Lecture Computer Networks

Ethernet and FDDI

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Institut für Organisation und Management von
Informationssystemen

Thomas Nau, kiz

Ethernet and FDDI

- Ethernet
  - History, Evolution, Overview
  - OSI-Model
    - Physical Layer: Coding Schemes
    - MAC-Layer: CSMA/CD
  - Ethernet Principles
    - Versions and Parameters
    - Topologies
    - Communication Modes
    - Collision Domain
    - Framing
  - Standards up to Gigabit Ethernet
  - Gigabit Ethernet
  - VLAN
- FDDI

History - Ethernet and DIX Consortium

Creation of Ethernet

- by Dr. Robert Metcalfe
- at Xerox Corporation in Palo Alto, California, 1973
- operated at 2.94Mbps
- goal was to improve the connection speed between computers and printers

DEC-Intel-Xerox (DIX) Consortium

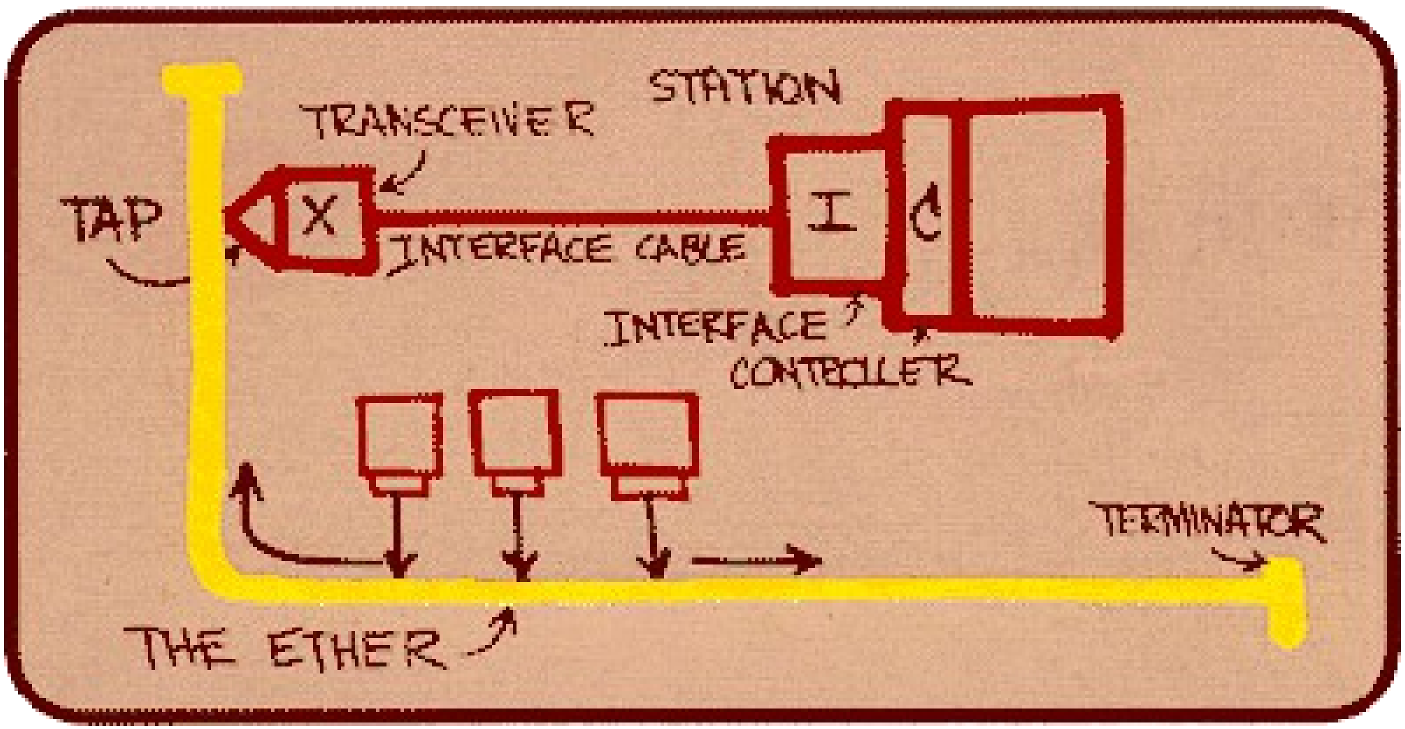
- developed the standard for 10Mbps Ethernet, 1980
- thick multi-drop coaxial cable

IEEE 802 standards, 1980

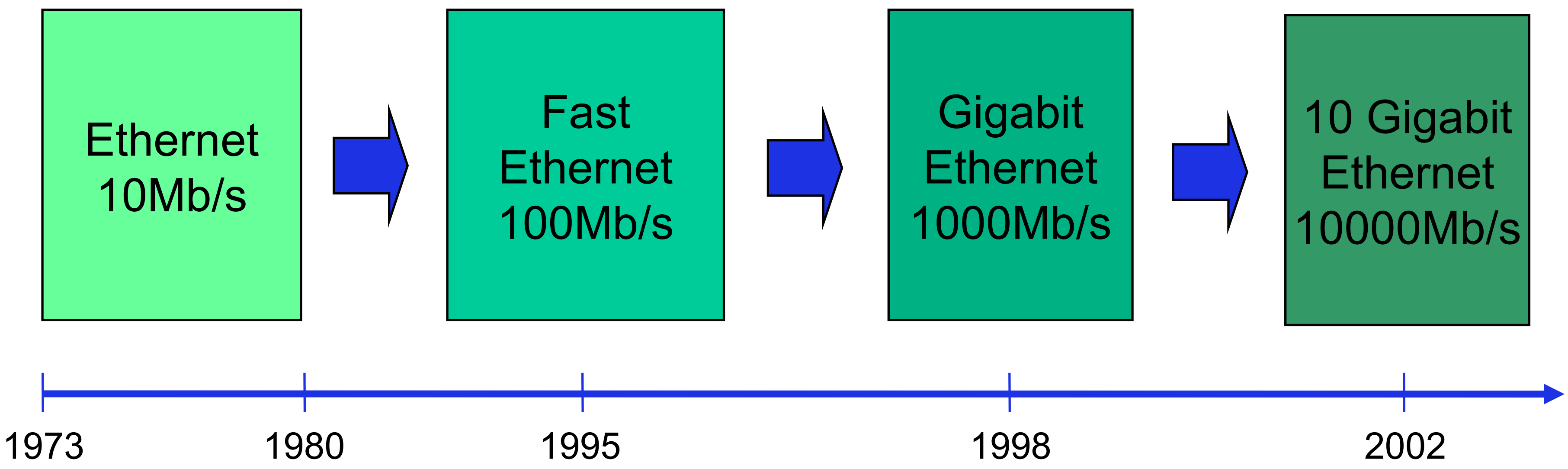
- IEEE 802.3 for Ethernet
- IEEE 802.4 for Token Bus
- IEEE 802.5 for Token Ring

In the beginning

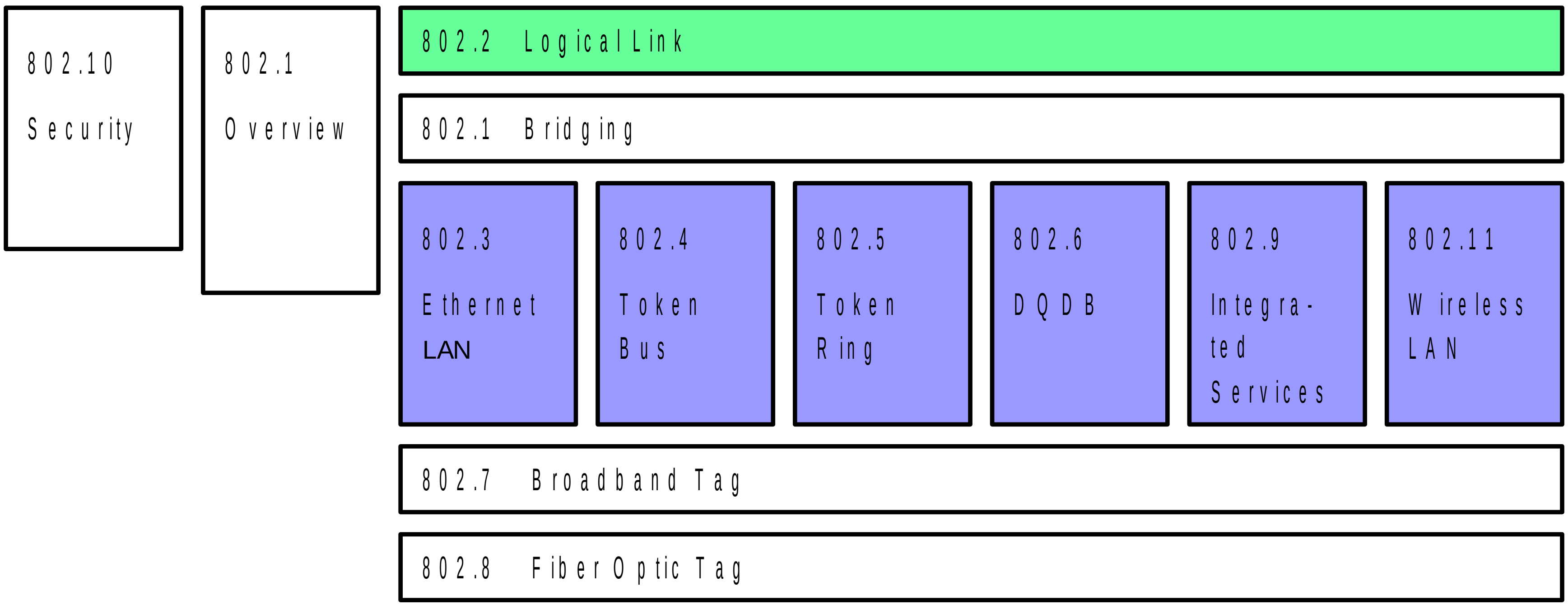
1976 R. Metcalfe presented Ethernet for the first time;
he used this diagram



Evolution


Ethernet 10Mb/s
Fast Ethernet 100Mb/s
Gigabit Ethernet 1000Mb/s
10 Gigabit Ethernet 10000Mb/s
1973
1980
1995
1998
2002

