
- LAP-F: Frame Relay
- LLC (IEEE 802.2): LAN's
- LAPM: PSTN modems

## NETWORK LAYER

**IP protocol was designed to work over almost any physical medium**

| Medium |
| --- |
| X.25 |
| Ethernet |
| 802.x |
| FDDI |
| PPP |
| Frame Relay |
| ATM |


7. Application
Network process to application
DNS, WWW/HTTP, P2P, EMAIL/POP, SMTP, Telnet, FTP
6. Presentation
Data representation and encryption
Recognizing data: HTML, DOC, JPEG, MP3, AVI, Sockets
5. Session
Interhost communication
Session establishment in TCP, SIP, RTP, RPC-Named pipes
4. Transport
End-to-end connections and reliability
TCP, UDP, SCTP, SSL, TLS
3. Network
Path determination and logical addressing
IP, ARP, IPsec, ICMP, IGMP, OSPF
2. Data Link
Router MAC
MAC
Physical addressing
Ethernet, 802.11, MAC/LLC, VALN, ATM, HDP, Fibre Channel,
Frame Relay, HDLC, PPP, Q.921, Token Ring
1. Physical
Media, signal, and binary transmission
RS-232, RJ45, V.34, 100BASE-TX, SDH, DSL, 802.11



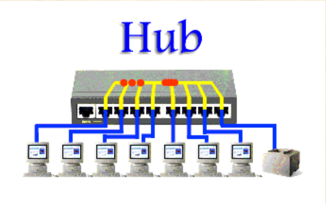

Routers

Switches ("Intelligent Hubs": MAC addressing)

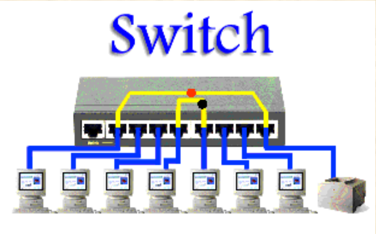
Repeaters (Hubs)

**Each level in a node (i.e, device) is able to communicate to the same lever in another node.**

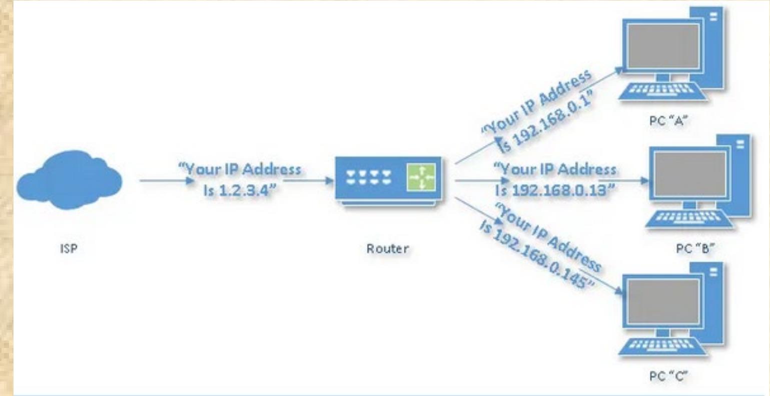
**HUB**: Retransmits data to ALL the devices in the same network (frames)

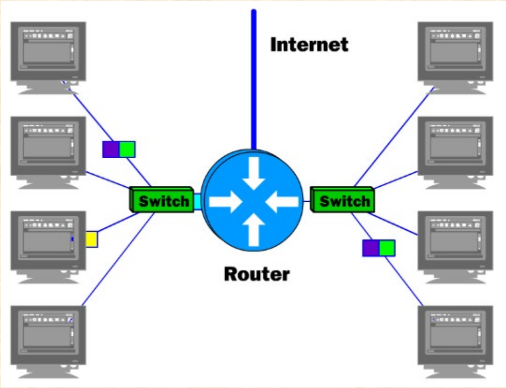



**SWITCH**: Filters and transmits data to the SELECTED device (MANAGED: MAC Addressing, MANAGED: virtual IP addressing – named ”layer 3”, because can connect different VLANs)



