

Networking Basics



ETHERNET FUNDAMENTALS

The **Cisco Certified**
Network Associate
Curriculum



Version 3.0
Cisco Regional Networking Academy



► Objectives

- Describe the basics of Ethernet technology.
- Explain naming rules of Ethernet technology.
- Define how Ethernet and the OSI model interact.
- Describe the Ethernet framing process and frame structure.
- List Ethernet frame field names and purposes.
- Identify the characteristics of CSMA/CD.
- Describe the key aspects of Ethernet timing, interframe spacing and backoff time after a collision.
- Define Ethernet errors and collisions.
- Explain the concept of auto-negotiation in relation to speed and duplex.

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ETHERNET FUNDAMENTALS

► Introduction to Ethernet

- In 1970's
 - CSMA/CD developed at the University of Hawaii
- In 1980's
 - First experimental Ethernet system at Xerox PARC
- In 1985, IEEE 802.3 released
- Digital Equipment, Intel, and Xerox jointly develop & release Ethernet Version 2.0
 - Substantially compatible with IEEE 802.3
- In 1995, IEEE announced a standard for a 100-Mbps Ethernet. This was followed by standards for Gigabit ethernet in 1998 and 1999.

► The success of Ethernet is due to the following factors

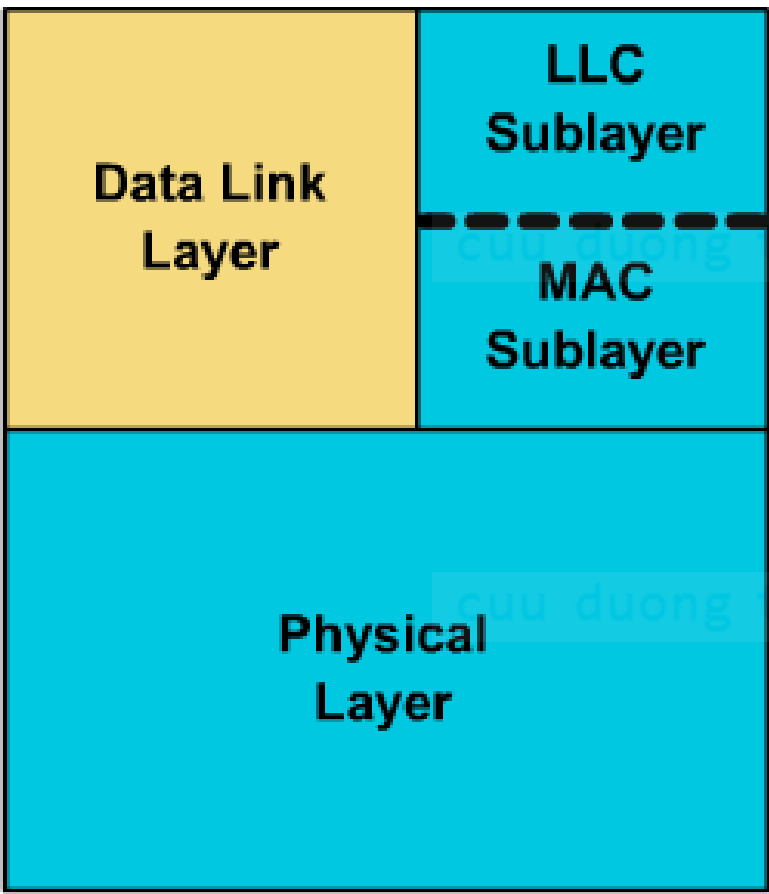
- Simplicity and ease of maintenance
- Ability to incorporate new technologies
- Reliability
- Low cost of installation and upgrade

► IEEE Ethernet naming rules

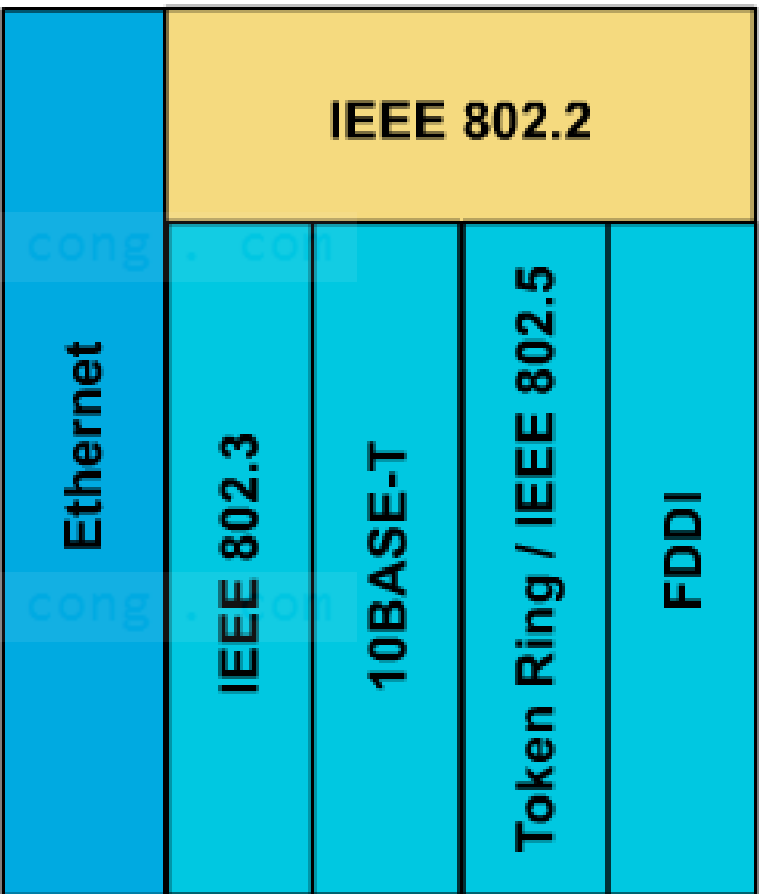
- 10Base-2: 50 Ω Thin cable, 185m.
- 10Base-5: 50 Ω Thick cable, 500m.
- 10Base-T: 100 Ω UTP cable, 100m.
- 10Base-F: Fiber optic cable, 1000m.
- 100Base-TX: 100 Ω UTP/STP cable, 100m.
- 100Base-T4: 100 Ω UTP (4p) cable, 100m.
- 100Base-FX: Fiber optic cable, 400m.
- 1000Base-T: 100 Ω UTP/STP cable, 100m.

▶ Ethernet and the OSI model

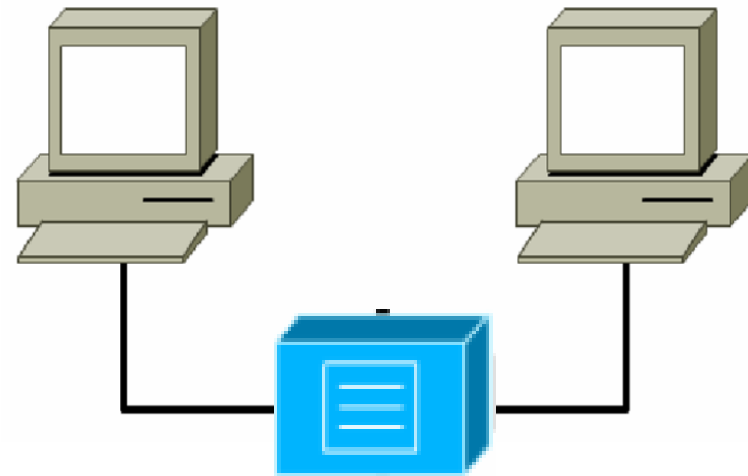
OSI Layers



LAN Specification



► A Repeater



- Standards guarantee minimum bandwidth and operability by specifying the maximum number of stations per segment, maximum segment length, maximum number of repeaters between stations, etc.
- Stations separated by repeaters are within the same collision domain. Stations separated by bridges or routers are in different collision domains.

