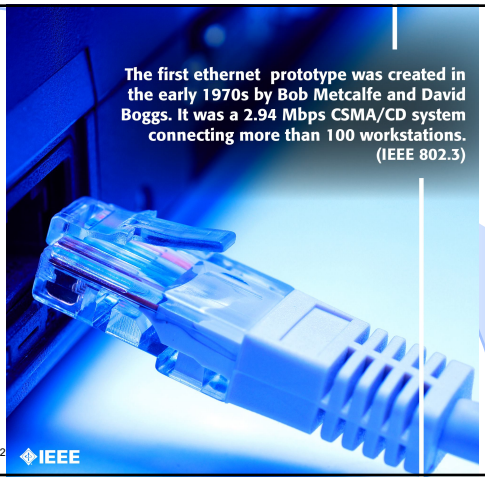
IEEE 802.3

Carrier Sense Multiple Access with Collision Detection (CSMA/CD) - Ethernet

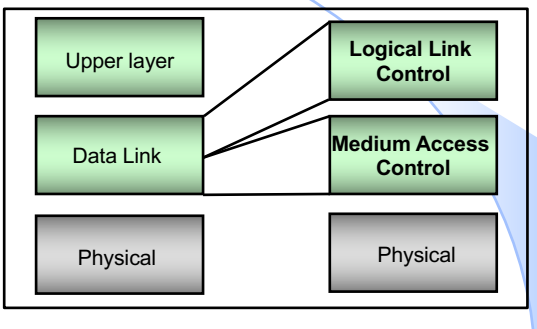
Dr. Miguel Angel León Chávez



Ethernet

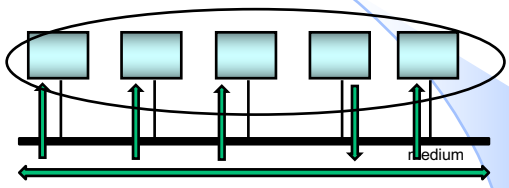
- IEEE 802.3 Std.
- MAC frame format
- CSMA/CD protocol
- The Binary Exponential Backoff Algorithm
- Ethernet Cabling
- Switched Ethernet
- VLAN

IEEE 802 Model



IEEE 802.3

- Bus topology



IEEE 802.3 Std.

- 1976 - Xerox Palo Alto Research Center
  - Ethernet - 2.94 Mb/s data rate
- IEEE Std 802.3-1985, 10 Mb/s
- IEEE Std 802.3u, 100 Mb/s, Fast Ethernet
- IEEE Std 802.3x, full duplex operation and a flow control protocol
- IEEE Std 802.3z, 1000 Mb/s, Gigabit Ethernet
- IEEE Std 802.3ae, 10 Gb/s, 10 Gigabit Ethernet
- IEEE Std 802.3ah, Ethernet in the First Mile
- IEEE Std 802.3-2005-2008-2012-2015

IEEE 802.3 Std (1)

- **IEEE 802.3-15**
- **IEEE 802.3bn-2016**: IEEE Standard for Ethernet Amendment 6: Physical Layer Specifications and Management Parameters for Ethernet Passive Optical Networks Protocol over Coax
- **IEEE 802.3bp-2016**: IEEE Standard for Ethernet Amendment 4: Physical Layer Specifications and Management Parameters for 1 Gb/s Operation over a Single Twisted-Pair Copper Cable
- **IEEE 802.3bq-2016**: IEEE Standard for Ethernet Amendment 3: Physical Layer and Management Parameters for 25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

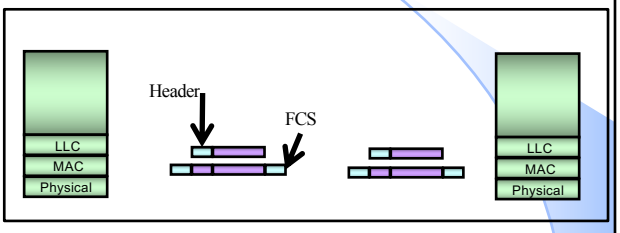
IEEE 802.3 Std (2)

- **IEEE 802.3br-2016**: IEEE Standard for Ethernet Amendment 5: Specification and Management Parameters for Interspersing Express Traffic
- **IEEE 802.3bw-2015**: IEEE Standard for Ethernet Amendment 1: Physical Layer Specifications and Management Parameters for 100 Mb/s Operation over a Single Balanced Twisted Pair Cable (100BASE-T1)
- **IEEE 802.3by-2016**: IEEE Standard for Ethernet - Amendment 2: Media Access Control Parameters, Physical Layers, and Management Parameters for 25 Gb/s Operation