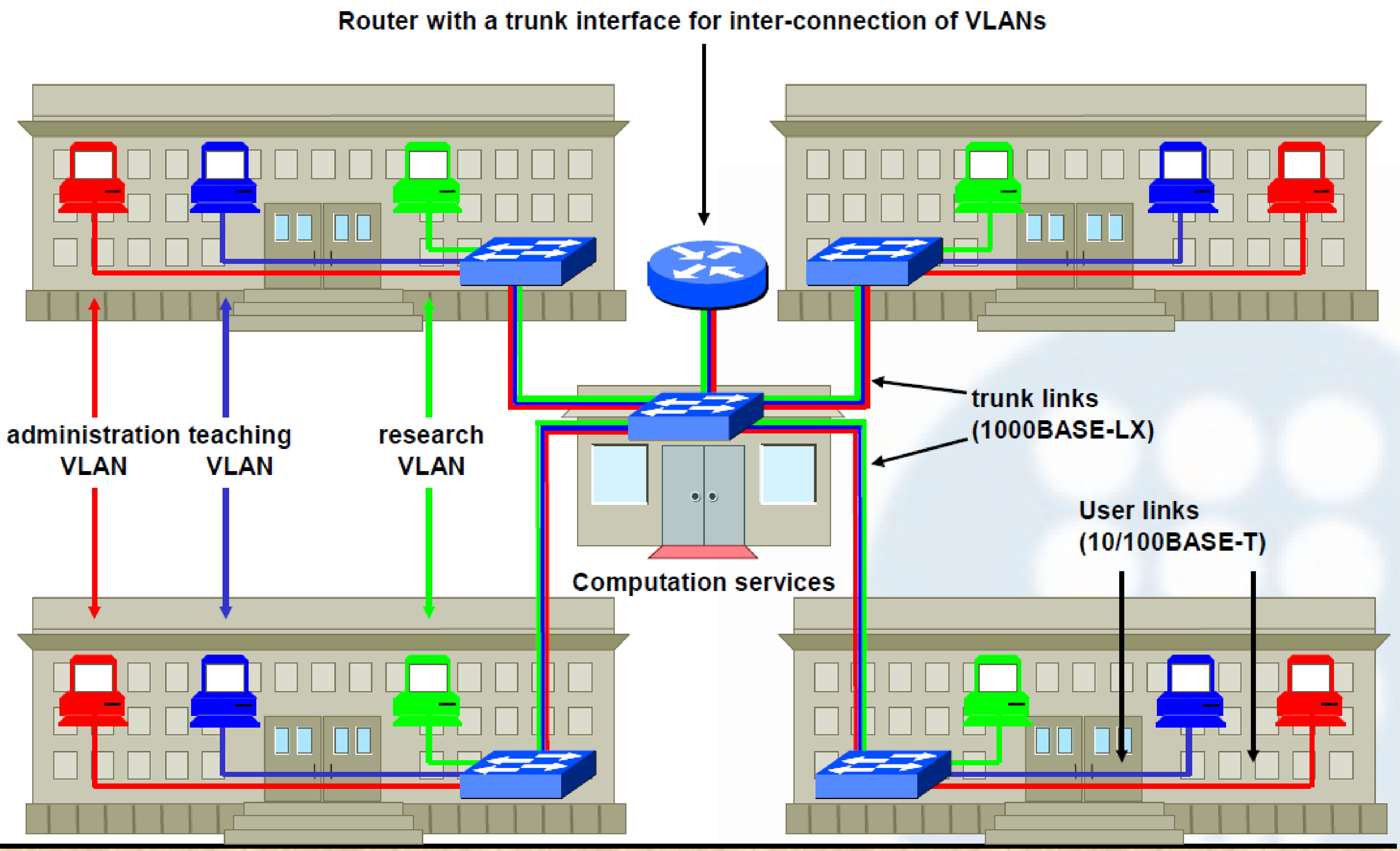

**ROUTER**: Transmits data between different networks (packets). Whether the router connects different protocols or architectures, usually not at domestic level: GATEWAY (ie, PROXYs).



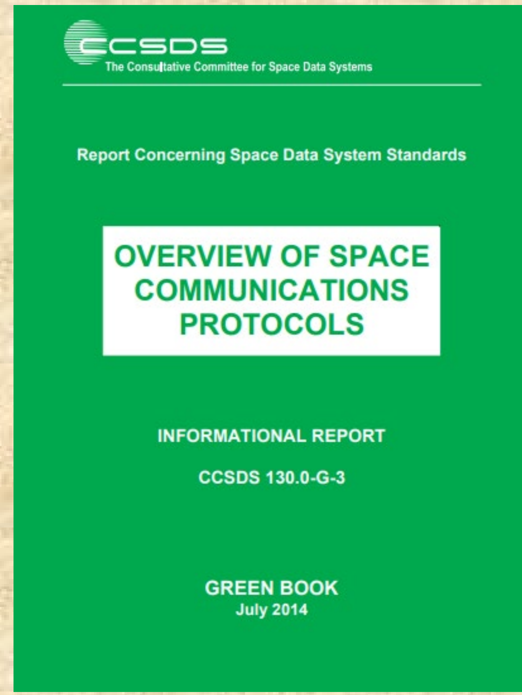




**BRIDGE** (several cases, confusing): 1.- In a router, when the WiFi is turn-off. 2.- LAN bridges, MAC addressing (= switches), 3.- Used to connect/isolate **two** LAN **segments** (segments=sections, not devices – as it does a switch).