► Layer 1 vs Layer 2

- Layer 1 cannot organize streams of bits.
- Layer 2 uses *framing* to organize or group the bits.
- Layer 1 cannot name or identify computers.
- Layer 2 uses an *addressing* process to identify computers.
- Layer 1 cannot communicate with the upper-level layers.
- Layer 2 uses *Logical Link Control (LLC)* to communicate with the upper-level layers.
- Layer 1 cannot decide which computer will transmit binary data.
- Layer 2 uses *Media Access Control (MAC)* to decide which computer will transmit.

► Ethernet and the OSI mode

| Logical Link Control Sublayer | | | | | | | | |
|-------------------------------|-----------------|--|-----------------------------------|--------------------------------------|--|--|--|---------------------------------------|
| 802.3 Media Access Control | | | | | | | | |
| Physical Signaling sublayer | Physical Medium | 10BASE5 (500m) 50 Ohm Coax N-Style | 10BASE2 (185m) 50 Ohm Coax BNC | 10BASE-T (100m) 100 Ohm UTP RJ-45 | 100BASE-TX (100m) 100 Ohm UTP RJ-45 | 1000BASE-CX (25m) 150 Ohm STP mini-DB-9 | 1000BASE-T (100m) 100 Ohm UTP RJ-45 | 1000BASE-SX (220-550m) MM Fiber SC |
| | | 1000BASE-LX (550-5000m) MM or SM Fiber SC | | | | | | |

► Naming

- Every computer has a unique way of identifying itself : MAC address or physical address.
- The physical address is located on the Network Interface Card (NIC).
- MAC addresses have no structure, and are considered flat address spaces. MAC addresses are sometimes referred to as *burned-in addresses* (*BIAs*) because they are burned into read-only memory (**ROM**) and are copied into random-access memory (**RAM**) when the NIC initializes.
- 0000.0c12.3456 or 00-00-0c-12-34-56.

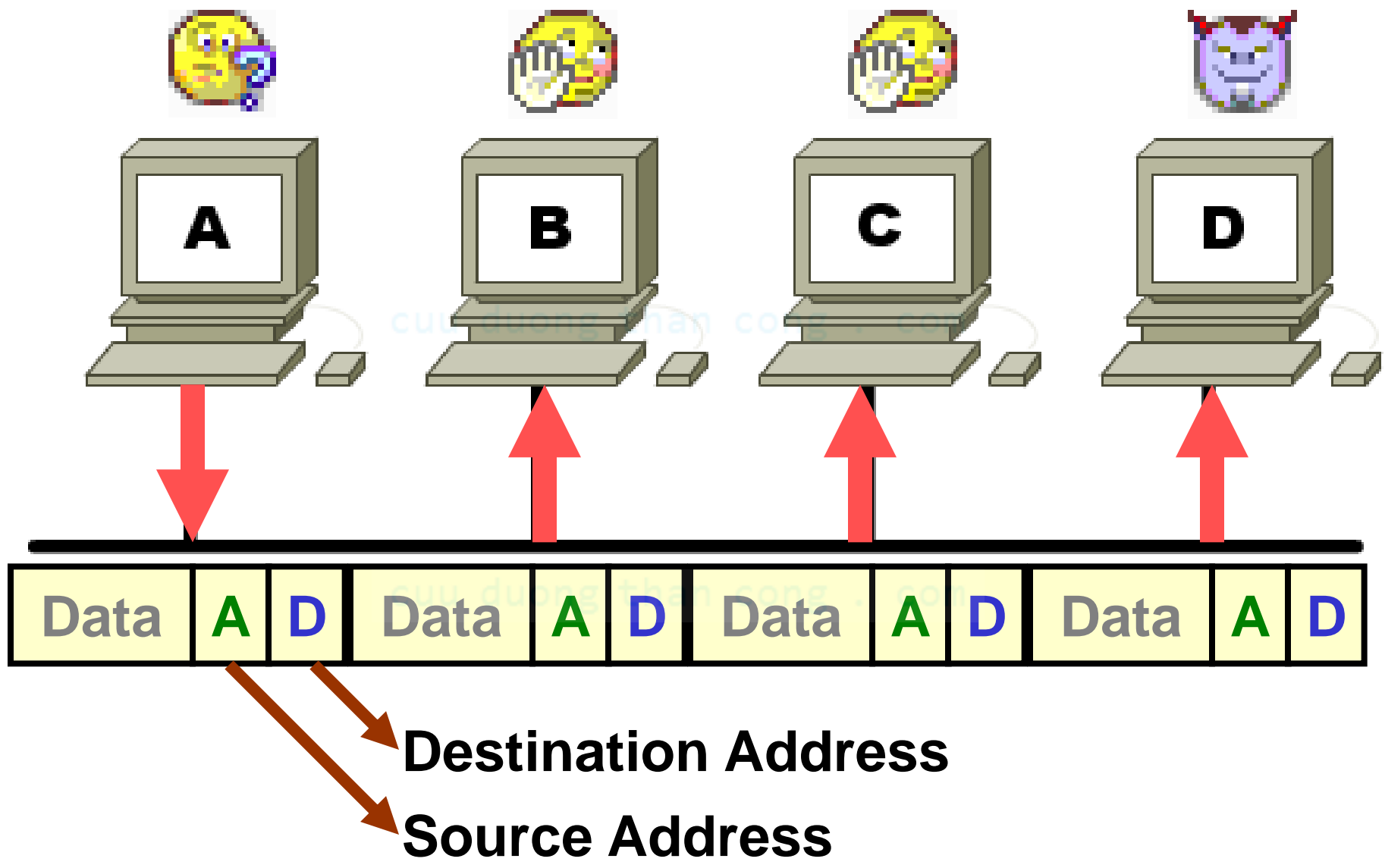
► MAC address format



The remaining six hexadecimal digits comprise the interface serial number.

The first six hexadecimal digits identify the vendor.