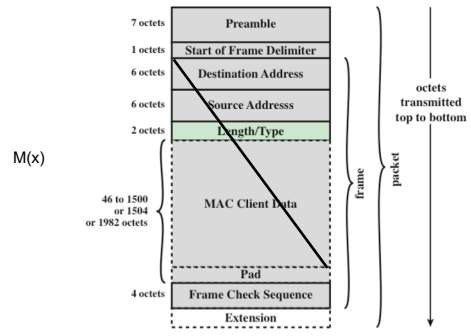
IEEE 802.3 Std (3)

- **IEEE 802.3bz-2016**: IEEE Standard for Ethernet Amendment 7: Media Access Control Parameters, Physical Layers, and Management Parameters for 2.5 Gb/s and 5 Gb/s Operation, Types 2.5GBASE-T and 5GBASE-T
- **IEEE 802.3.1-2013**: IEEE Standard for Management Information Base (MIB) Definitions for Ethernet

Headers

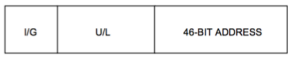


IEEE 802.3 Frame format [1]



IEEE 802.3 Frame Format fields

- Preamble field
  - 7-octet field that is used to allow the PLS circuitry to reach its steady-state synchronization with the received packet's timing
- Start Frame Delimiter (SFD) field
  - It is the sequence **10101011**
- Address fields – **48 bits - Hex**



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

Dirección MAC

- Hex
  - 0,1,2,3…9,A,B,C,D,E,F
  - 0000, 0001, …,1001,1010,1011,1100,1101,1110,1111
- 94-B8-6D-70-63-EF
- 48 bits

M(x)

- 11010110 =
- $2^7 + 2^6 + 2^5 + 2^4 + 2^3 + 2^2 + 2^1 + 2^0$
- $x^7 + x^6 + x^5 + x^4 + x^3 + x^2 + x^1 + x^0 = M(x)$

IEEE 802.3 Frame Format fields

- MAC sublayer address is one of two types:
- a) **Individual Address**. The address associated with a particular station on the network.
- b) **Group Address**. A multidestination address, associated with one or more stations on a given network. There are two kinds of multicast addresses:
  - 1) **Multicast** - Group Address. An address associated by higher-level convention with a group of logically related stations.
  - 2) **Broadcast** Address. A distinguished, predefined multicast address that always denotes the set of all stations on a given LAN.

IEEE 802.3 Frame Format fields

- Length/Type field
  - This two-octet field takes one of two meanings, depending on its numeric value:
  - If the value of this field is less than or equal to 1500 decimal, then it indicates the number of MAC client data octets contained in the subsequent MAC Client Data field
  - If the value of this field is greater than or equal to 1536 decimal, then the Length/Type field indicates the Ethertype of the MAC client protocol

IEEE 802.3 Frame Format fields

- MAC Client Data field
  - 1500 decimal—basic frames
  - 1504 decimal—Q-tagged frames
  - 1982 decimal—envelope frames
- Pad field
  - The size of the Pad, if any, is determined by the size of the MAC Client Data field supplied by the MAC client and the minimum MAC frame size and address size MAC parameters
  - The length of the Pad field required for MAC Client Data that is clientDatasize/8 octets long is max [0, minFrameSize – (clientDatasize + 2 × addressSize + 48)] bits.

IEEE 802.3 Frame Format fields

- Frame Check Sequence (FCS) field
  - A **cyclic redundancy check** (CRC) is used by the transmit and receive algorithms to generate a CRC value for the FCS field
  - Generating polynomial
  - $G(x)=x^{32}+x^{26}+x^{23}+x^{22}+x^{16}+x^{12}+x^{11}+x^{10}+x^{8}+x^{7}+x^{5}+x^{4}+x^{2}+x+1$

CRC

- a) The first 32 bits of the frame are complemented.
- b) The n bits of the protected fields are then considered to be the coefficients of a polynomial $M(x)$ of degree $n-1$.
- The first bit of the Destination Address field corresponds to the $x^{(n-1)}$ term and the last bit of the MAC Client Data field (or Pad field if present) corresponds to the x^0 term
- c) $M(x)$ is multiplied by x^{32} and divided by $G(x)$, producing a remainder $R(x)$ of degree ≤ 31
- d) The coefficients of $R(x)$ are considered to be a 32-bit sequence
- e) The bit sequence is complemented and the result is the CRC

CRC (mod 2)