# Campus network organization example



# SATELLITE: CCSDS: 5 LEVELS of OSI


CCSDS
The Consultative Committee for Space Data Systems

Report Concerning Space Data System Standards

OVERVIEW OF SPACE COMMUNICATIONS PROTOCOLS

INFORMATIONAL REPORT

CCSDS 130.0-G-3

GREEN BOOK
July 2014

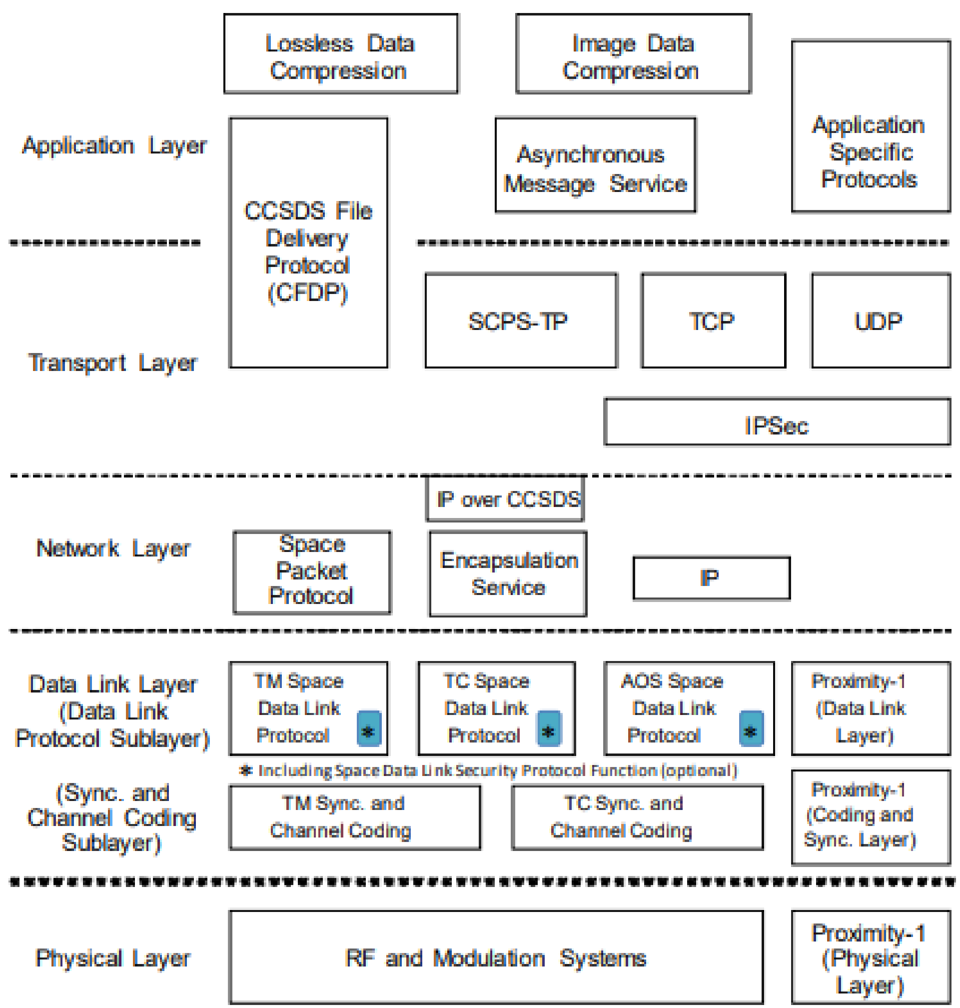
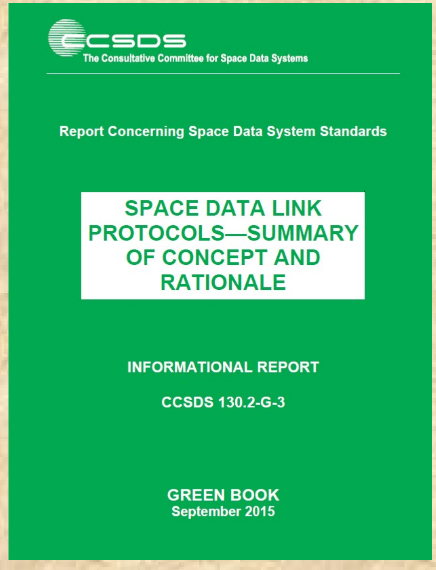



**Figure 2-1: Space Communications Protocols Reference Model**

Check references within this publication


CCSDS
The Consultative Committee for Space Data Systems

Report Concerning Space Data System Standards

SPACE DATA LINK PROTOCOLS—SUMMARY OF CONCEPT AND RATIONALE

INFORMATIONAL REPORT

CCSDS 130.2-G-3

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September 2015

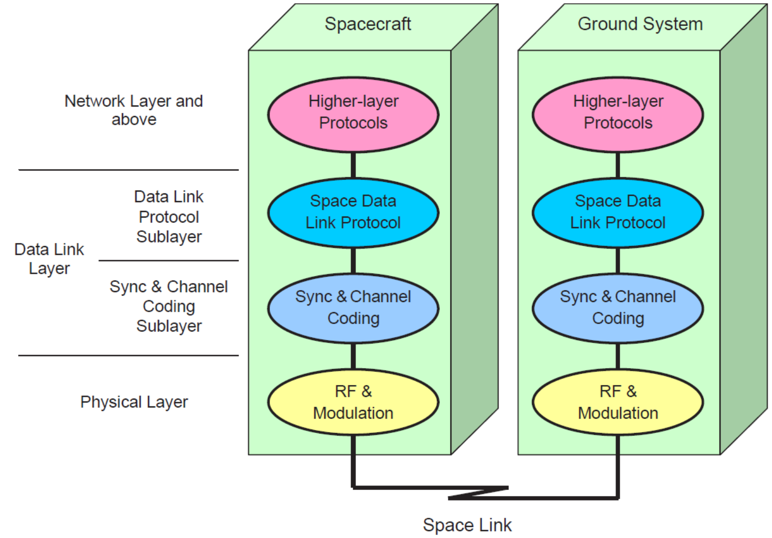
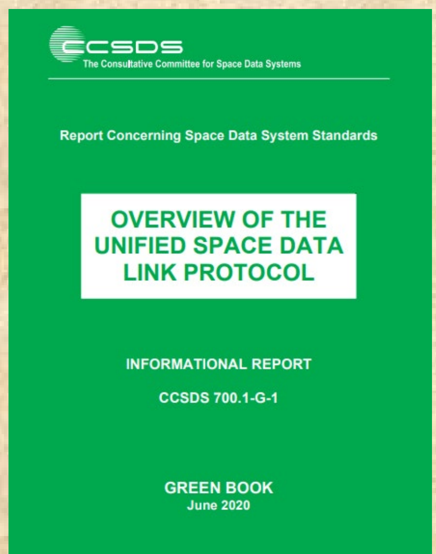



**Figure 2-3: Layer Architecture**


CCSDS
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Report Concerning Space Data System Standards