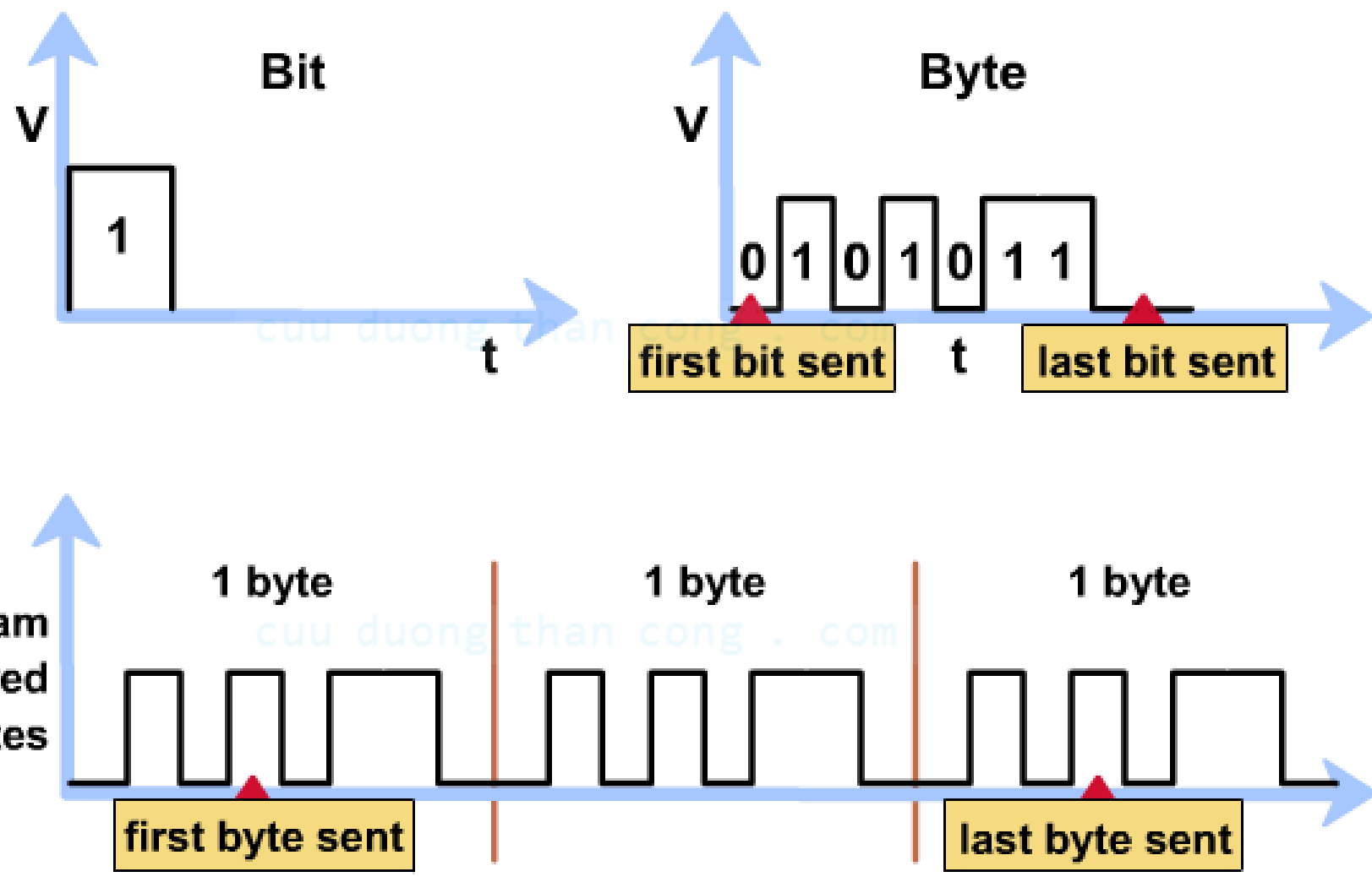
▶ Using MAC addresses



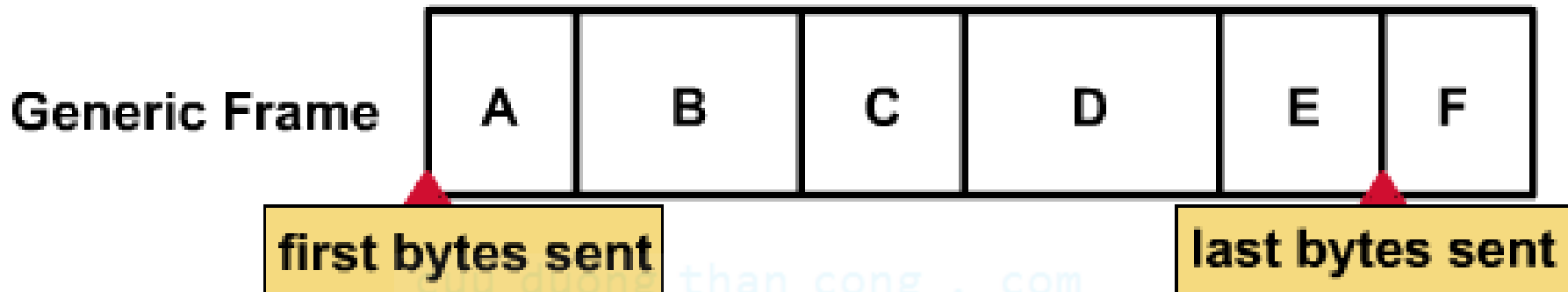
► Layer 2 framing : Why framing is necessary?

- Which computers are communicating with one another.
- When communication between individual computers begins and when it terminates.
- A record of errors that occurred during the communication.
- Whose turn it is to “talk” in a computer “conversation”.

▶ Frame format diagram



▶ Frame format diagram



A, B, C, D, E, F multiple, often many, bytes

- The frame format diagram shows different groupings of bits (*fields*) that perform other functions.
- Read them from left to right.

► Generic frame format

| Field Names | | | | | |
|-------------------|---------------|-------------------|------------|-----------|------------------|
| A | B | C | D | E | F |
| Start Frame Field | Address Field | Type/Length Field | Data Field | FCS Field | Stop Frame Field |

- There are many different types of frames described by various standards.

► Start frame field

| Field Names | | | | | |
|-------------------|---------------|-------------------|------------|-----------|------------------|
| A | B | C | D | E | F |
| Start Frame Field | Address Field | Type/Length Field | Data Field | FCS Field | Stop Frame Field |

- The **Start Frame field** tells other devices on the network that a frame is coming down the wire.

► Address field

| Field Names | | | | | |
|-------------------|---------------|-------------------|------------|-----------|------------------|
| A | B | C | D | E | F |
| Start Frame Field | Address Field | Type/Length Field | Data Field | FCS Field | Stop Frame Field |

- The **Address field** stores the source and destination MAC addresses.

► Length/Type field

| Field Names | | | | | |
|-------------------|---------------|-------------------|------------|-----------|------------------|
| A | B | C | D | E | F |
| Start Frame Field | Address Field | Type/Length Field | Data Field | FCS Field | Stop Frame Field |

- The Type/Length field is an optional field
- Exact length of frame, or
- Layer 3 protocol making the sending request, or
- Not used

► Data field

| Field Names | | | | | |
|-------------------|---------------|-------------------|------------|-----------|------------------|
| A | B | C | D | E | F |
| Start Frame Field | Address Field | Type/Length Field | Data Field | FCS Field | Stop Frame Field |

- The **Data field** is the actual information being sent by the upper layer protocols. Therefore, it will be all upper layer data.

► FCS field

| Field Names | | | | | |
|-------------------|---------------|-------------------|------------|-----------|------------------|
| A | B | C | D | E | F |
| Start Frame Field | Address Field | Type/Length Field | Data Field | FCS Field | Stop Frame Field |

- ***Cyclic Redundancy Check (CRC) - performs polynomial calculations on the data***
- ***Two-dimensional parity - adds an 8th bit that makes an 8 bit sequence have an odd or even number of binary 1's***
- ***Internet checksum - adds the values of all of the data bits to arrive at a sum***

► Stop frame field

| Field Names | | | | | |
|-------------------|---------------|-------------------|------------|-----------|------------------|
| A | B | C | D | E | F |
| Start Frame Field | Address Field | Type/Length Field | Data Field | FCS Field | Stop Frame Field |

- The **Stop Frame** field, also called the Frame Trailer, is an optional field that is used when the length of the frame was not specified in the Type/Length field.

► Ethernet frame structure

| Ethernet-II(DIX 2.0) | | | | | |
|-----------------------|---------------|----------------|------|---------|-----|
| 7+1 | 6 | 6 | 2 | 46-1500 | 4 |
| Preamble | Dest. Address | Source Address | Type | Data | FCS |

| IEEE 802.3 | | | | | | |
|------------|-----------------------|---------------|----------------|--------|---------------------|-----|
| 7 | 1 | 6 | 6 | 2 | 64-1500 | 4 |
| Preambl e | Start Frame Delimiter | Dest. Address | Source Address | Length | 802.2 Header & Data | FCS |

▶ Preamble Field

| IEEE 802.3 | | | | | | |
|------------|-----------------------|---------------|----------------|--------|---------------------|-----|
| 7 | 1 | 6 | 6 | 2 | 64-1500 | 4 |
| Preamble | Start Frame Delimiter | Dest. Address | Source Address | Length | 802.2 Header & Data | FCS |

- Preamble
 - Alternating patterns of 1s and 0s, ended by 2 bits **11**
 - Tells receiving stations whether frame is Ethernet or IEEE 802.3
 - Preamble + SOF(101010**11**) = Ethernet frame

▶ Start of Frame

| IEEE 802.3 | | | | | | |
|------------|-----------------------|---------------|----------------|--------|---------------------|-----|
| 7 | 1 | 6 | 6 | 2 | 64-1500 | 4 |
| Preamble | Start Frame Delimiter | Dest. Address | Source Address | Length | 802.2 Header & Data | FCS |

- Start of Frame
 - IEEE 802.3 only
 - Delimiter byte ends with 2 consecutive 1 bits
 - Synchronize the frame-reception, ready to receive
 - Explicitly specified in Ethernet

▶ Address

| IEEE 802.3 | | | | | | |
|------------|-----------------------|---------------|----------------|--------|---------------------|-----|
| 7 | 1 | 6 | 6 | 2 | 64-1500 | 4 |
| Preamble | Start Frame Delimiter | Dest. Address | Source Address | Length | 802.2 Header & Data | FCS |

- Destination and source addresses
 - 1st 3 bytes are vendor-specific
 - Specified by IEEE
 - Last 3 bytes are specified by vendor
 - Ethernet or IEEE 802.3 vendor
 - Source address is always unicast
 - Destination can be unicast, multicast, or broadcast

▶ Type/Length

| IEEE 802.3 | | | | | | |
|------------|-----------------------|---------------|----------------|--------|---------------------|-----|
| 7 | 1 | 6 | 6 | 2 | 64-1500 | 4 |
| Preamble | Start Frame Delimiter | Dest. Address | Source Address | Length | 802.2 Header & Data | FCS |

- **Type:** DIX versions of Ethernet used, Specifies the upper-layer protocol to receive the data
- **Length:** Early IEEE Ethernet versions used
- If \Rightarrow 0x600 (hexadecimal), then the frame is interpreted according to the Ethernet II type code indicated.