Transmitter: $G(x)\sqrt{M(x)}$, $\frac{Q(x)}{R(x)}$

$M(X) + R(x)$

Receiver: $G(x)\sqrt{M(x) + R(x)}$, $\frac{Q'(x)}{R'(x)}$

If $R'(x) = 0$ No error detected

else Error detected

mod n (enteros)

- a ≡ b mod n (a es congruente a b módulo n)
- a = b + nk (k está en los enteros)
- a ≡ 24 mod 4
- a ≡ 24 + 4(k) : k = 1, 2, 3, 4, 5, …
- a ≡ 28, 32, 36, …

suma mod 8

+	0	1	2	3	4	5	6	7
0	0	1	2	3	4	5	6	7
1	1	2	3	4	5	6	7	0
2	2	3	4	5	6	7	0	1
3	3	4	5	6	7	0	1	2
4	4	5	6	7	0	1	2	3
5	5	6	7	0	1	2	3	4
6	6	7	0	1	2	3	4	5
7	7	0	1	2	3	4	5	6

resta mod 8

- a + (-a) = 0

multiplicación mod 8

x	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	**1**	2	3	4	5	6	7
2	0	2	4	6	0	2	4	6
3	0	3	6	**1**	4	7	2	5
4	0	4	0	4	0	4	0	4
5	0	5	2	7	4	**1**	6	3
6	0	6	4	2	0	6	4	2
7	0	7	6	5	4	3	2	**1**

dividir mod 8

- a x (a^{-1}) = 1

mod 2

+	0	1
0	0	1
1	1	0

XOR

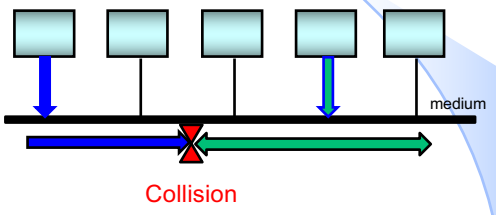
x	0	1
0	0	0
1	0	1

AND

Modes of operation of the MAC sublayer

- Half duplex mode
  - on all supported media
- Full duplex mode
  - 10BASE-T, 10BASE-FL, and 100BASE-TX/FX
  - No Collisions

Multiple Access



Collision

Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

- 0. If the node have SDU
  - PDU = H || SDU || CRC
- 1. Carrier Sense
  - Listen the medium
- 2. If the medium is free (idle) then transmit
  - a) Transmits
  - b) Carrier Sense
  - c) If a collision is detected then stop transmission
    - i) call **Backoff**
    - ii) go to 1
  - d) else successful transmission
    - i) go to 0
- 2. else (the medium is busy)
  - a) call **Backoff**
  - b) go to 1

Truncated Binary Exponential Backoff

```
var maxBackoff: 2..1024; {Working variable of Backoff}
procedure Backoff()
begin
if attempts = 1 then maxBackoff := 2
else if attempts ≤ backoffLimit then
        maxBackoff := maxBackoff x 2;
Wait(slotTime x Random(0, maxBackoff))
end; {Backoff}
```


Truncated Binary Exponential Backoff

- The number of slot times to delay before the *n*th retransmission attempt is chosen as a uniformly distributed random integer *r* in the range:

$$0 \le r < 2^k$$

- Where k = min (n, 10)

Ethernet Cabling

The most common kinds of Ethernet cabling [2]

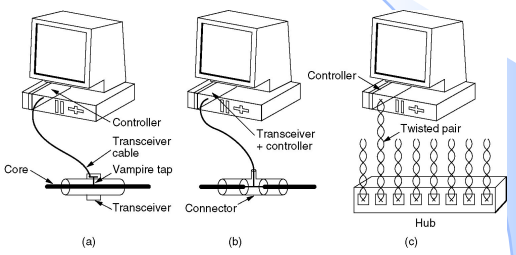
Name	Cable	Max. seg.	Nodes/seg.	Advantages
10Base5	Thick coax	500 m	100	Original cable; now obsolete
10Base2	Thin coax	185 m	30	No hub needed
10Base-T	Twisted pair	100 m	1024	Cheapest system
10Base-F	Fiber optics	2000 m	1024	Best between buildings

Ethernet Cabling [1]

	10BASE5	10BASE2	10BASE-T	10BASE-FP
Transmission medium	Coaxial cable (50 ohm)	Coaxial cable (50 ohm)	Unshielded twisted pair	850-nm optical fiber pair
Signaling technique	Baseband (Manchester)	Baseband (Manchester)	Baseband (Manchester)	Manchester/on-off
Topology	Bus	Bus	Star	Star
Maximum segment length (m)	500	185	100	500
Nodes per segment	100	30	—	33
Cable diameter (mm)	10	5	0.4 to 0.6	62.5/125 μm