OVERVIEW OF THE UNIFIED SPACE DATA LINK PROTOCOL

INFORMATIONAL REPORT

CCSDS 700.1-G-1

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June 2020

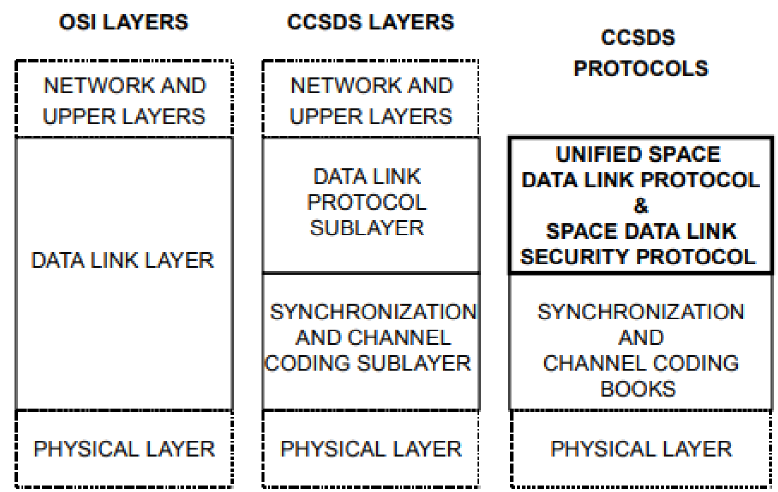
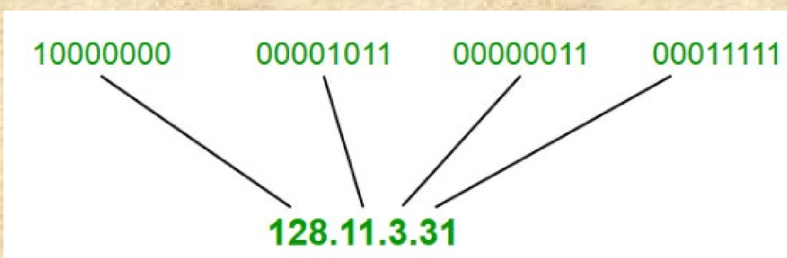


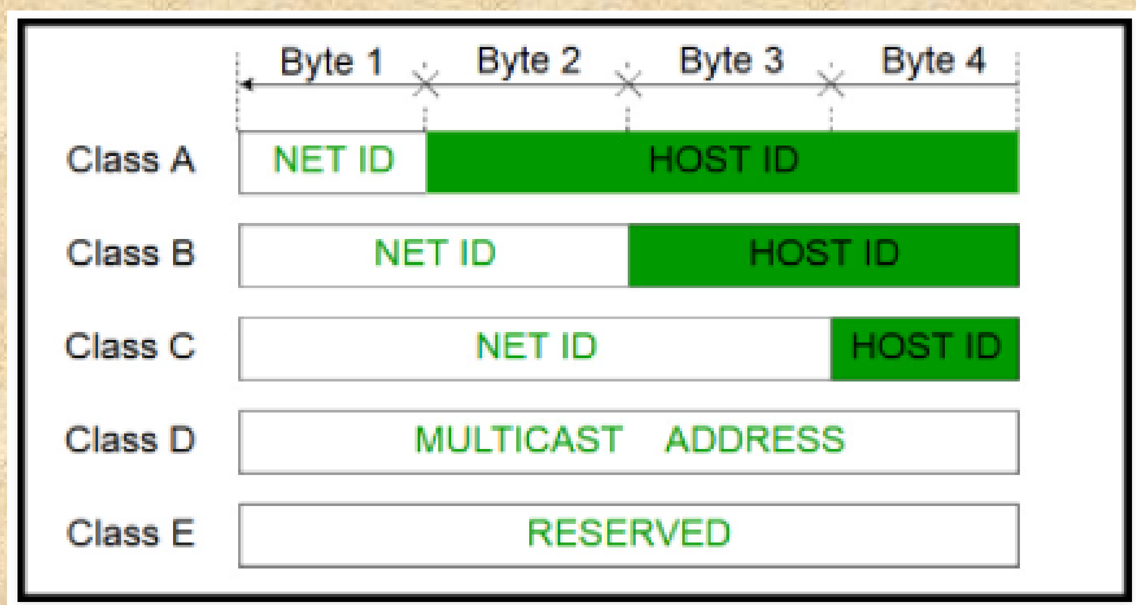

**Figure 2-1: OSI and CCSDS Protocol Stack**

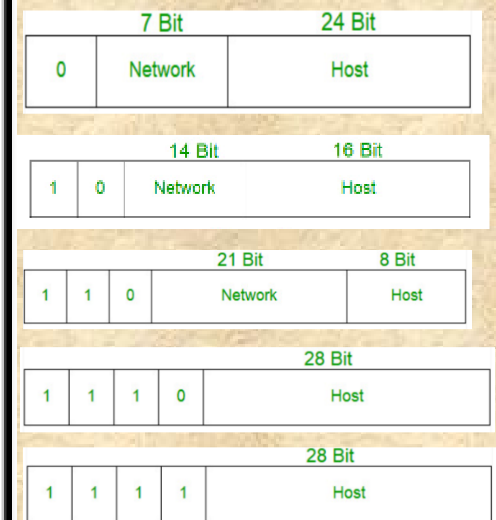
# IP Addressing (IPv4)