► Data - Ethernet

| Ethernet-II(DIX 2.0) | | | | | |
|-----------------------|------------------|-------------------|------|---------|-----|
| 7+1 | 6 | 6 | 2 | 46-1500 | 4 |
| Preamble | Dest. Address | Source Address | Type | Data | FCS |

- Data—Ethernet
 - At least 46 bytes of data
 - Padding bytes inserted as needed

► Data IEEE 802.3

| IEEE 802.3 | | | | | | |
|------------|-----------------------|---------------|----------------|--------|---------------------|-----|
| 7 | 1 | 6 | 6 | 2 | 64-1500 | 4 |
| Preamble | Start Frame Delimiter | Dest. Address | Source Address | Length | 802.2 Header & Data | FCS |

- Data—IEEE 802.3
 - Upper-layer protocol destination is defined within the data portion of the frame (DSAP, SSAP, Control)
 - At least 64 bytes
 - Padding bytes inserted as needed

Ethernet-II(DIX 2.0)

| 7+1 | 6 | 6 | 2 | 46-1500 | 4 |
|-----------------|--------------------------|---------------------------|-------------|----------------|------------|
| Preamble | Dest. Address | Source Address | Type | Data | FCS |

- Frame Check Sequence
 - 4 byte CRC value



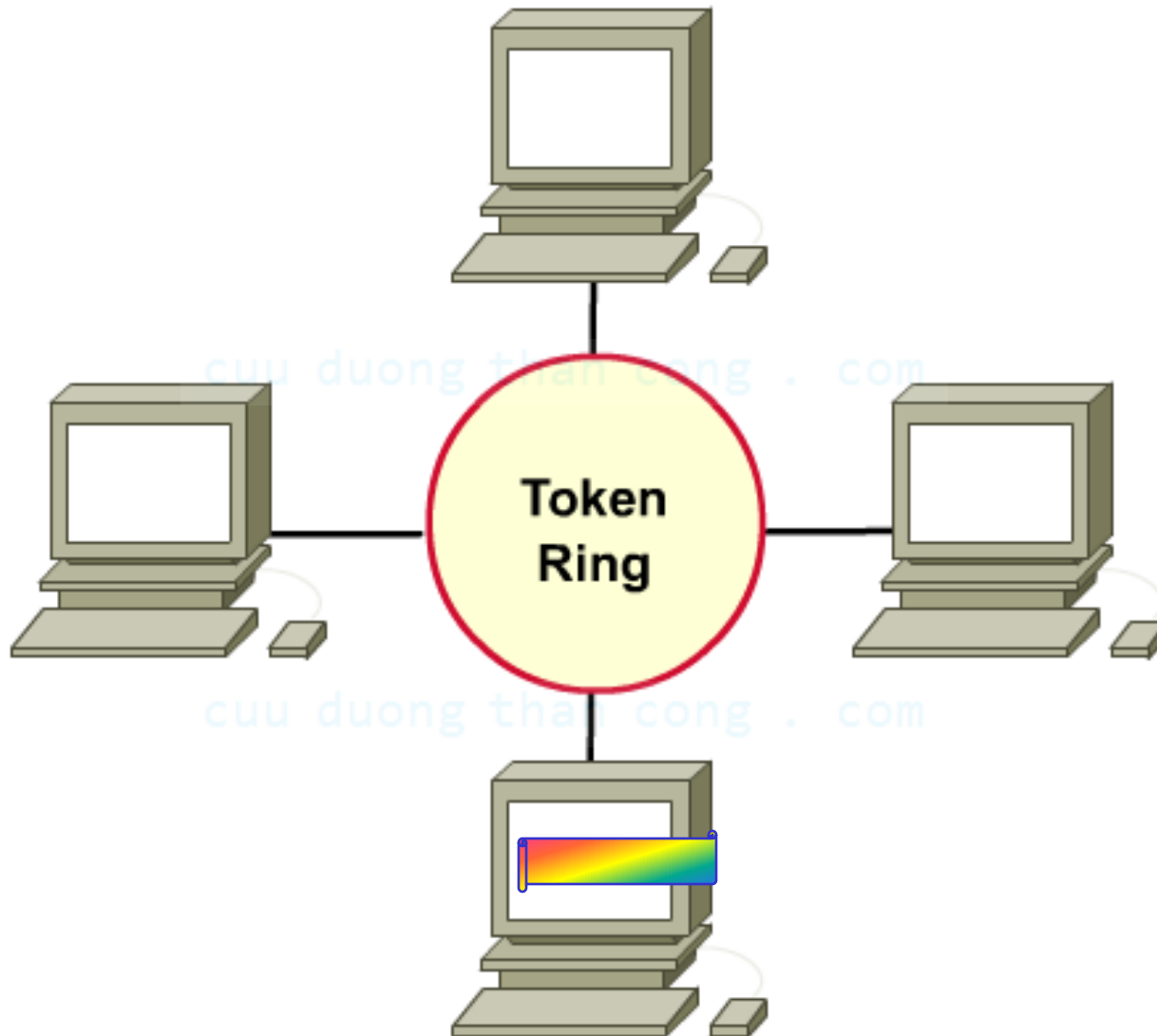
ETHERNET OPERATION

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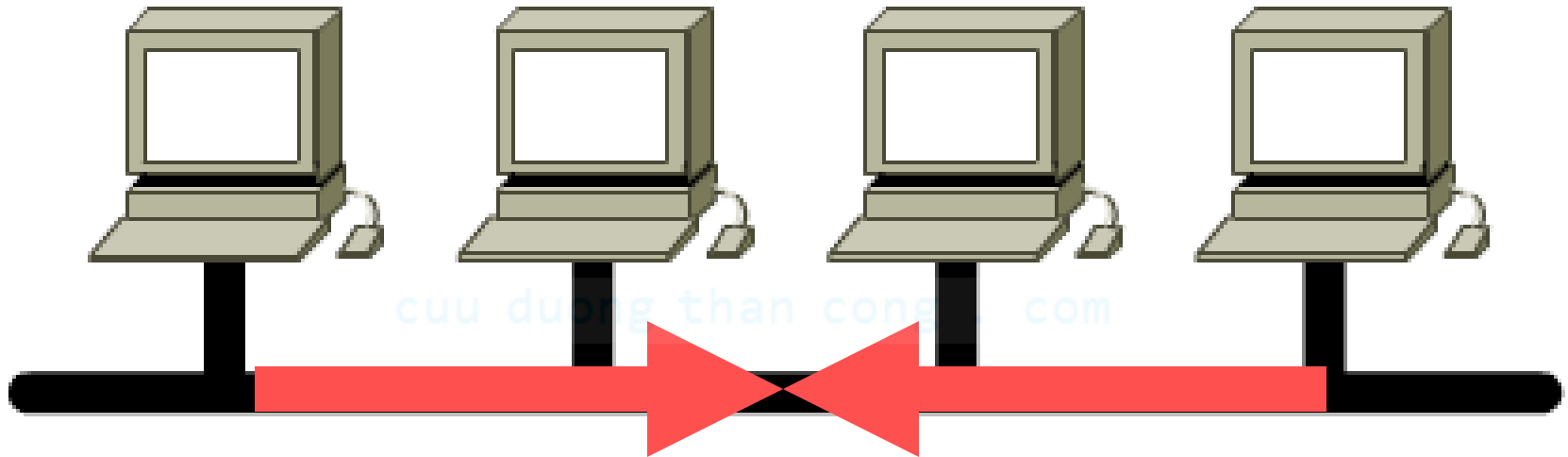
► Media Access Control (MAC)