IEEE Standards



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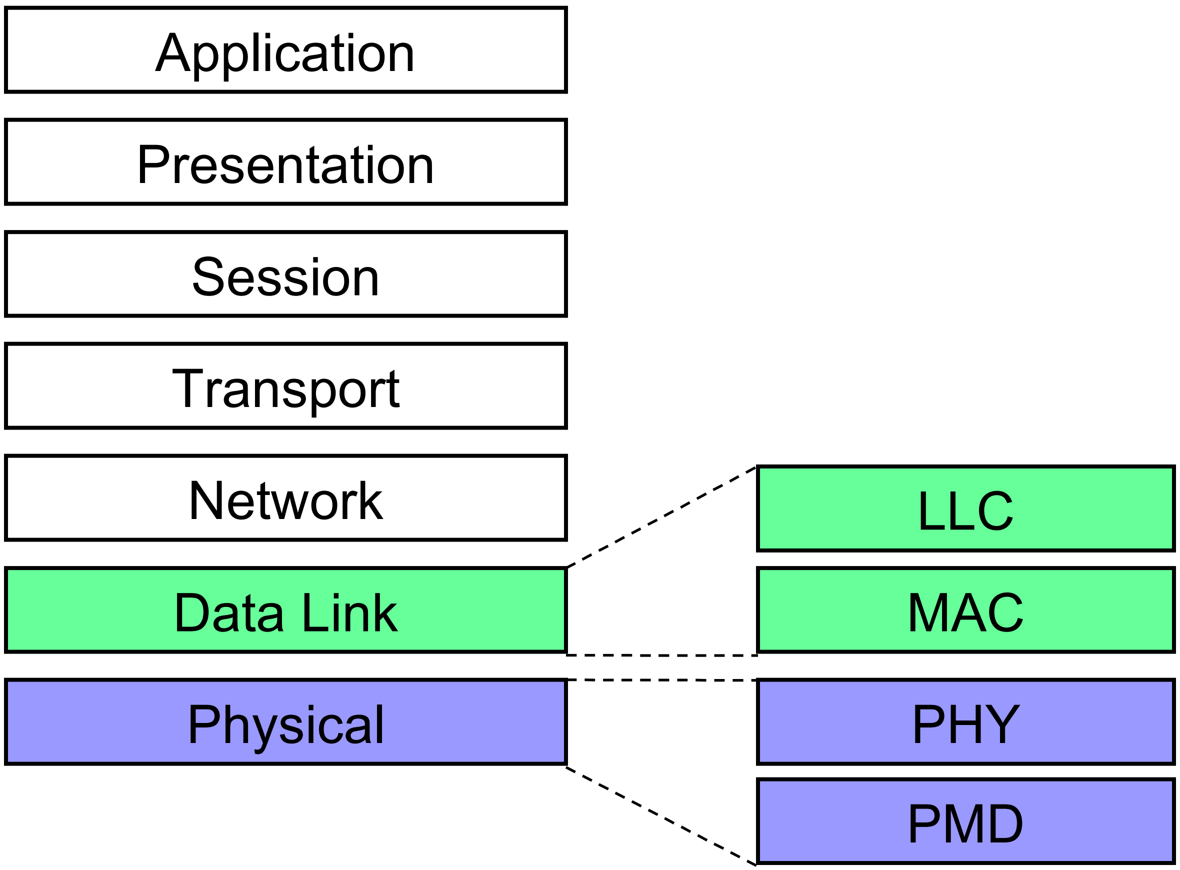
OSI Layers


Application
Presentation
Session
Transport
Network
Data Link
Physical
LLC
MAC
PHY
PMD

Sub-Layers

LLC Logical Link Control

(de)multiplexing packets from the network layers

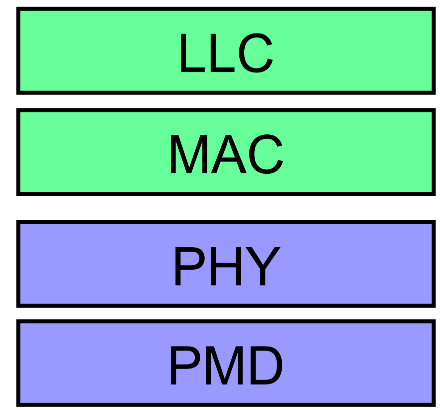
MAC Media Access Control

frame formats, addressing, sharing of the medium

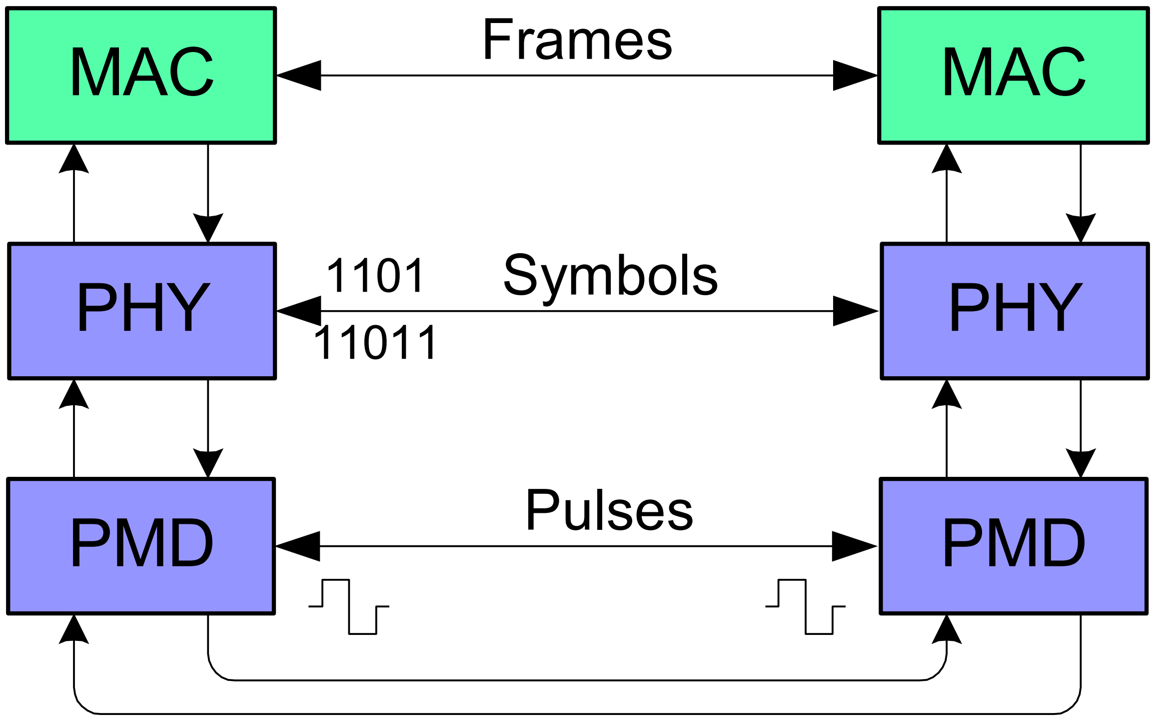
PHY physical medium independent layer

encoding/decoding bits into pulses, synchronization of the transceiver clocks

PMD Physical Medium Dependent Layer
handling with electrical components



Inter-Layer Connections



Bandwidth Sharing (Half Duplex Mode)

For a bus or any other half duplex topology a method for bandwidth sharing is mandatory.

In the development days of the Ethernet the following methods were tested:

Pure Aloha

Slotted Aloha

CSMA

CSMA/CD

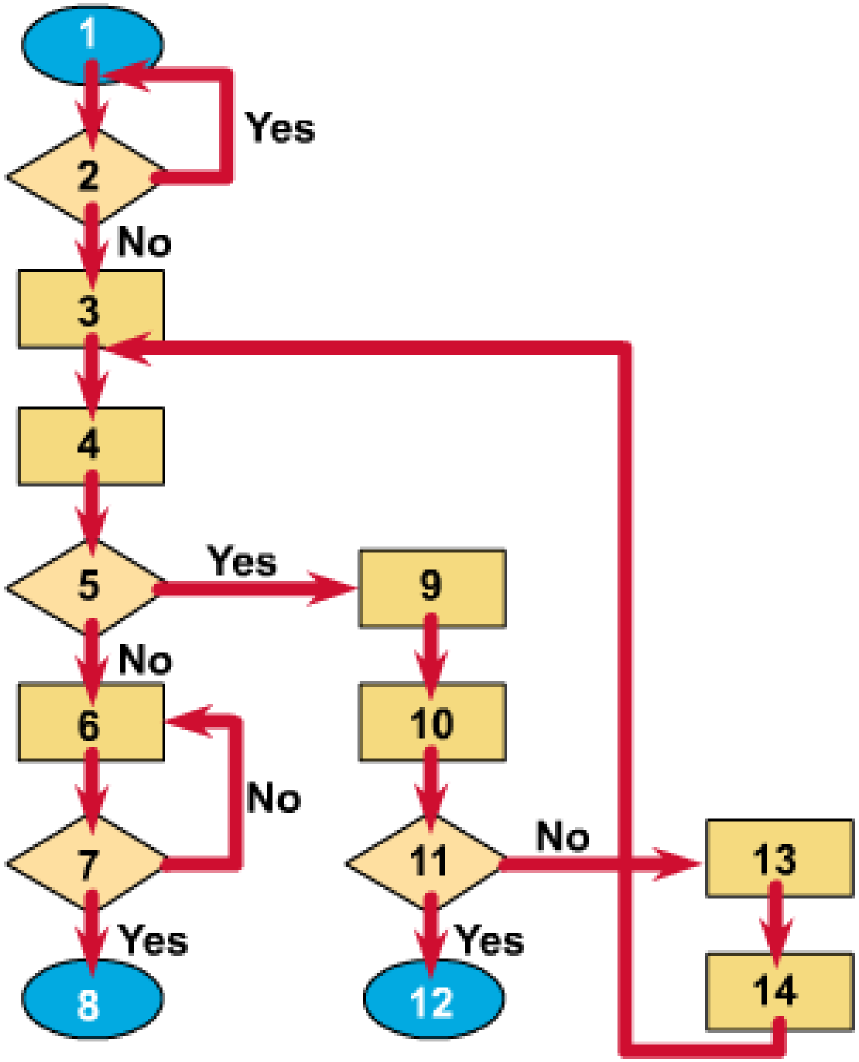
CSMA/CD

Carrier Sense Multiple Access with Collision Detection

- Wait until medium is available
  - medium must be idle for the Interframe Gap (IFG) time before sending
- Start transmission
- If a collision is detected while transmitting,
  - transmit a jam signal
  - wait for a random time and retry (up to 16 times)
- Collision detection is done by comparing transmitted and received signals