32 bits in IPv4

128 bits in *IPv6 (safety, routing, speed)*
*ex: 2001:db8::ff00:42:8329*



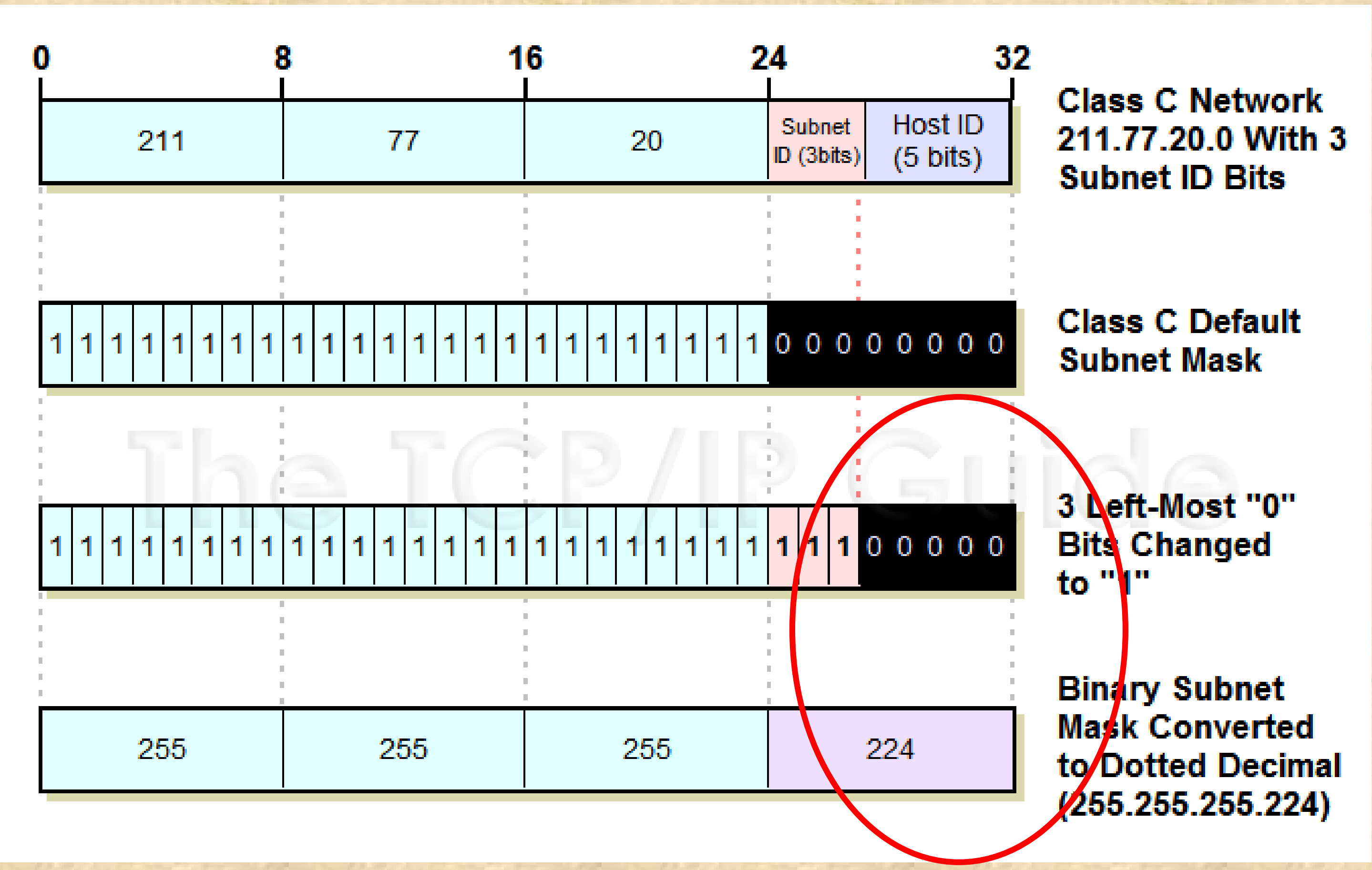




| Class | First octet value |
|---|---|
| A | 0-127 |
| B | 128-191 |
| C | 192-223 |
| D | 224-239 |
| E | 240-255 |

Some IP are reserved for private (inner) communications, without connection to Internet. I,e, 10.x.x.x. These nodes access to Internet using the IP assigned to the router (other IP, which may be of different class).

IP: May be static or dynamic – **DHCP** (*Dynamic Host Configuration Protocol*, a network server that automatically provides and assigns IP addresses