- Specified by the technology being used.
- Determine who can transmit and when.
- Two types:
 - **Deterministic:** “Let’s take turns”.
 - *Token-Ring, FDDI.*
 - **Non-deterministic:** “First come, first serve”.
 - *Ethernet : CSMA/CD.*

► Deterministic MAC protocol

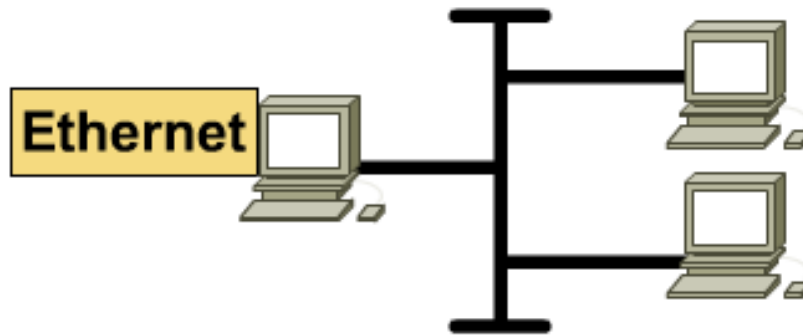


► Non-deterministic MAC protocol

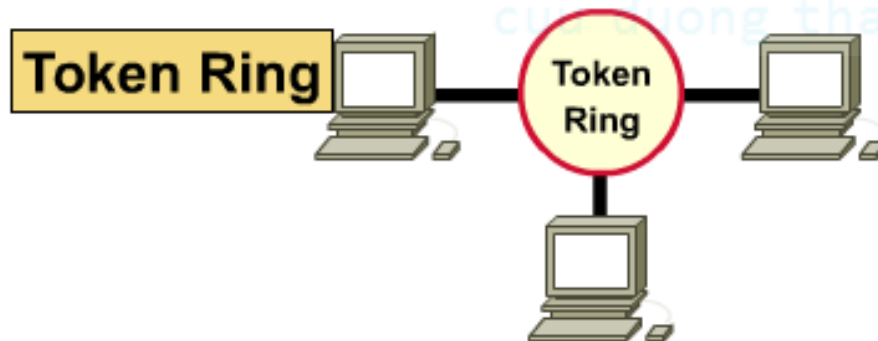


- Carrier Sense Multiple Access with Collision Detection (CSMA/CD).

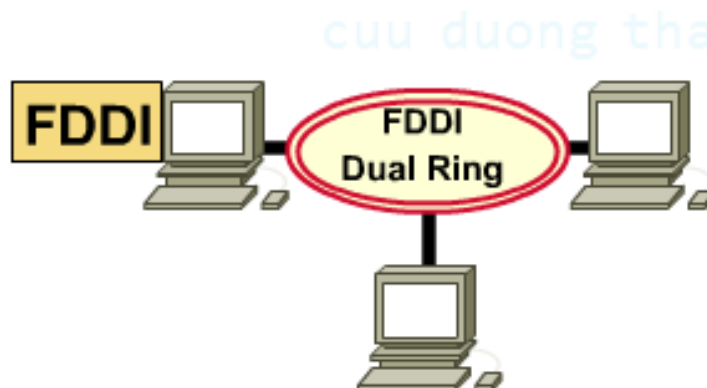
▶ Three common Layer 2 technologies



- **Ethernet**: logical broadcast topology



- **Token Ring**: logical token ring topology



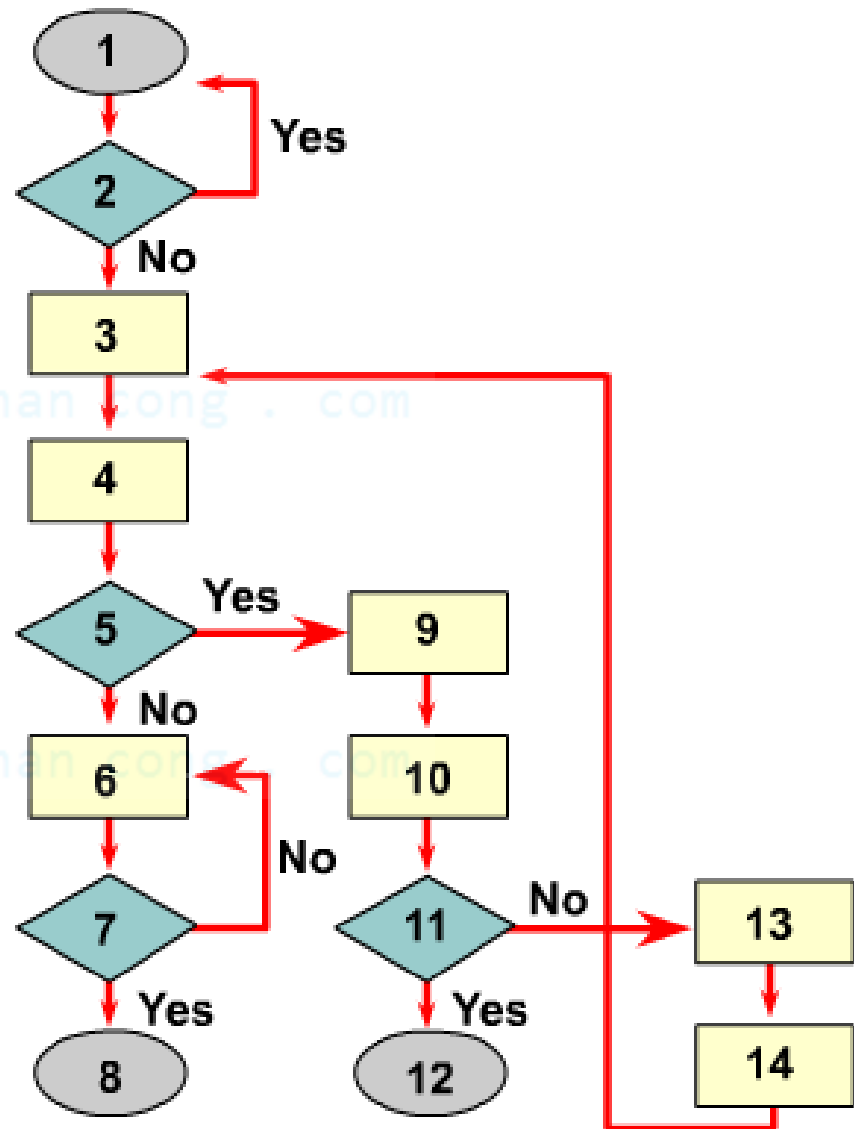
- **FDDI**: logical token ring topology

▶ MAC rules and collision detection/backoff

- Ethernet is a shared-media broadcast technology. The access method CSMA/CD used in Ethernet performs three functions:
 - Transmitting and receiving data packets 1
 - Decoding data packets and checking them for valid addresses before passing them to the upper layers of the OSI model
 - Detecting errors within data packets or on the network

► CSMA/CD Process

1. Host wants to transmit
2. Is carrier sensed?
3. Assemble frame
4. Start transmitting
5. Is a collision detected?
6. Keep transmitting
7. Is the transmission done?
8. Transmission completed
9. Broadcast jam signal
10. Attempts = Attempts + 1
11. Attempts > Too many?
12. Too many collisions; abort transmission
13. Algorithm calculates backoff
14. Wait for t microseconds



► Ethernet timing

- The electrical signal takes time to travel down the cable (delay), and each subsequent repeater.
- Because of the delay and latency, it is possible for more than one station to begin transmitting at or near the same time. This results in a collision.
- In full duplex collisions should not occur
→ eliminates the concept of slot time.
- In half duplex, assuming that a collision does not occur, the 64 bits of preamble must be sent for timing synchronization first.