CSMA/CD

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 seconds



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Ethernet Versions

Two incompatible versions:

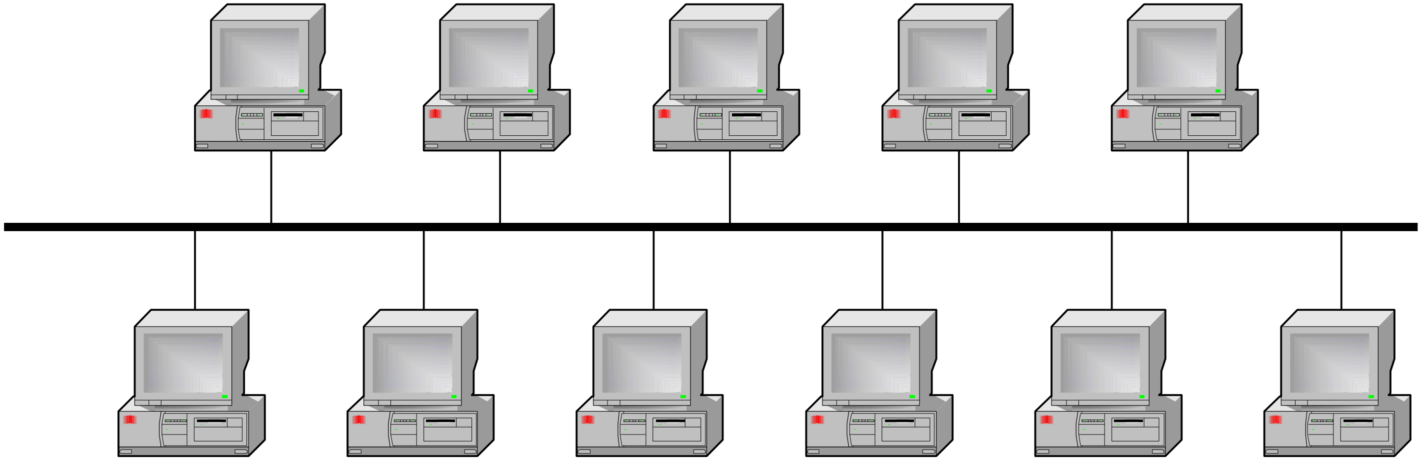
- Ethernet II (DIX - consortium of the companies DEC, Intel and Xerox)
- Ethernet 802.3 (standard of IEEE)
    - PMD, PHY, and MAC layers are covered in the standard IEEE 802.3
    - LLC - covered in the standard IEEE 802.2 (general standard, not only for Ethernet)

Ethernet II Principles

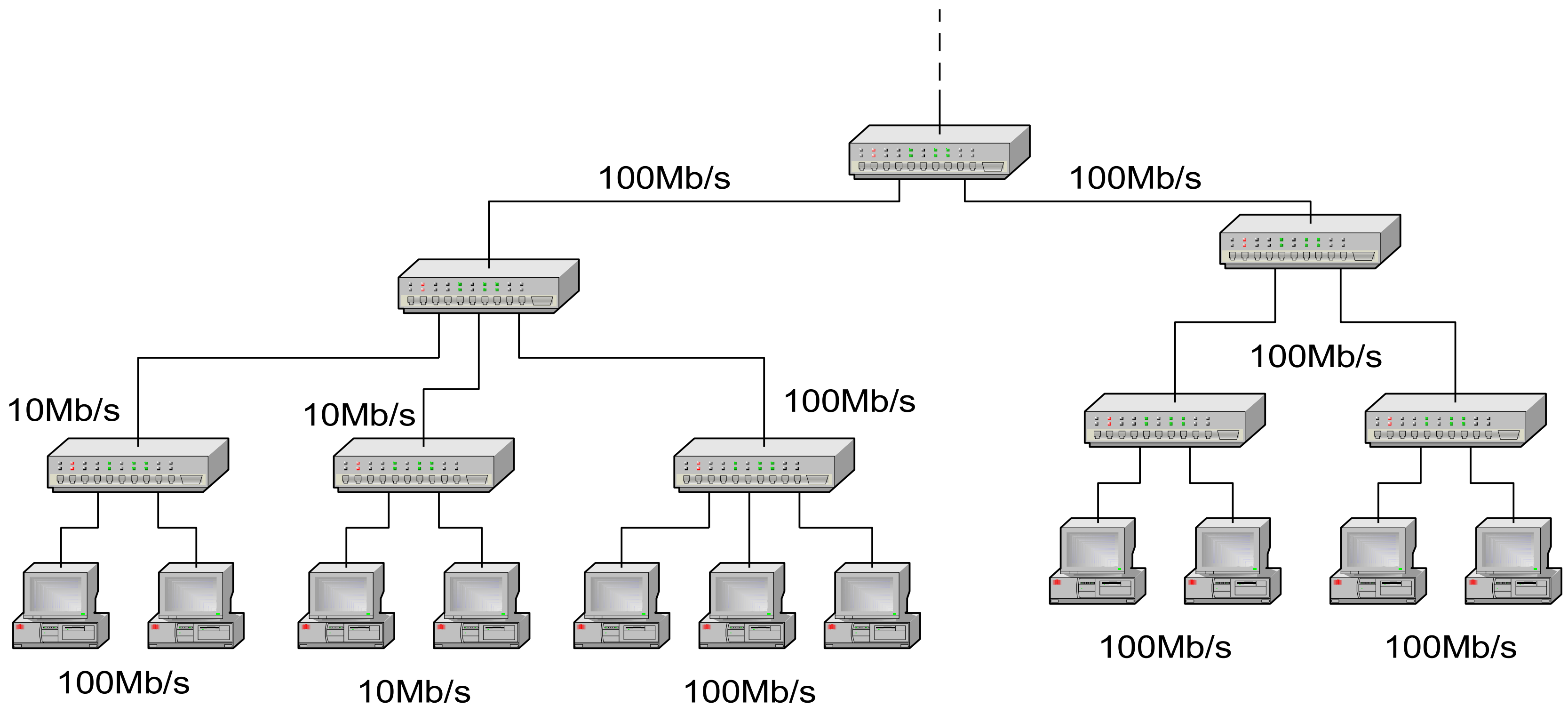
- Fixed 10Mbps Manchester coded signals
- CSMA/CD used for bandwidth sharing
- Frame size range 64 to1518 bytes
- Truncated binary back-off algorithm used for retransmission
- Little-endian bit-order
- 64 bit preamble at front and 9.6μs delay between frames
- Bus topology
- Ethernet is a passive network, only transmitting stations can be detected

Example for a Bus Topology (very obsolete by now)