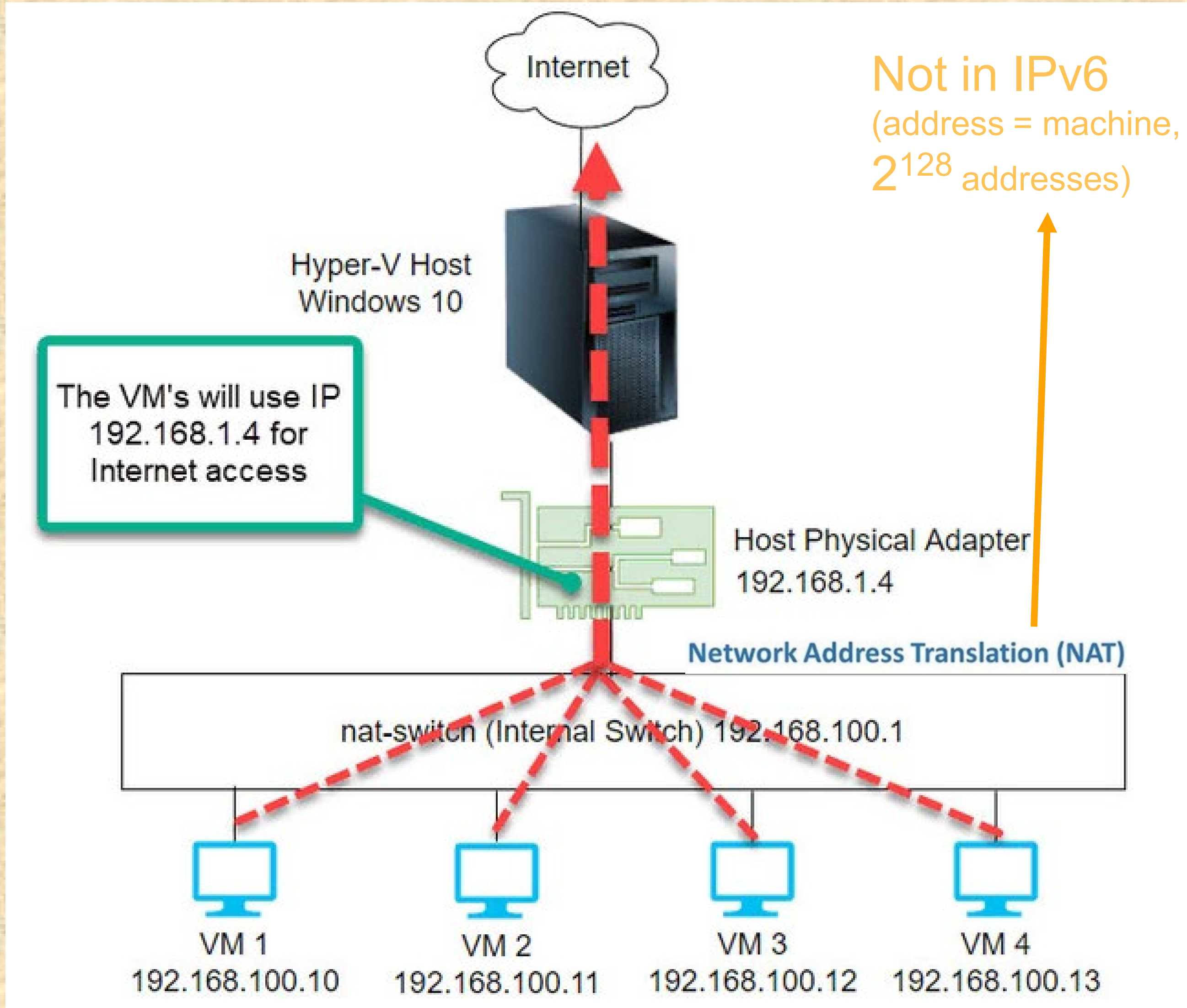
# SUBNET MASK



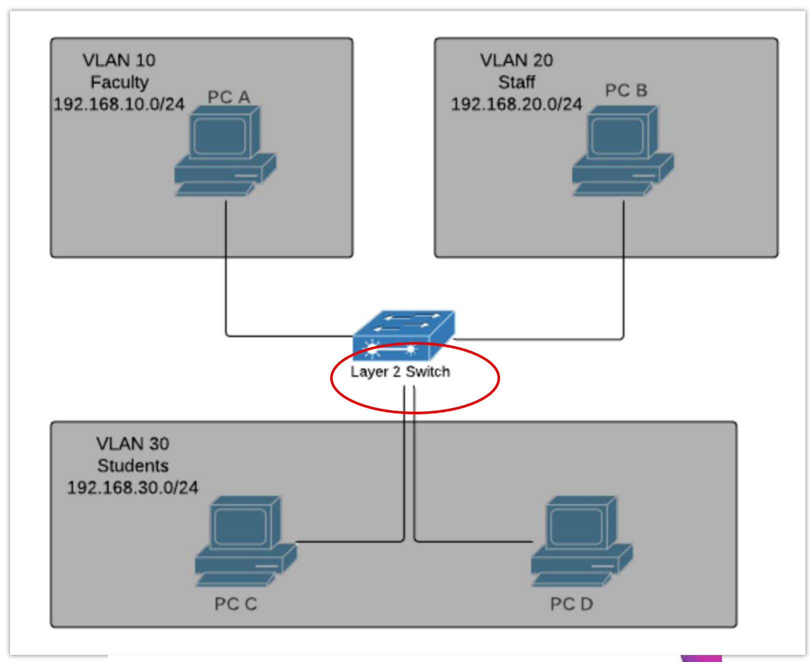

211.77.20.0/24 initially, 211.77.20.0/27 after subnet mask (27 bits allocated for the subnetwork prefix)

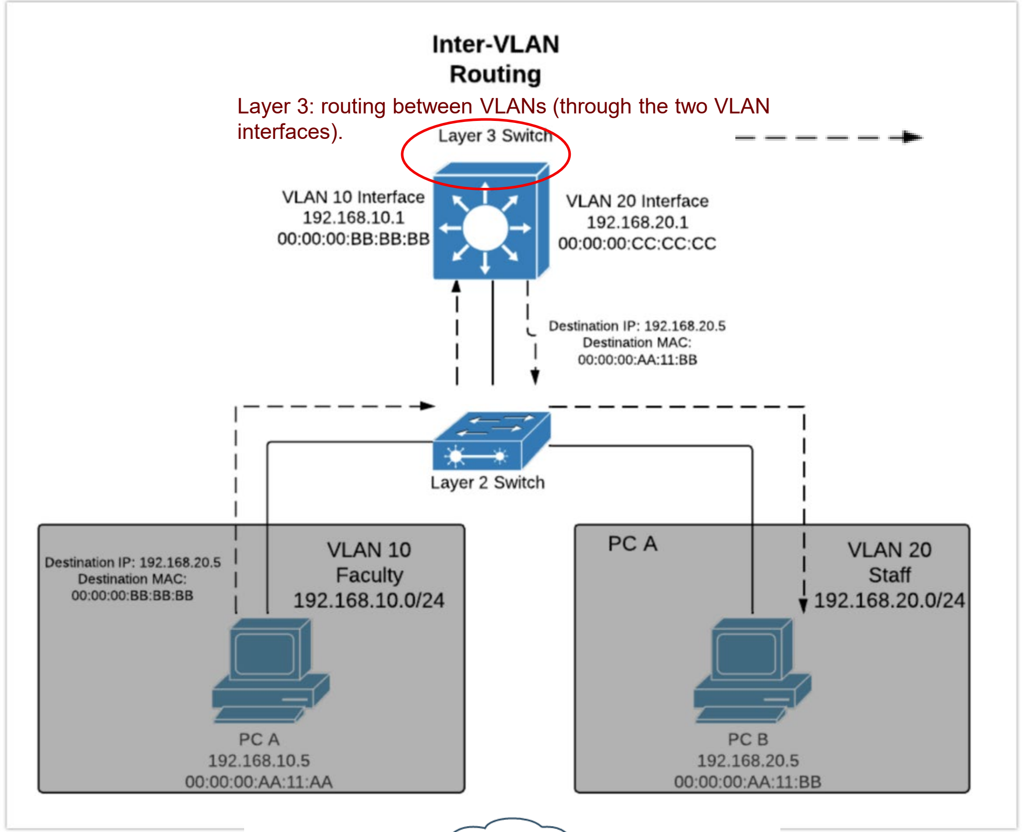
**Subnet** (maybe a type of VLAN): Based on the **mask**. Creation of different logical networks (switch)