► Ethernet timing

- 10 Mbps and slower versions of Ethernet are asynchronous.
- 100 Mbps and higher speed implementations of Ethernet are synchronous.
- For all speeds of Ethernet transmission at or below 1000 Mbps, the standard describes how a transmission may be no smaller than the slot time.

| Speed | Slot Time | Time Interval |
|----------|----------------|----------------|
| 10 Mbps | 512 bit-times | 51.2 μ s |
| 100 Mbps | 512 bit-times | 5.12 μ s |
| 1 Gbps | 4096 bit-times | 4.096 μ s |
| 10 Gbps | not applicable | not applicable |

► Ethernet timing

| Ethernet Speed | Bit time |
|-----------------------|----------|
| 10 Mbps | 100 ns |
| 100 Mbps | 10 ns |
| 1000 Mbps = 1 Gbps | 1 ns |
| 10,000 Mbps = 10 Gbps | .1 ns |

► Interframe spacing

- The minimum spacing between two non-colliding frames is also called the interframe spacing.
- Spacing gap.

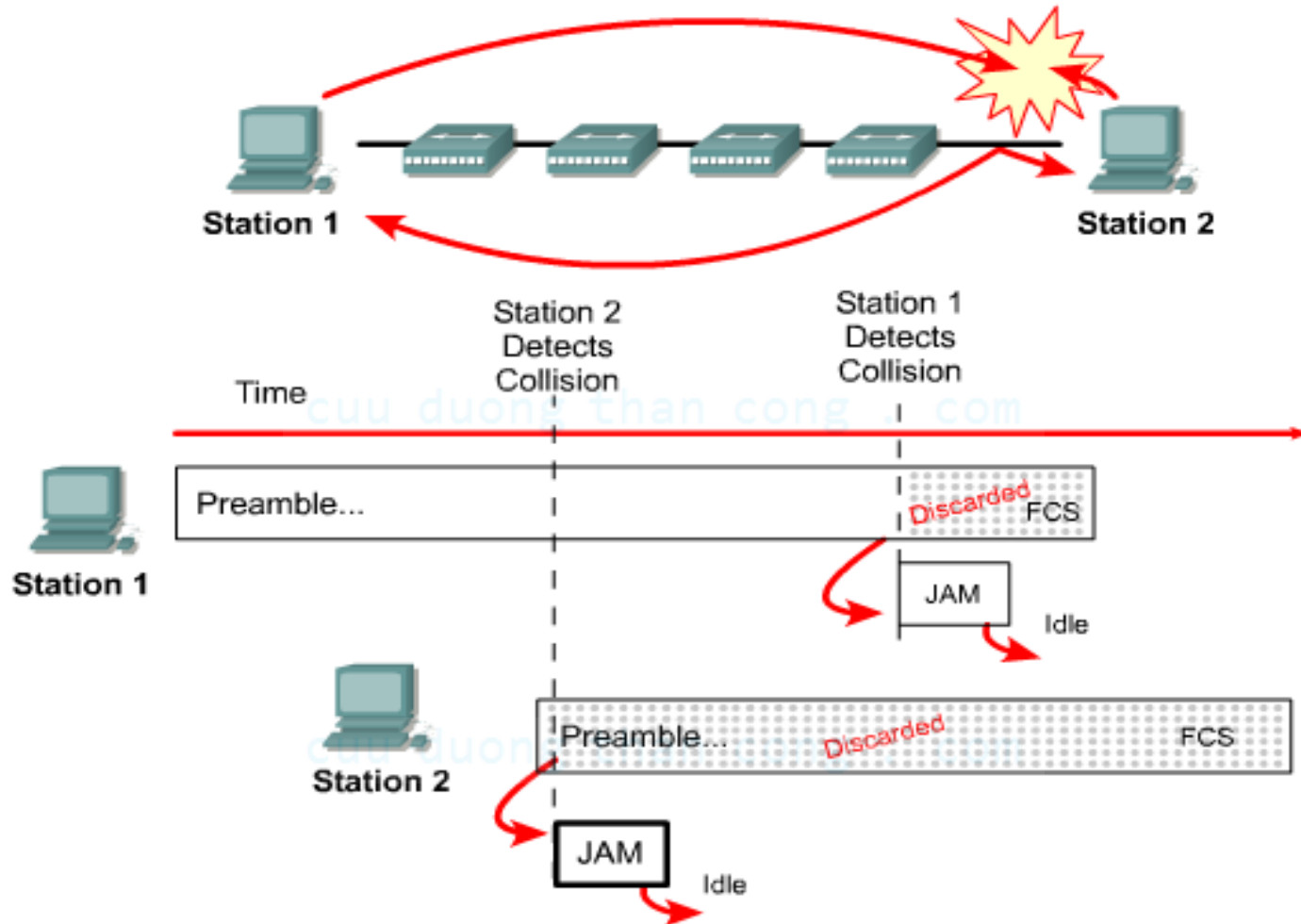
| Speed | Interframe Spacing | Time required |
|----------|--------------------|----------------|
| 10 Mbps | 96 bit-times | 9.6 μ s |
| 100 Mbps | 96 bit-times | 0.96 μ s |
| 1 Gbps | 96 bit-times | 0.096 μ s |
| 10 Gbps | 96 bit-times | 0.0096 μ s |

► Backoff algorithm

| Speed | Slot Time | Time Interval |
|----------|----------------|----------------|
| 10 Mbps | 512 bit-times | 51.2 μ s |
| 100 Mbps | 512 bit-times | 5.12 μ s |
| 1 Gbps | 4096 bit-times | 4.096 μ s |
| 10 Gbps | not applicable | not applicable |

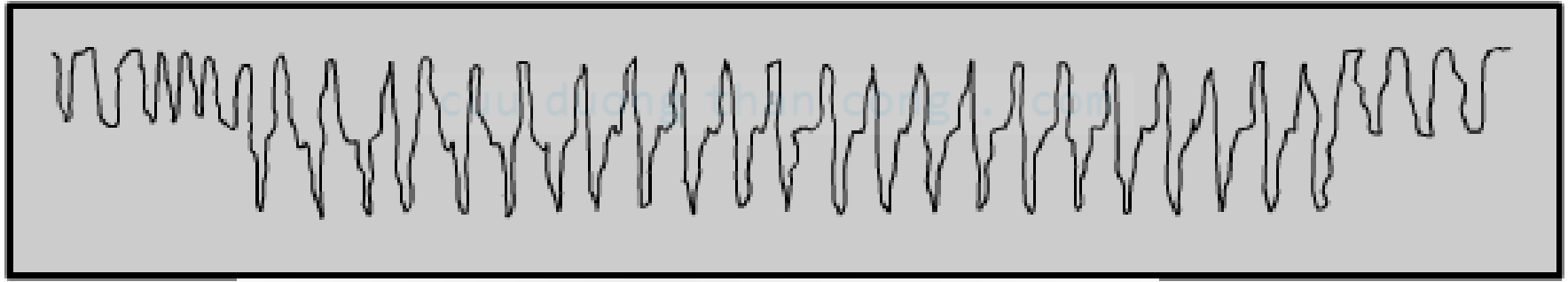
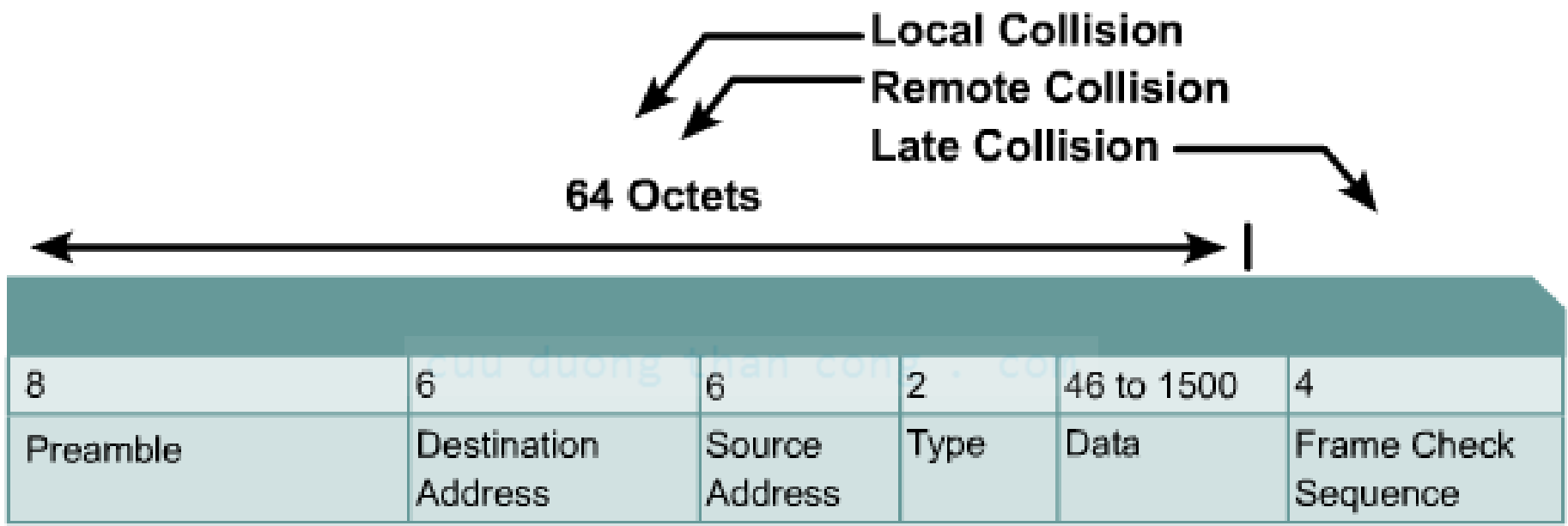
- Backoff is the process by which a transmitting interface determines how long to wait following a collision before attempting to retransmit the frame.
- All transmitting interface then stop sending for a backoff time (randomly 0 .. $2^n - 1$ of 51.2ms).
- The range continues to expand until after 10 attempts it reaches 0 to 1023.
- unsuccessful after 16 attempts, the MAC function reports an **excessive collision error**.