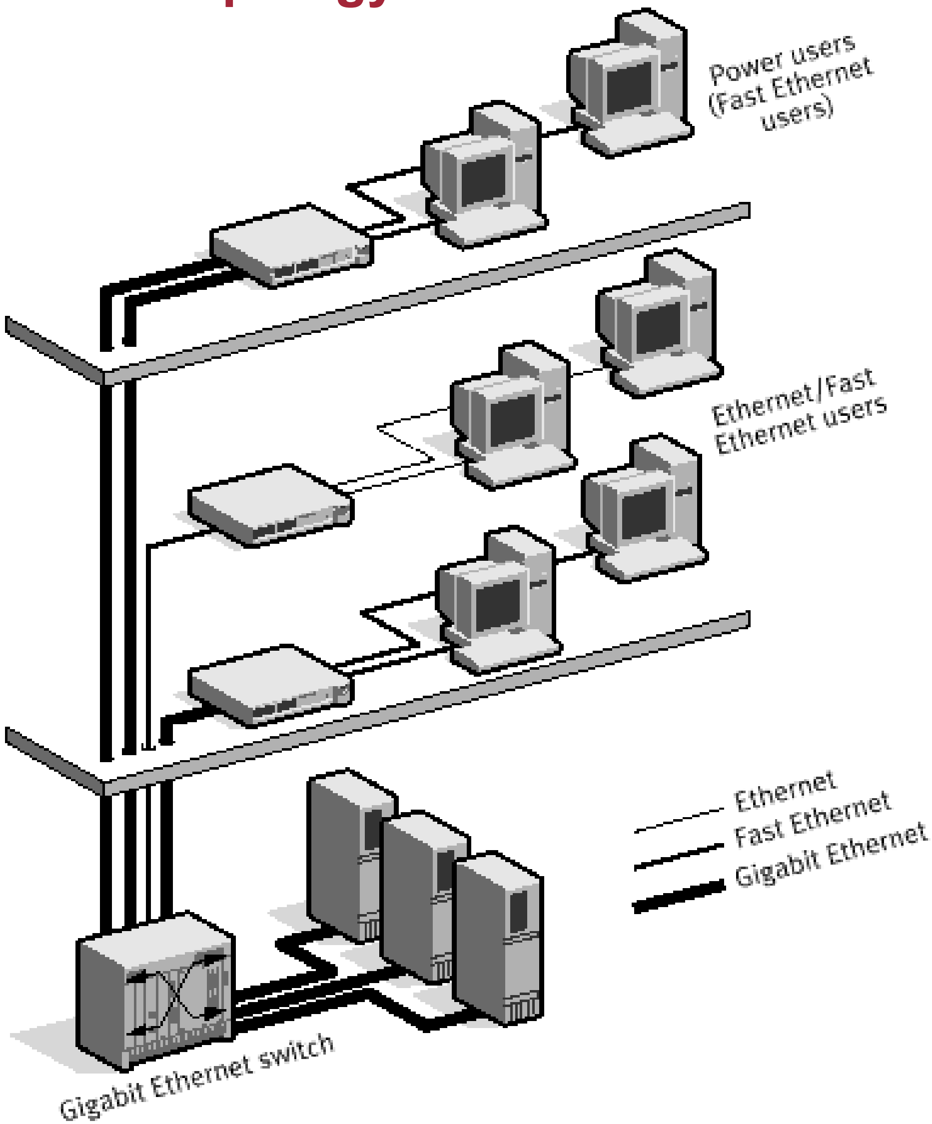
10Mb/s



Example for a Star/Tree Topology



Example for a Star Topology

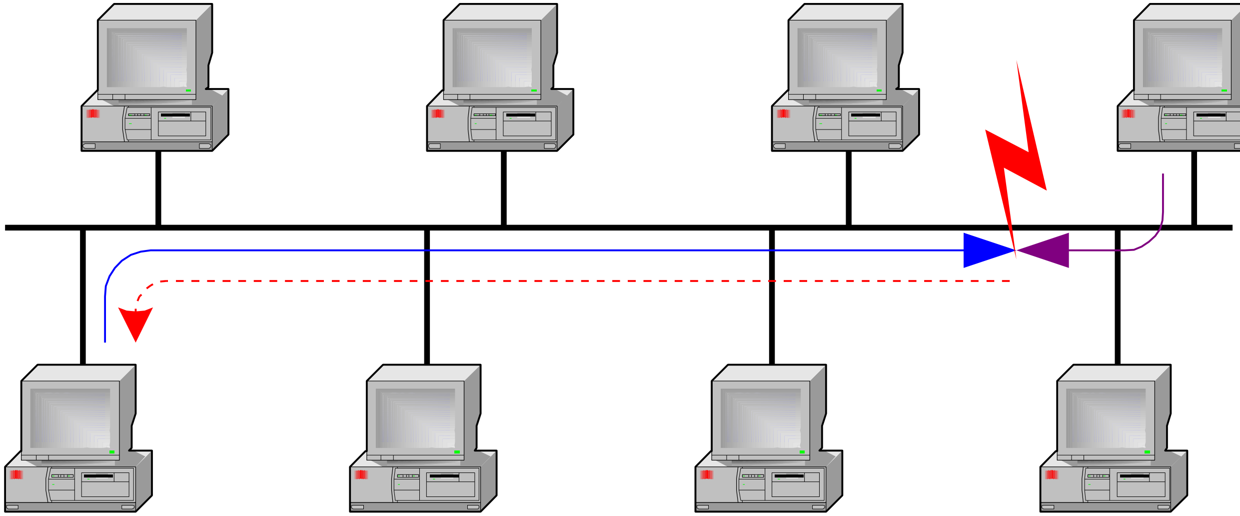


Half-duplex Mode

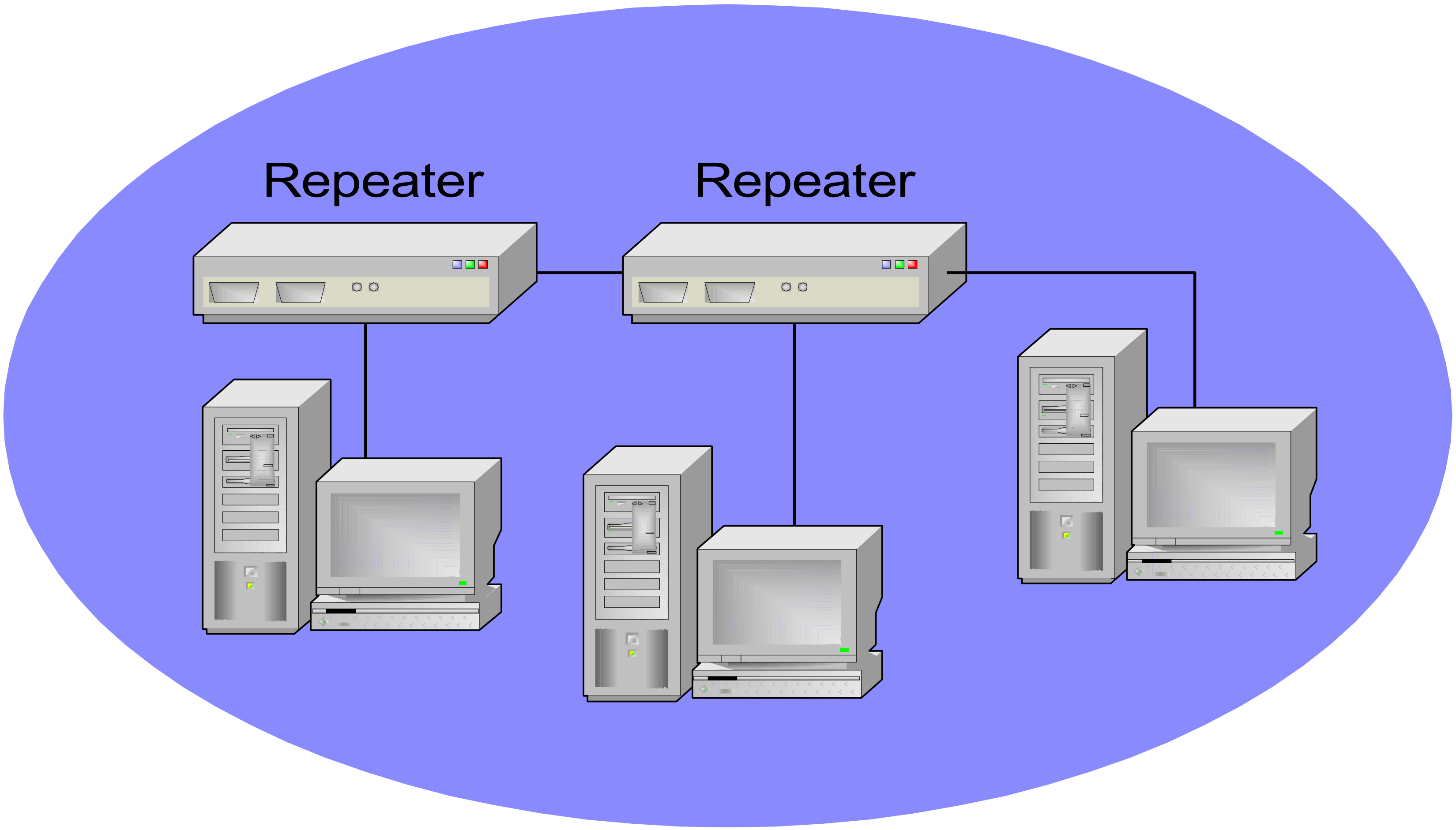
- Stations share a single Ethernet channel by using a medium access control protocol (see CSMA/CD)
- Only one station can send data over the channel at any given time
- Disadvantage: segment length is limited by timing requirement caused by requirements of collision detection mechanism

Physical Extension

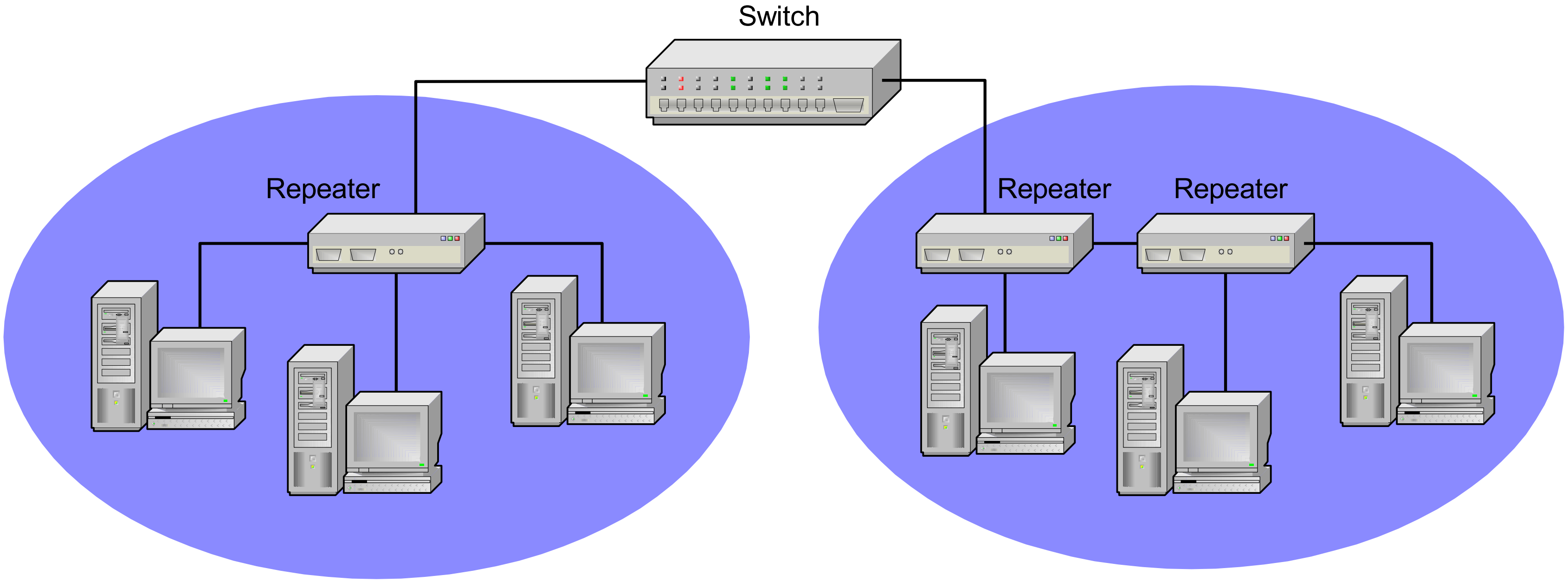
- Ethernet cards detect collisions only while transmitting. A collision that occurs at the far end of the medium must reach the sender before it stops transmitting.