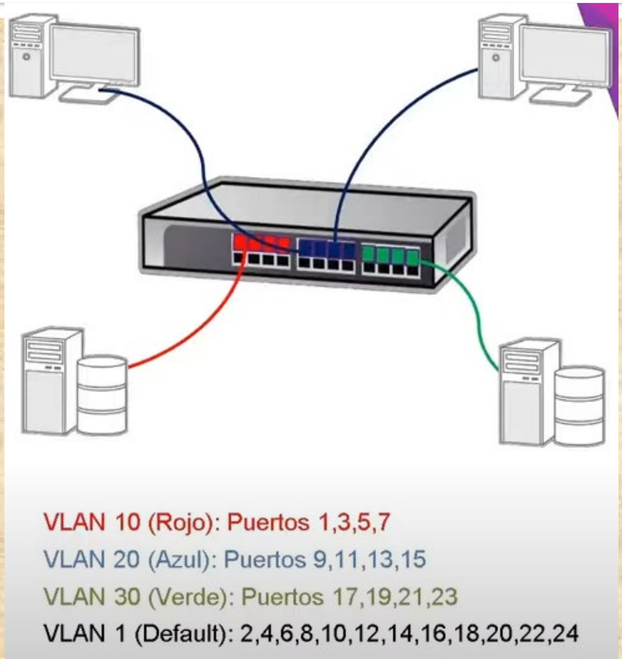
**VLAN**: A LAN domain logically partitioned (and potentially "independent / transparent") into smaller networks. Switches use the protocol types (managed switches), or "virtual" IP addresses (managed switches), or the MAC addresses (unmanaged switches) to make groups of devices). A VLAN can have internal IPs (managed switches software facilitates the set up of the configuration), but connect to the network the IP is the network gateway one.

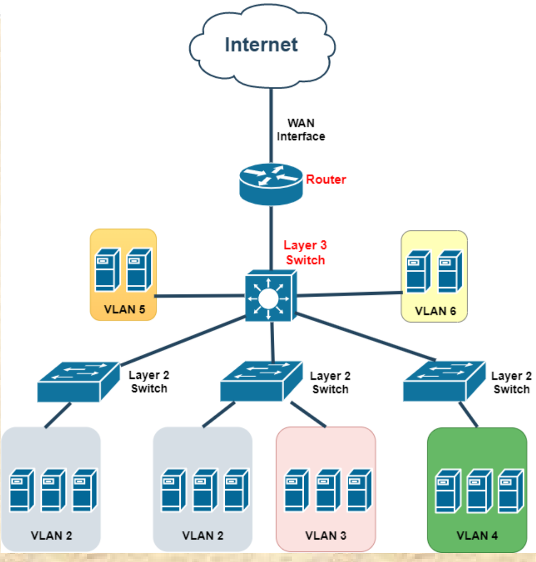

Internet
Not in IPv6
(address = machine,
2^128 addresses)
Hyper-V Host
Windows 10
The VM's will use IP 192.168.1.4 for Internet access
Host Physical Adapter
192.168.1.4
Network Address Translation (NAT)
nat-switch (Internal Switch) 192.168.100.1
VM 1
192.168.100.10
VM 2
192.168.100.11
VM 3
192.168.100.12
VM 4
192.168.100.13

# VLAN (SWITCHES)



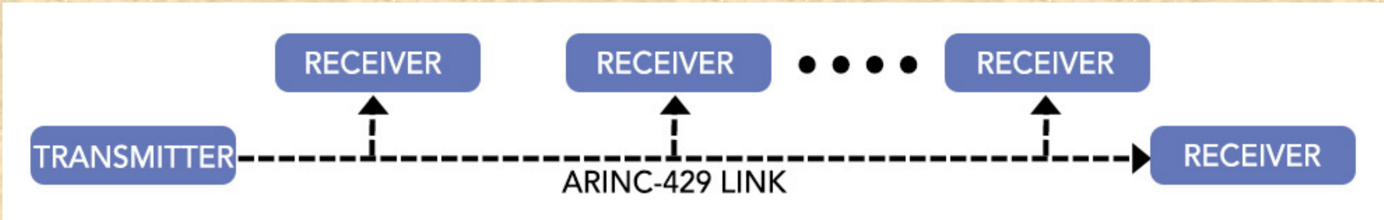



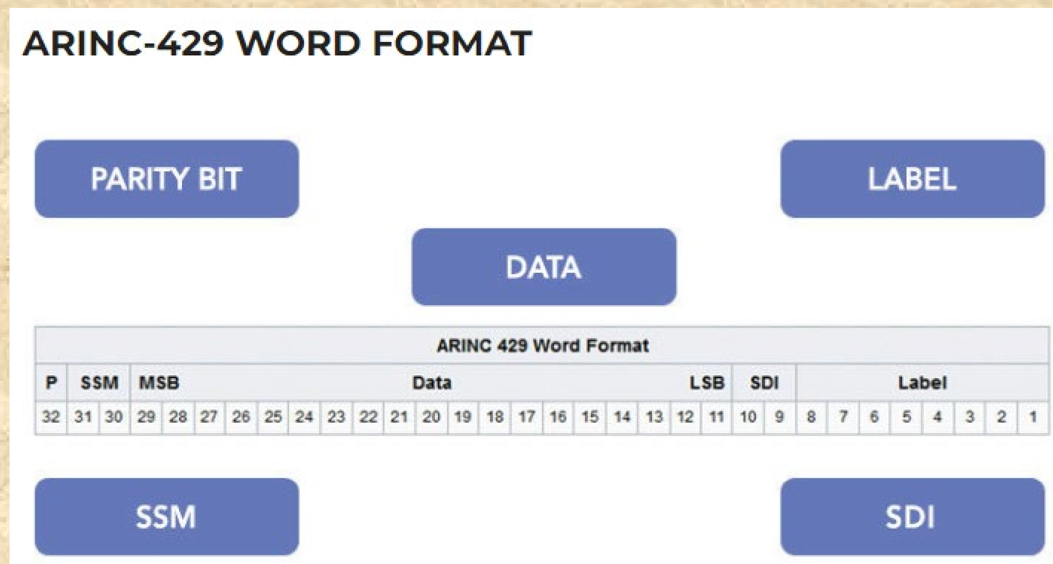



Aircraft:
ARINC standards (429)