► Error handling: Collision



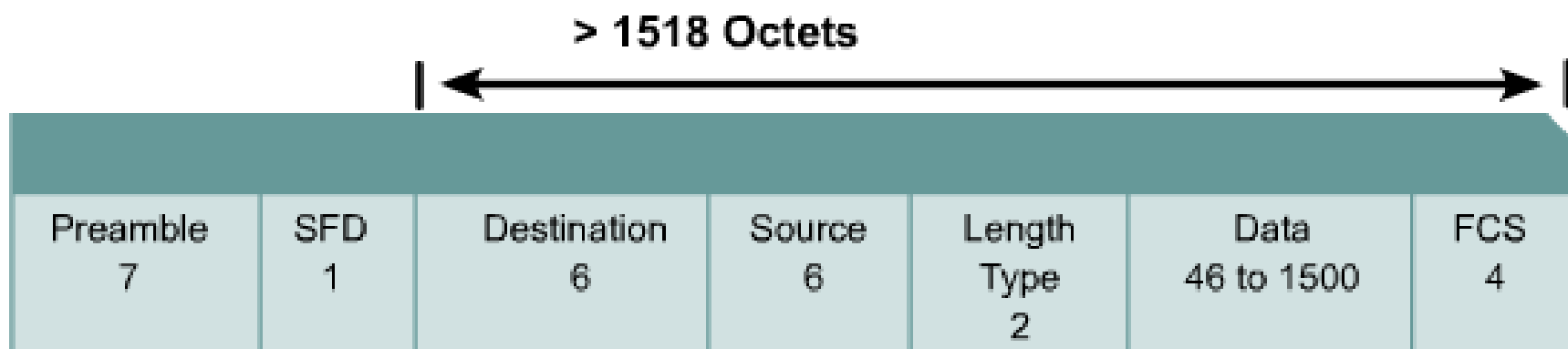
- The corrupted, partially transmitted messages are often referred to as collision fragments or runts.

►Types of collisions

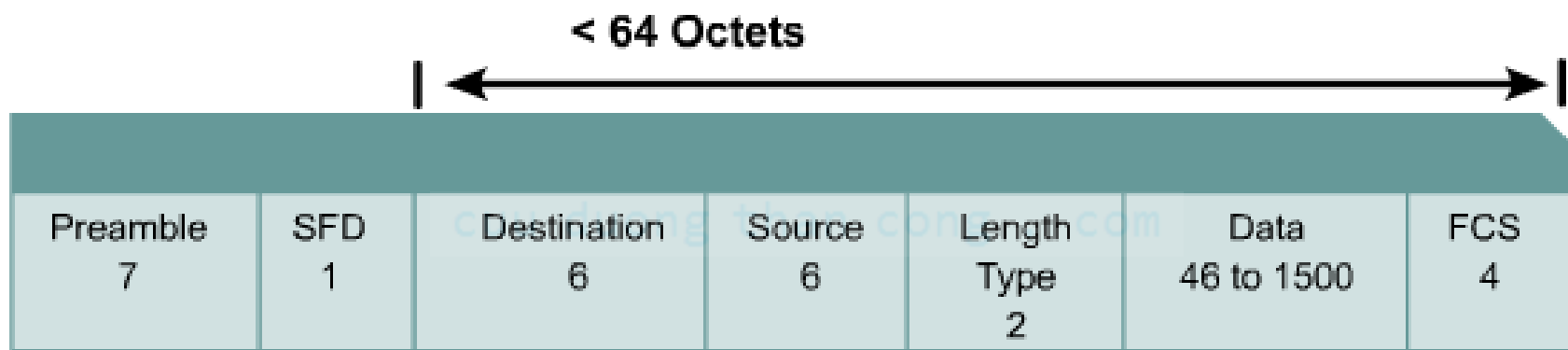


Midframe 10BASE2 /10BASE5 collision captured by a digital storage oscilloscope.

▶ Ethernet errors



Jabber and Long Frames are both in excess of the maximum frame size. Jabber is significantly larger.



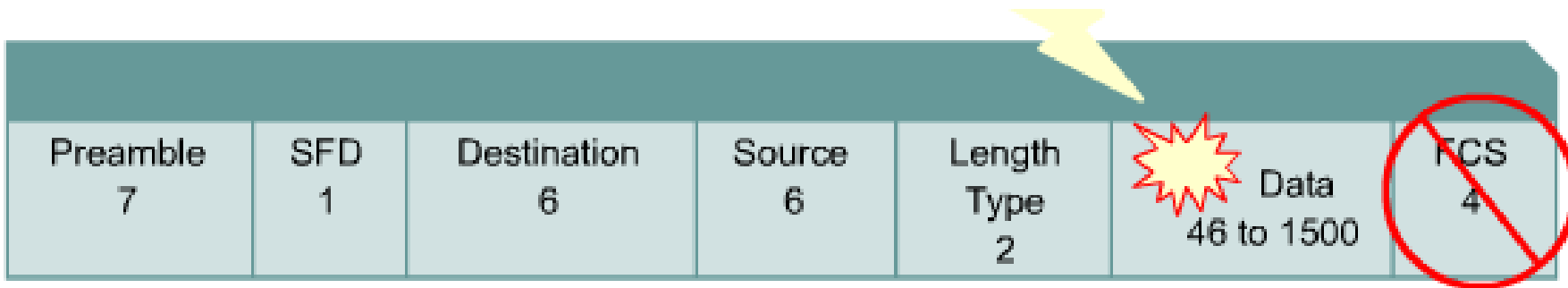
Short frames are properly formed in all but one aspect and have valid FCS checksums, but are less than the minimum frame size (64 octets).