Collision Domain



Separate Collision Domains



Full-duplex Mode

- Point-to-point links over twisted pair or fiber optic media
- Both devices may send data at any time
  - Disable the carrier sense function
  - Disable collision detect
  - Disable the looping back of transmitted data onto the receiver input
- Advantages:
  - Segment length is limited by the signal-carrying capabilities of the segment media
  - The multiple access algorithm (CSMA/CD) is unnecessary
- Standard IEEE 802.3x

Framing

- Layer 2 encapsulation
- Breaking the stream into fields
    - Start and stop indicator fields
    - Naming or addressing fields
    - Data fields
    - Quality control fields

IEEE MAC Address

I/G 1 Bit	U/L 1 Bit	OUI 22 Bit	assigned by OUI owner 24 Bit

I/G Individual/Group

U/L Universal/Local

OUI Organizationally Unique Identifier
specifies the manufacturer of the Ethernet card

Ethernet II Frame

← Frame Header →

Preamble (8 Byte)	Destination Address (6 Byte)	Source Address (6 Byte)	Type (2 Byte)	Data (46 - 1500 Byte)	FCS (4 Byte)

Preamble	for synchronization of the stations
Type	specifies Layer 3 Protocol
FCS	Frame Check Sequence

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Some of the (very old) Standards for 10Mbit/s

	Standard-first released	Topology	Medium	Max Cable Segment [m]	
				half-duplex	full-duplex
10Base5	DIX-1980 802.3-1983	Bus	single 50 Ohm coaxial cable (10mm thick) - thicknet	500	not supported
10Base2	802.3a-1985	Bus	single 50 Ohm RG 58 coaxial cable (5mm thick) - thinnet	185	not supported
10Base-T	802.3i-1990	Star	two pairs of 100 Ohm Cat3 or better UTP cable	100	100
10Base-F	802.3j-1993	Star	two optical fibres	2000	> 2000

10 stands for 10Mbit/s

Base stands for Baseband

Standards for 100Mbit/s

	Standard-first released	Top.	Medium	Max Cable Segment [m]	
				half-duplex	full-duplex
100Base-TX	802.3u-1995	Star	two pairs of 100 Ohm Cat5 UTP cable	100	100
100Base-FX	802.3u-1995	Star	two optical fibres	412	2000
100Base-T4	802.3u-1995	Star	four pairs of 100 Ohm Cat3 or better UTP cable	100	not supported
100Base-T2	802.3y-1997	Star	two pairs of 100 Ohm Cat3 or better UTP cable	100	100

Standards for 1Gbit/s

	Standard -first released	Top.	Medium	Max Cable Segment [m]	
				half-duplex	full-duplex
1000Base-LX	802.3z-1998	Star	long wavelength laser: - 62.5µm multi-mode fiber - 50µm multi-mode fiber - 10µm single-mode fiber	 316 316 316	 550 550 5000
1000Base-SX	802.3z-1998	Star	short wavelength laser: - 62.5µm multi-mode fiber - 50µm multi-mode fiber	 275 316	 275 550
1000Base-CX	802.3z-1998	Star	specialty shielded balanced copper jumper cable assemblies (“twinax”)	25	25
1000Base-T	802.3ab-1999	Star	four pairs of 100 Ohm Cat5 or better cable	100	100

Encodings used by the IEEE Standards

Ethernet	Manchester coding	
Fast Ethernet	100Base-FX	NRZI and 4B/5B encoding
	100Base-TX	MLT-3 (or NRZI-3) and 4B/5B encoding
	100Base-T4	8B/6T encoding
Gigabit Ethernet	1000Base-LX	8B/10B encoding
	1000Base-SX	8B/10B encoding
	1000Base-CX	8B/10B encoding
	1000Base-T	PAM5

Parameters

	10MBit/s	100MBit/s	1GBit/s
nominal Bit Time	0,1 µs	0,01 µs	0,001 µs
Slot Time [Bit Times]	512	512	4096
Interframe Gap	9,6 µs	0,96 µs	0,096 µs
Max Frame Size	1518 Byte	1518 Byte	1518 Byte
Min Frame Size	64 Byte	64 Byte	64 Byte
Extended Size	0 Bit	0 Bit	Slot-Time-MinFrameSize
Burst Limit	no	no	65536 Bit

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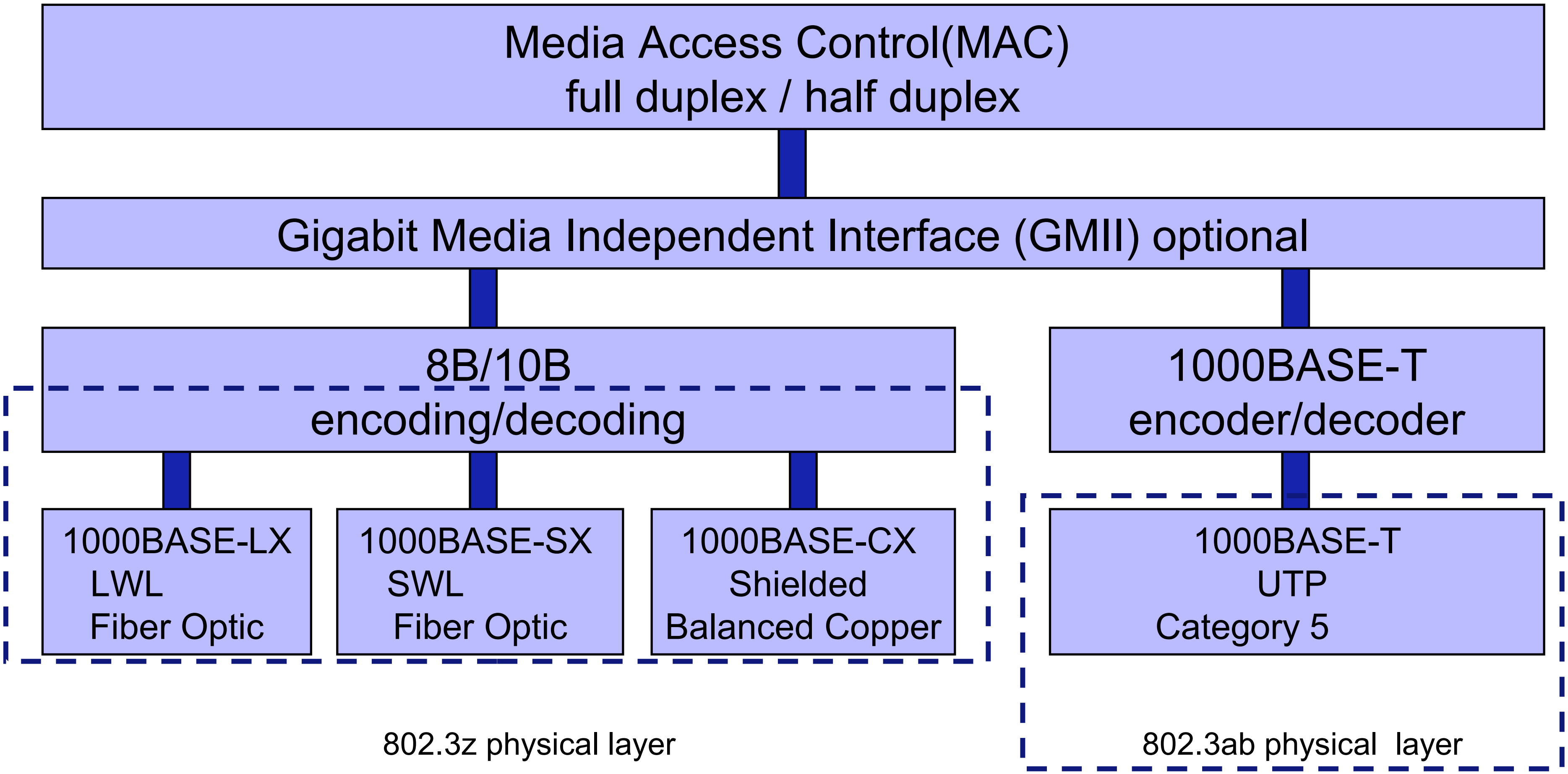
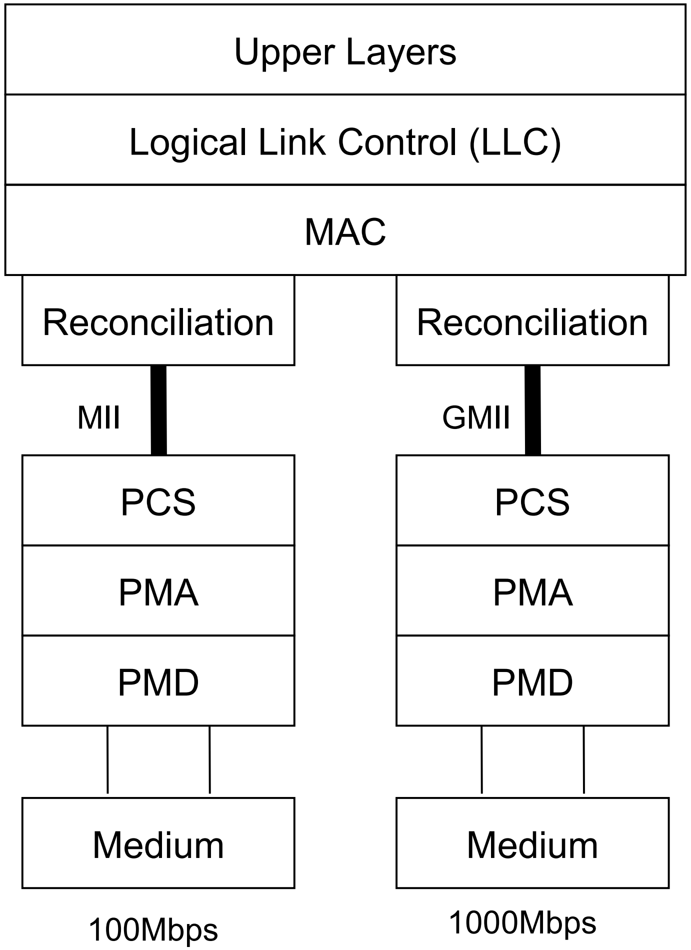
Gigabit Ethernet Standards



Migration to Gigabit Ethernet

- Gigabit Ethernet looks identical to Ethernet from data link layer upwards
- Changes are made to physical interface
  - Gigabit Ethernet Physical Media Attachment (PMA) is identical to Fiber Channel PMA
- Standard takes advantage of
  - High speed physical interface of fiber channel
  - IEEE 802.3 Ethernet frame format
  - Full or half duplex CSMA/CD

IEEE 802.3z Gigabit Ethernet



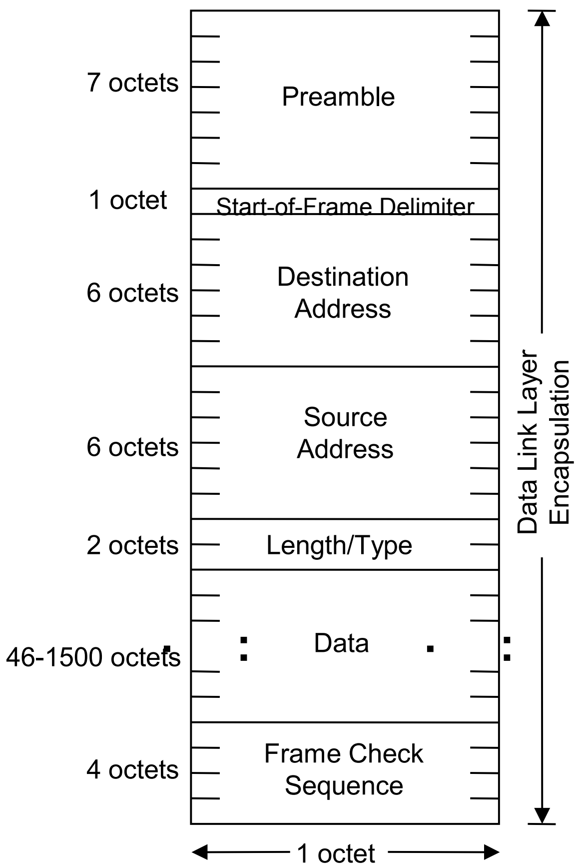
GMII: Gigabit Media Independent Interface
PMA: Physical Media Attachment
PMD: Physical Media Dependent