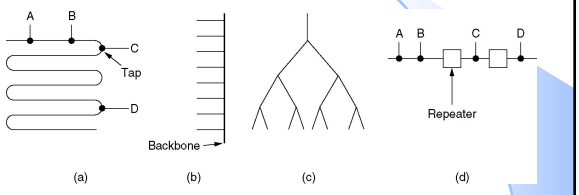
Ethernet Cabling [2]

Three kinds of Ethernet cabling
(a) 10Base5, (b) 10Base2, (c) 10Base-T.



Ethernet Cabling [2]

Cable topologies. (a) Linear, (b) Spine, (c) Tree, (d) Segmented.



Fast Ethernet

The original fast Ethernet cabling [2]

Name	Cable	Max. segment	Advantages
100Base-T4	Twisted pair	100 m	Uses category 3 UTP
100Base-TX	Twisted pair	100 m	Full duplex at 100 Mbps
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

IEEE 802.3 100BASE-T Physical Layer [1]

	100BASE-TX		100BASE-FX	100BASE-T4
Transmission medium	2 pair, STP	2 pair, Category 5 UTP	2 optical fibers	4 pair, Category 3, 4, or 5 UTP
Signaling technique	MLT-3	MLT-3	4B5B, NRZI	8B6T, NRZ
Data rate	100 Mbps	100 Mbps	100 Mbps	100 Mbps
Maximum segment length	100 m	100 m	100 m	100 m
Network span	200 m	200 m	400 m	200 m

Gigabit Ethernet

Gigabit Ethernet cabling [2]

Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 μ) or multimode (50, 62.5 μ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

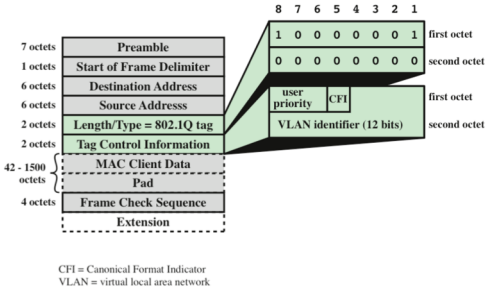
Full Duplex Operation

- Traditional Ethernet half duplex
- Using full-duplex, station can transmit and receive simultaneously
- 100-Mbps Ethernet in full-duplex mode, giving a theoretical transfer rate of 200 Mbps
- Stations must have full-duplex adapter cards
- And must use switching hub
  - Each station constitutes separate collision domain
  - CSMA/CD algorithm no longer needed
  - 802.3 MAC frame format used

The IEEE 802.1Q standard

- Switches must indicate VLAN membership
- This is accomplished in 802.1Q by inserting a tag with a VLAN identifier (VID) with a value in the range from 1 to 4094
- Each VLAN in a LAN configuration is assigned a globally unique VID
- By assigning the same VID to end systems on many switches, one or more VLAN broadcast domains can be extended across a large network

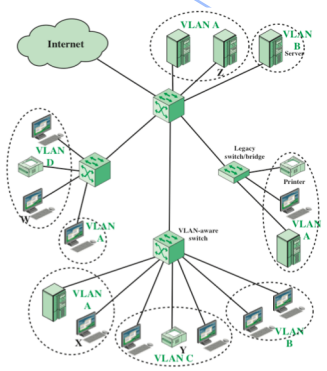
Tagged IEEE 802.3 frame format [1]



TCI field

- **User priority (3 bits):** The priority level for this frame.
- **Canonical format indicator (1 bit):** is always set to zero for Ethernet switches. CFI is used for compatibility reason between Ethernet type network and Token Ring type network. If a frame received at an Ethernet port has a CFI set to 1, then that frame should not be forwarded as it is to an untagged port.
- **VLAN identifier (12 bits):** the identification of the VLAN. Of the 4096 possible VIDs, a VID of 0 is used to identify that the TCI contains only a priority value, and 4095 (FFF) is reserved, so the maximum possible number of VLAN configurations is 4094.

VLAN configuration [1]



References

- IEEE Standard for Information technology—Telecommunications and information exchange between systems— Local and metropolitan area networks— Specific requirements Part 3: Carrier sense multiple access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications. 2015
- [1] Stallings, W., *Data and Computer Communications*. Ed. Pearson.
- [2] Tanembaun, A. S. *Redes de computadoras*. Ed. Pearson, 4a. ed., 2003.