https://www.ueidaq.com/de/arinc-429-tutorial#overview

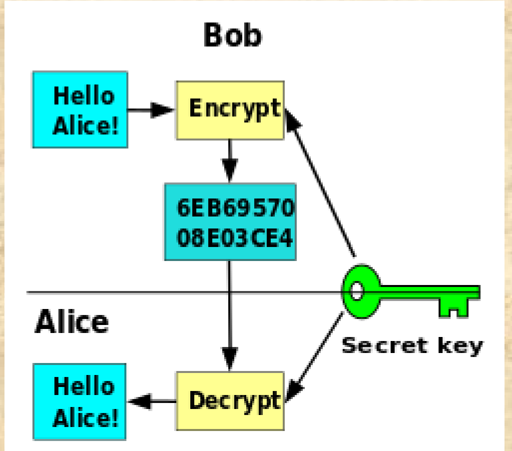



(single transmitter, 1 to 20 receivers)

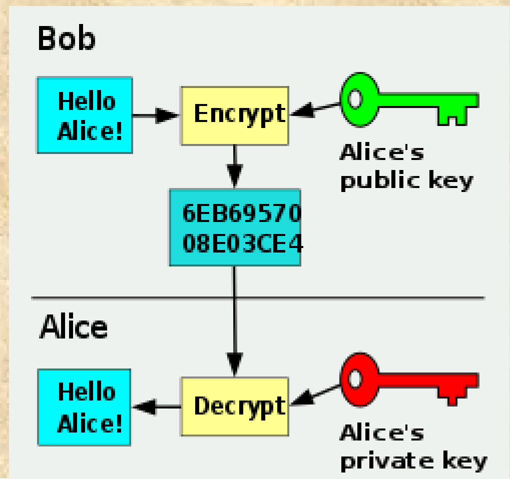


# SOME SECURE DATA COMMUNICATIONS METHODS

- Cryptography (**Encryption**)




Symmetric-key cryptography




(Asymmetric) Public-key cryptography: different keys for encryption and decryption

It remembers a master key system, which can open/close a number of pre-defined doors.

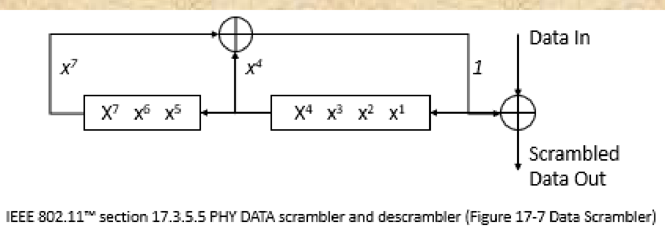
  - Sender (private key), receiver (public key of the sender) = digital signature
  - Sender (public key of the receiver), receiver (private key) = cyphered message

Private key is known (and stored) only by the user; the public key is available to everyone else (in a server, SSH (Secure SHell).

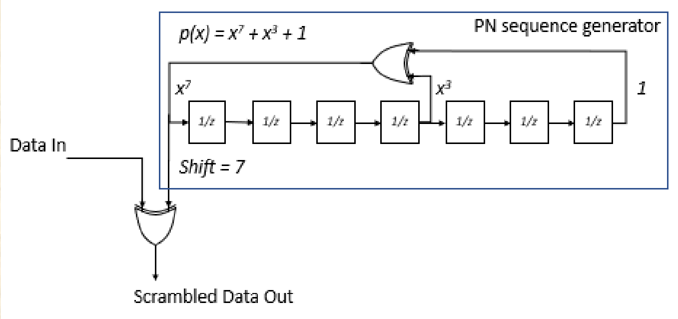
- Data scrambling (generator polynomial-shift register)
- FH Spread Spectrum (I.e, military aeronautics)

# SOME SECURE DATA COMMUNICATIONS METHODS

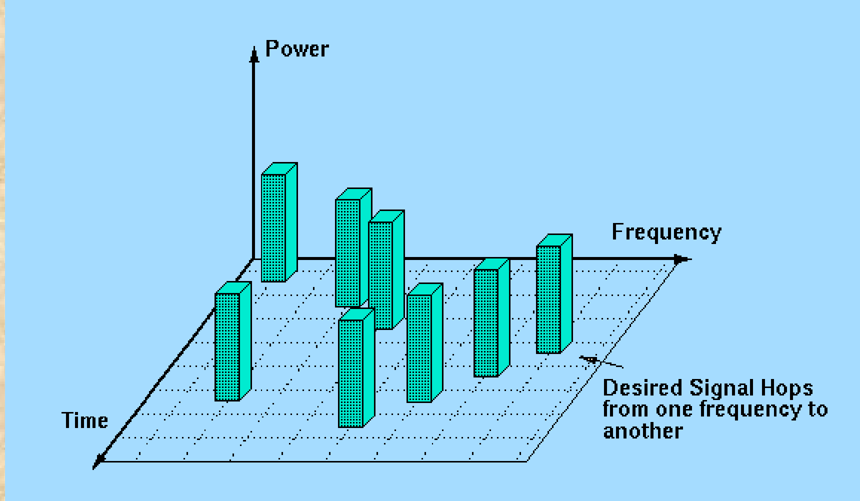
- Data scrambling (generator polynomial-shift register) :
  can be used to encrypt or to enable clock synchronization
  (if polynomials are known)




IEEE 802.11™ section 17.3.5.5 PHY DATA scrambler and descrambler (Figure 17-7 Data Scrambler)




- FH Spread Spectrum (I.e, military aeronautics)



## *Not to be used in this course (too detailed & advanced)*:

## CISCO.  PACKET TRACER:

https://www.telectronika.com/descargas/packet-tracer/