Reconciliation: Mapping between:

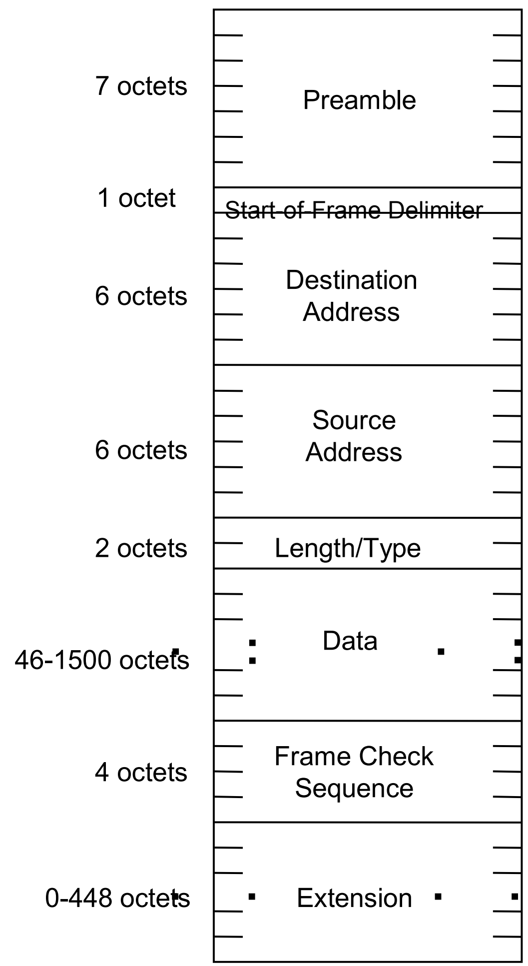
- Physical layer signaling primitives &
- Signals on GMII

Frame Formats

IEEE 802.3 frame format



Gigabit Ethernet frame format



Problems with Gigabit Ethernet

In half-duplex mode, the physical extension would - without further measures - be less than 20 meters

Reason: dependence between minimum sized frames, speed and physical extension

➔ The minimum CSMA/CD carrier time and the Ethernet slot time have been extended to 512 bytes.

➔ **Packets** ⬅512 bytes are not modified

➔ **Packets** < 512 bytes have a carrier extension field following the CRC field

Frame with Extension Field

Packets smaller than 512 Byte will be extended with an additional field:

Destination Address (6 Byte)	Source Address (6 Byte)	Type/ Length (2 Byte)	Data	FCS (4 Byte)	**Extension**

← 512 Byte →

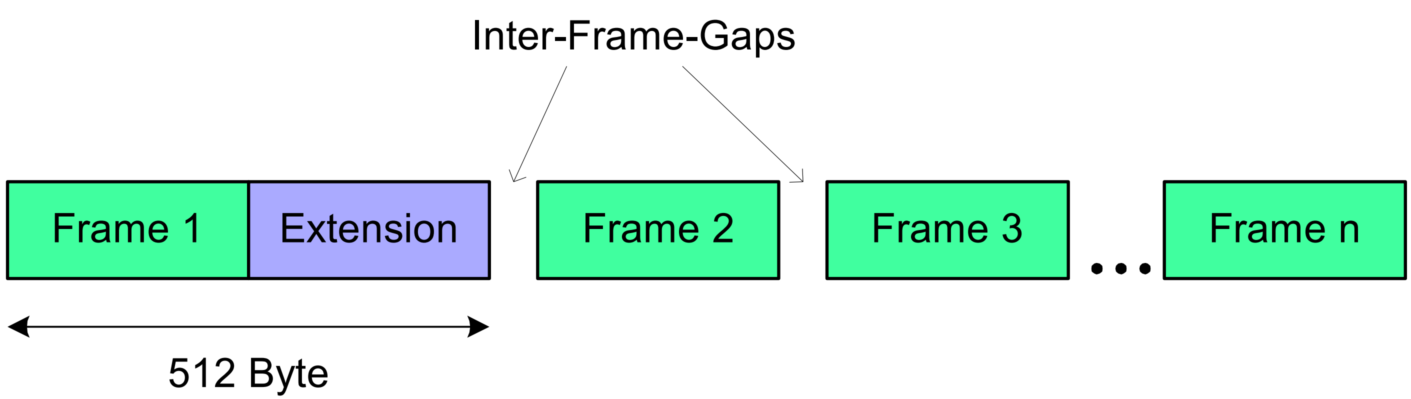
Packet Bursting

Mechanism to improve the performance of the small sized packets:

the devices are allowed to send some small packets together

but a burst limit is defined too:

one transmission of a station must not be longer than 65,536 bit times



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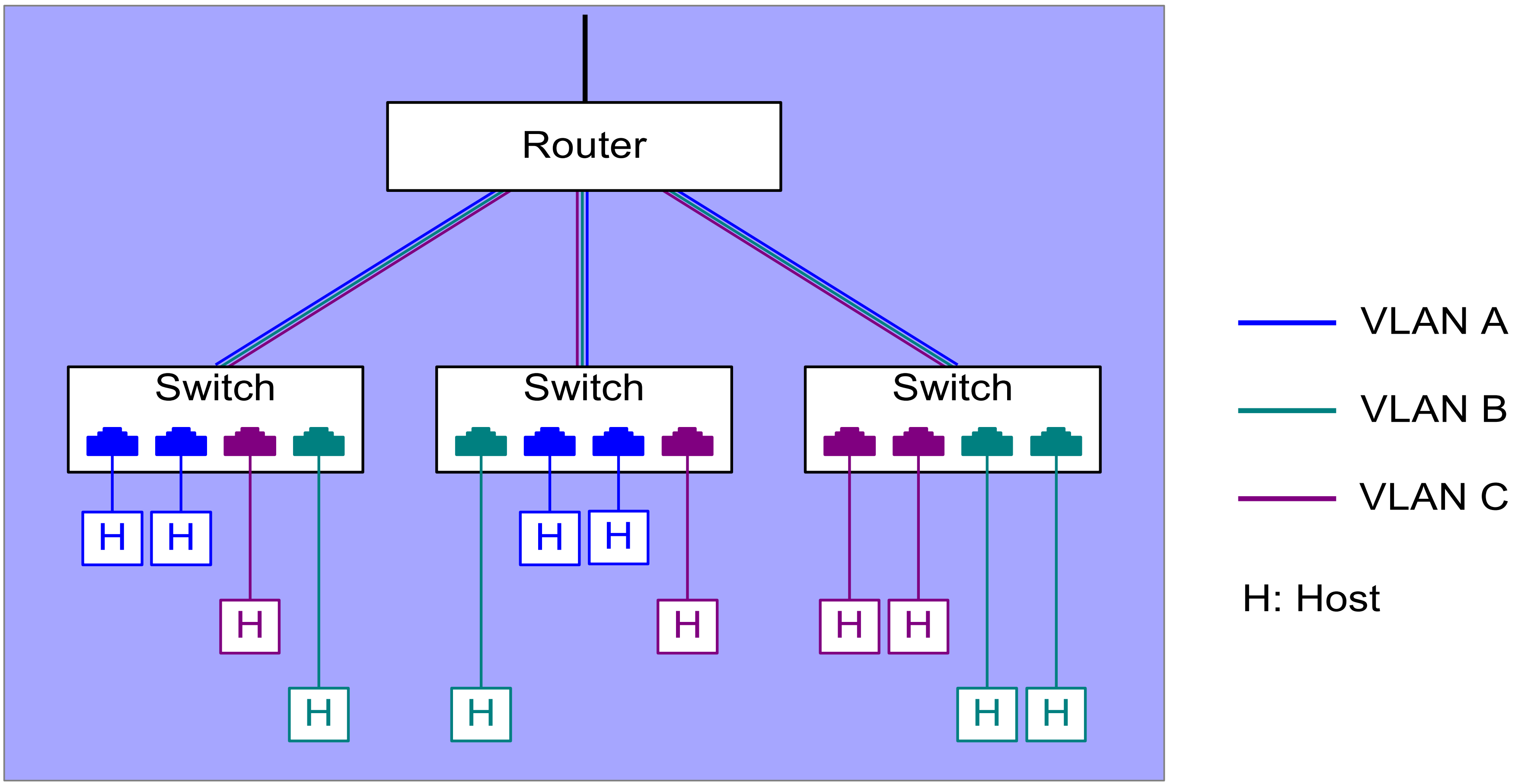
VLANs (Virtual Local Area Network)



Benefits of VLANs

- Facilitating network administration
- Allowing formation of work groups
- Enhancing network security
- Providing a means of limiting broadcast domains

VLAN Standards

- IEEE 802.3ac (1998) defines frame format extensions to support Virtual Local Area Network (VLAN) Tagging on Ethernet networks.
- IEEE 802.1Q defines the general VLAN protocol.

VLAN Tag

The VLAN protocol permits the insertion of an identifier, or "tag", into the Ethernet frame format to identify the VLAN to which the frame belongs. It allows frames from stations to be assigned to logical groups.