► Ethernet errors

The following are the sources of Ethernet error:

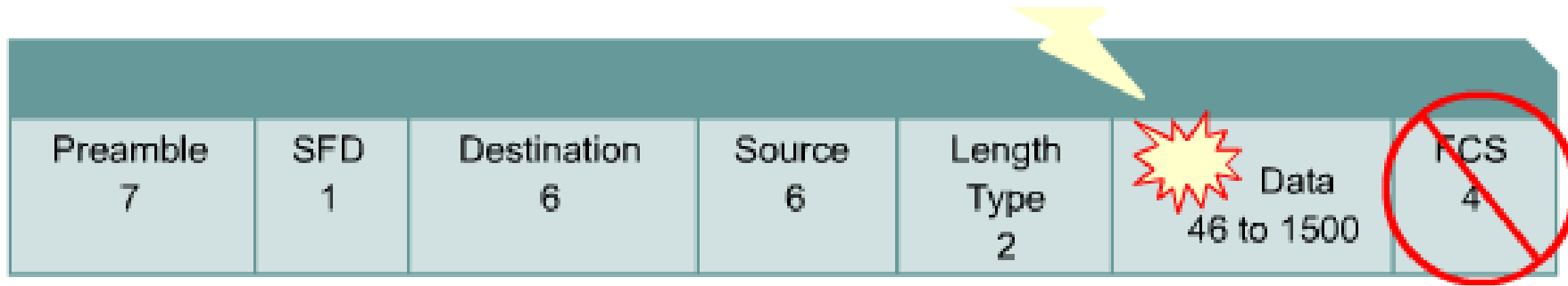
- **Collision or runt** – Simultaneous transmission occurring before slot time has elapsed
- **Late collision** – Simultaneous transmission occurring after slot time has elapsed
- **Jabber, long frame and range errors** – Excessively or illegally long transmission
- **Short frame, collision fragment or runt** – Illegally short transmission
- **FCS error** – Corrupted transmission
- **Alignment error** – Insufficient or excessive number of bits transmitted
- **Range error** – Actual and reported number of octets in frame do not match
- **Ghost or jabber** – Unusually long Preamble or Jam event

► FCS and beyond



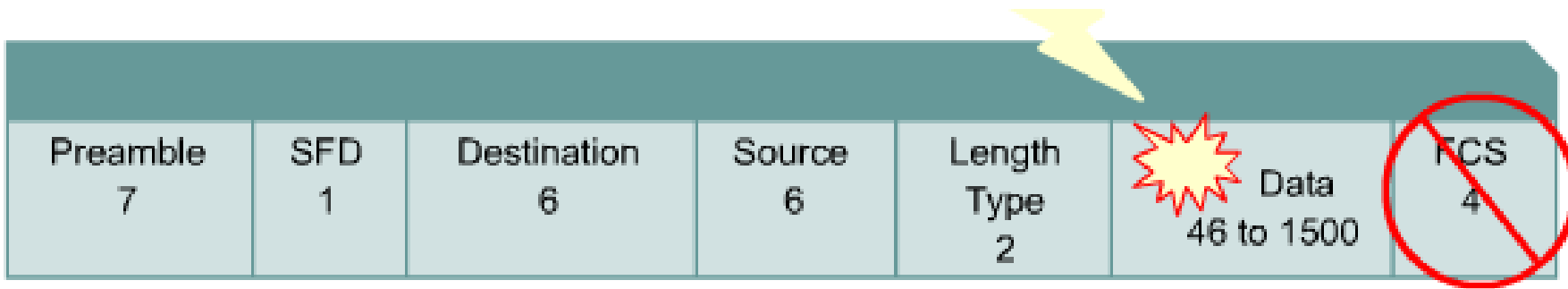
- High numbers of FCS errors from a single station usually indicates a faulty NIC and/or faulty or corrupted software drivers, or a bad cable connecting that station to the network.
- If FCS errors are associated with many stations, they are generally traceable to bad cabling, a faulty version of the NIC driver, a faulty hub port, or induced noise in the cable system.

► FCS and beyond: Alignment error



- A message that does not end on an octet boundary is known as an alignment error.
- Such a frame is truncated to the nearest octet boundary, and if the FCS checksum fails, then an alignment error is reported.
- This is often caused by bad software drivers, or a collision, and is frequently accompanied by a failure of the FCS checksum.

► FCS and beyond: Range error

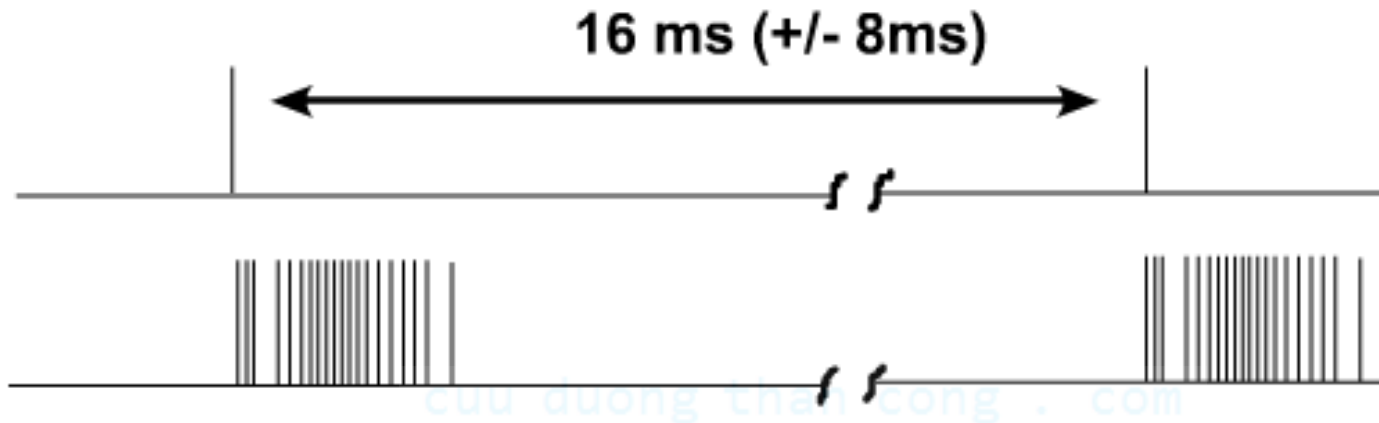


- A frame with a valid value in the Length field but did not match the actual number of octets counted in the data field of the received frame is known as a range error.
- This error also appears when the length field value is less than the minimum legal unpadded size of the data field. A similar error, Out of Range, is reported when the value in the Length field indicates a data size that is too large to be legal.

► FCS and beyond: Ghost

- Term ghost to mean energy (noise) detected on the cable that appears to be a frame, but is lacking a valid SFD.
- To qualify as a ghost, the frame must be at least 72 octets long, including the preamble. Otherwise, it is classified as a remote collision.
- Ground loops and other wiring problems are usually the cause of ghosting.
- Most network monitoring tools do not recognize the existence of ghosts for the same reason that they do not recognize preamble collisions.

► Ethernet auto-negotiation



- A process called Auto-Negotiation of speeds at half or full duplex was developed to make each technology interoperable
- Defines how two link partners may automatically negotiate a configuration offering the best common performance level.

▶ Link establishment and full and half duplex

- 1000BASE-T full duplex \leftrightarrow 1000BASE-T full duplex
- 1000BASE-T half duplex \leftrightarrow 1000BASE-T half duplex
- 100BASE-TX full duplex \leftrightarrow 100BASE-TX full duplex
- 100BASE-TX half duplex \leftrightarrow 100BASE-TX half duplex
- 10BASE-T full duplex \leftrightarrow 10BASE-T full duplex
- 10BASE-T half duplex \leftrightarrow 10BASE-T half duplex

► Summary

- *The basics of Ethernet technology*
- *The naming rules of Ethernet technology*
- *How Ethernet and the OSI model interact*
- *Ethernet framing process and frame structure*
- *Ethernet frame field names and purposes*
- *The characteristics and function of CSMA/CD*
- *Ethernet timing*
- *Interframe spacing*
- *The backoff algorithm and time after a collision*
- *Ethernet errors and collisions*
- *Auto-negotiation in relation to speed and duplex*

► Q&A



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