Destination Address (6 Byte)	Source Address (6 Byte)	Length/ Type 802.1Q Tag Type (2 Byte) **0x8100**	Tag Control Information (2 Byte)	Length/ Type (2 Byte)	Data (46 - 1500 Byte)	FCS (4 Byte)

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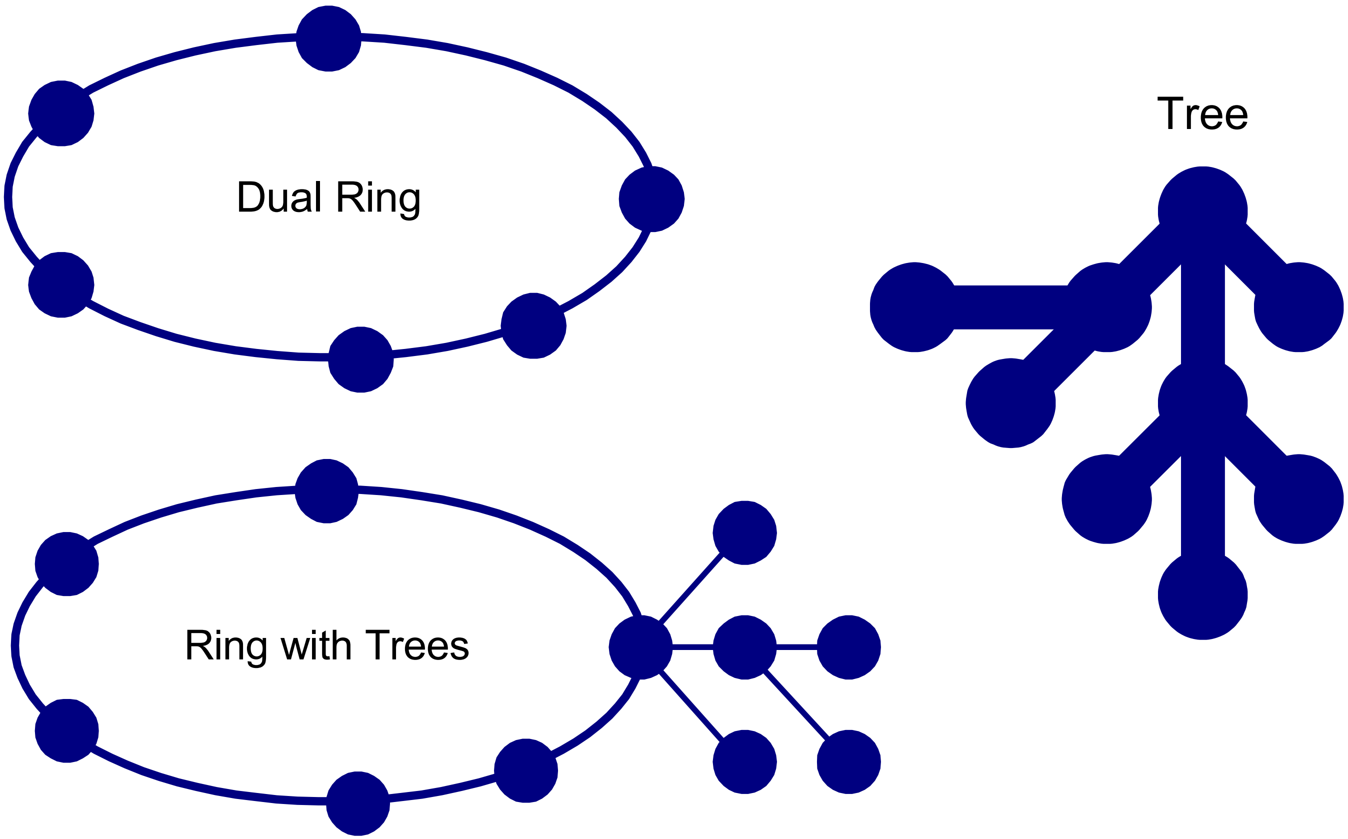
FDDI (Fiber Distributed Data Interface)

- 100Mbps bandwidth
- Up to 500 stations in one network
- Up to 60km between two stations
- Total length 200km
- Guaranteed waiting time
- Redundancy in topology

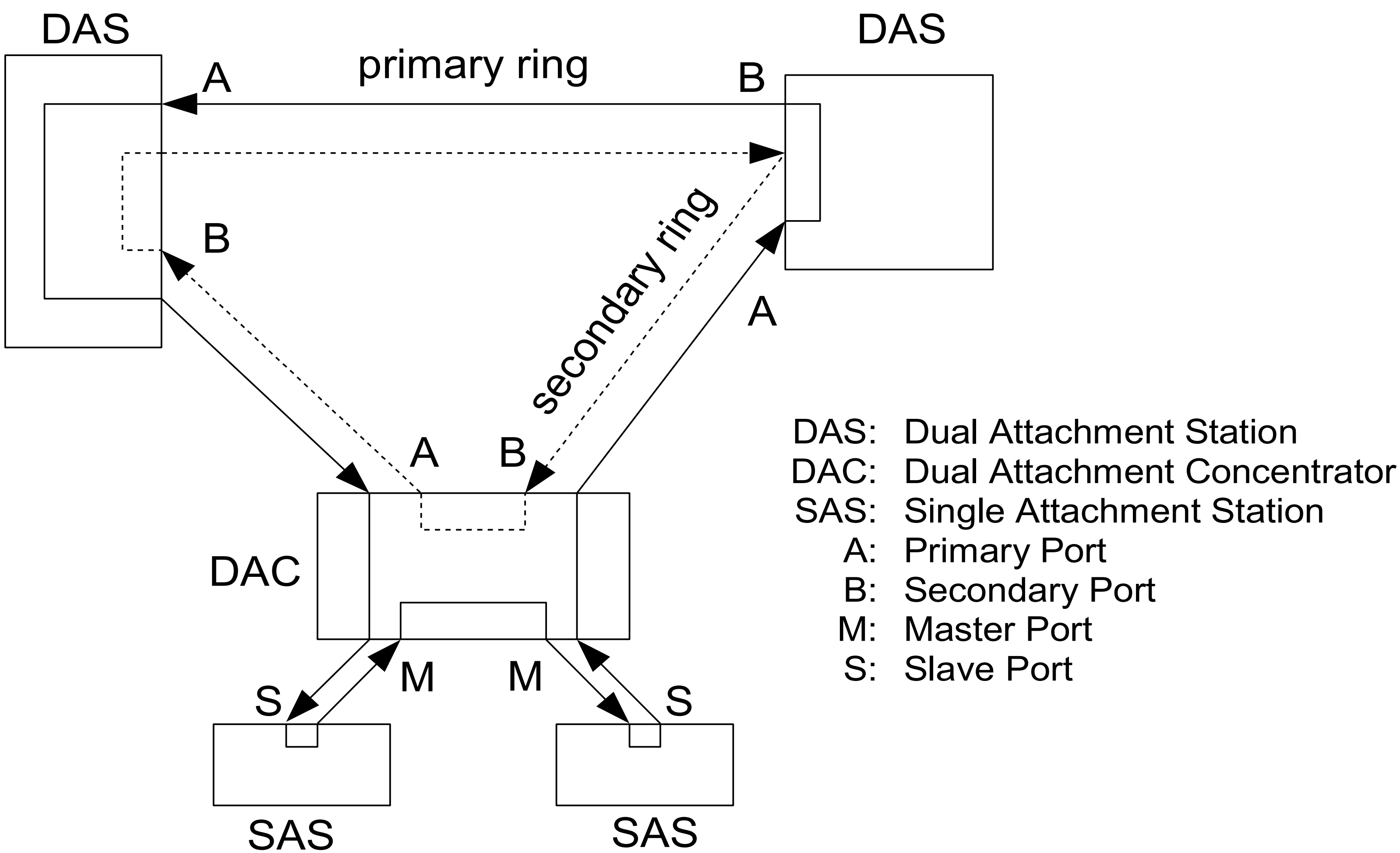
FDDI Summary

- Fixed 125Mbps 4b/5b coded signals
- Timed token rotation used for bandwidth sharing
- Frame size 3...4500 bytes
- Topology: dual ring of trees
- Big-endian bit order
- Offers synchronous and asynchronous transmissions
- Stations have station-management duties

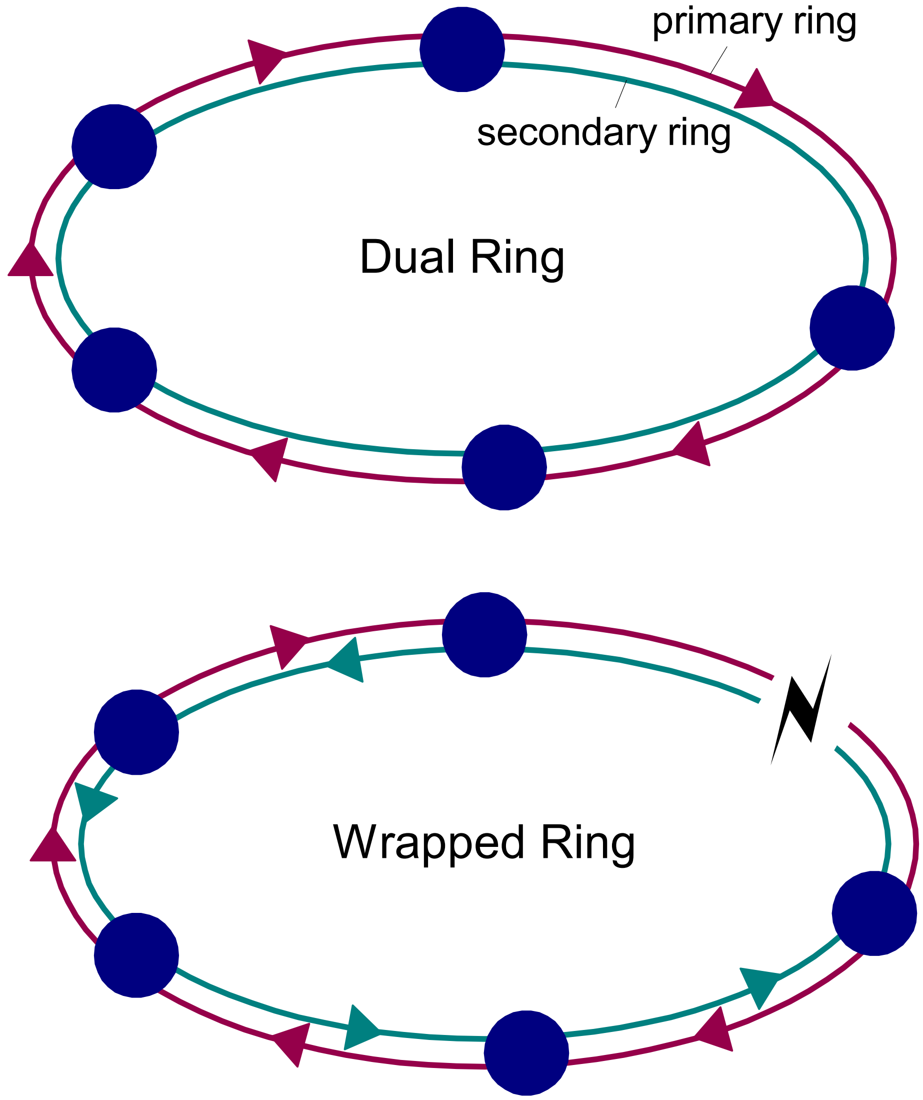
FDDI Topology



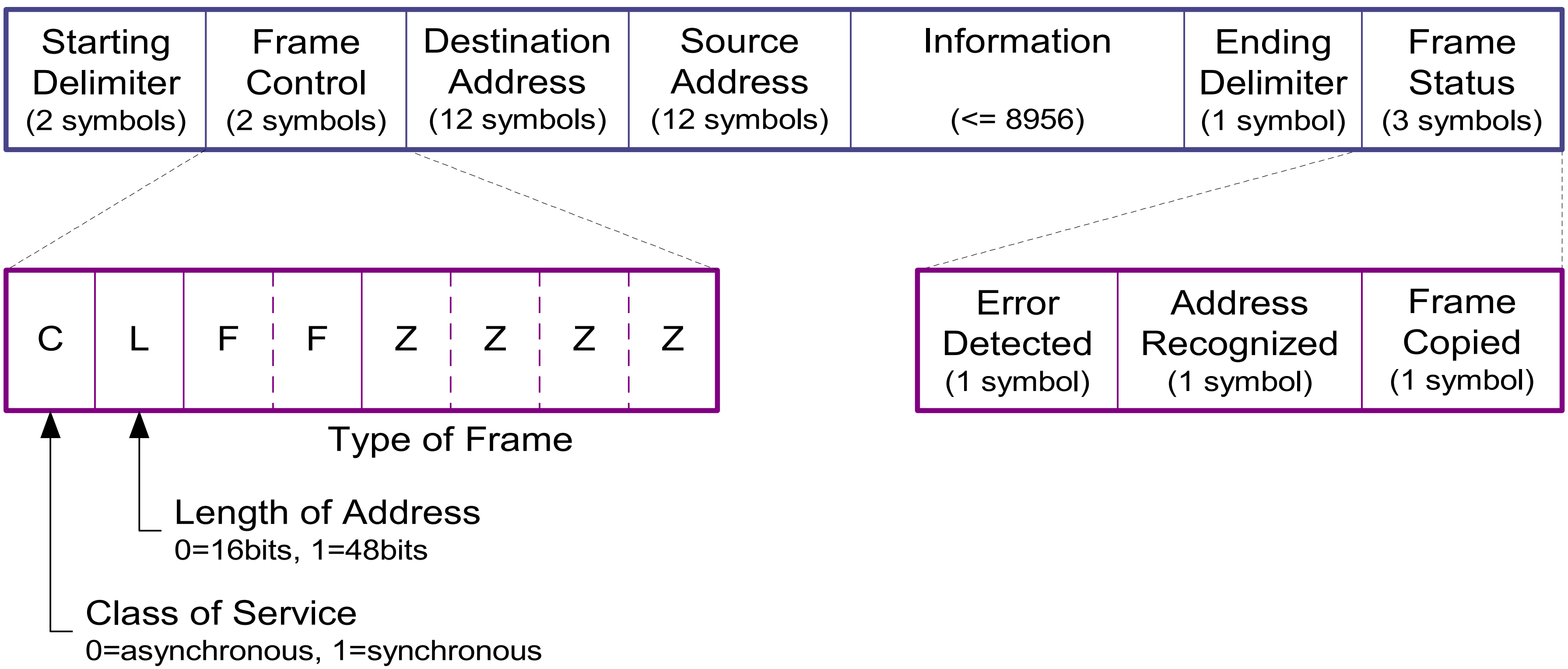
FDDI Stations



Wrapped Ring



FDDI Frame


Starting Delimiter (2 symbols)
Frame Control (2 symbols)
Destination Address (12 symbols)
Source Address (12 symbols)
Information (<= 8956)
Ending Delimiter (1 symbol)
Frame Status (3 symbols)
C
L
F
F
Z
Z
Z
Z
Type of Frame
Length of Address
0=16bits, 1=48bits
Class of Service
0=asynchronous, 1=synchronous
Error Detected (1 symbol)
Address Recognized (1 symbol)
Frame Copied (1 symbol)

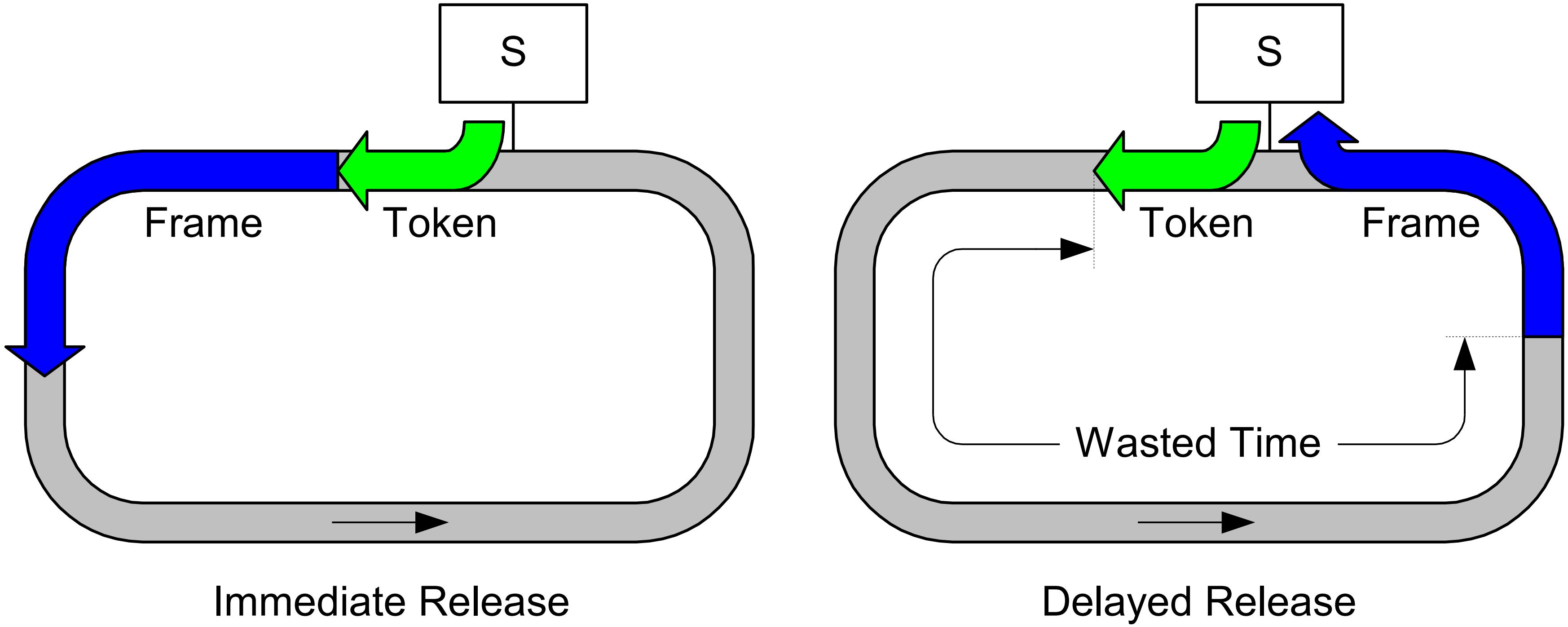
Access Method

For a right to initialize the token: 8ms, 8ms, 8ms, ...
Do I hear any 7?

FDDI Access Method

- There are 2 types of transfers: synchronous and asynchronous
- Synchronous transfers can be done whenever the station gets the token; was never really used
- Asynchronous traffic can be started whenever the station gets a token that is not late
- The last frame is always allowed to complete
- The token is immediately released after transmission
- The transmitting station removes its own data

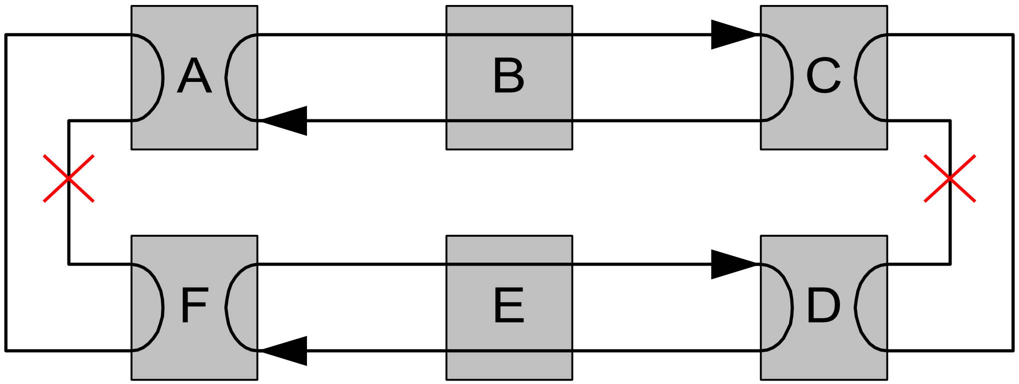
Token Release Methods



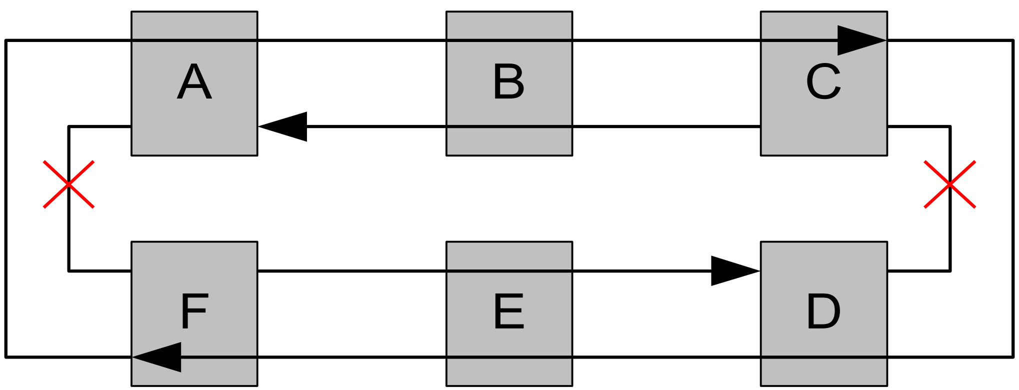
FDDI Error Detection

- A station suspects a fault in the ring
- It starts sending beacon frames
- Every station that receives a beacon frame stops sending beacons
- If a station receives its own beacon everything is OK
- Else the ring is broken right before the station
- The SMT takes action

FDDI Ring Wrapping and Hold



wrapping results in partitions



global hold maintains primary ring