

# EE 233. LIGHTWAVE SYSTEMS

## Local Area Networks



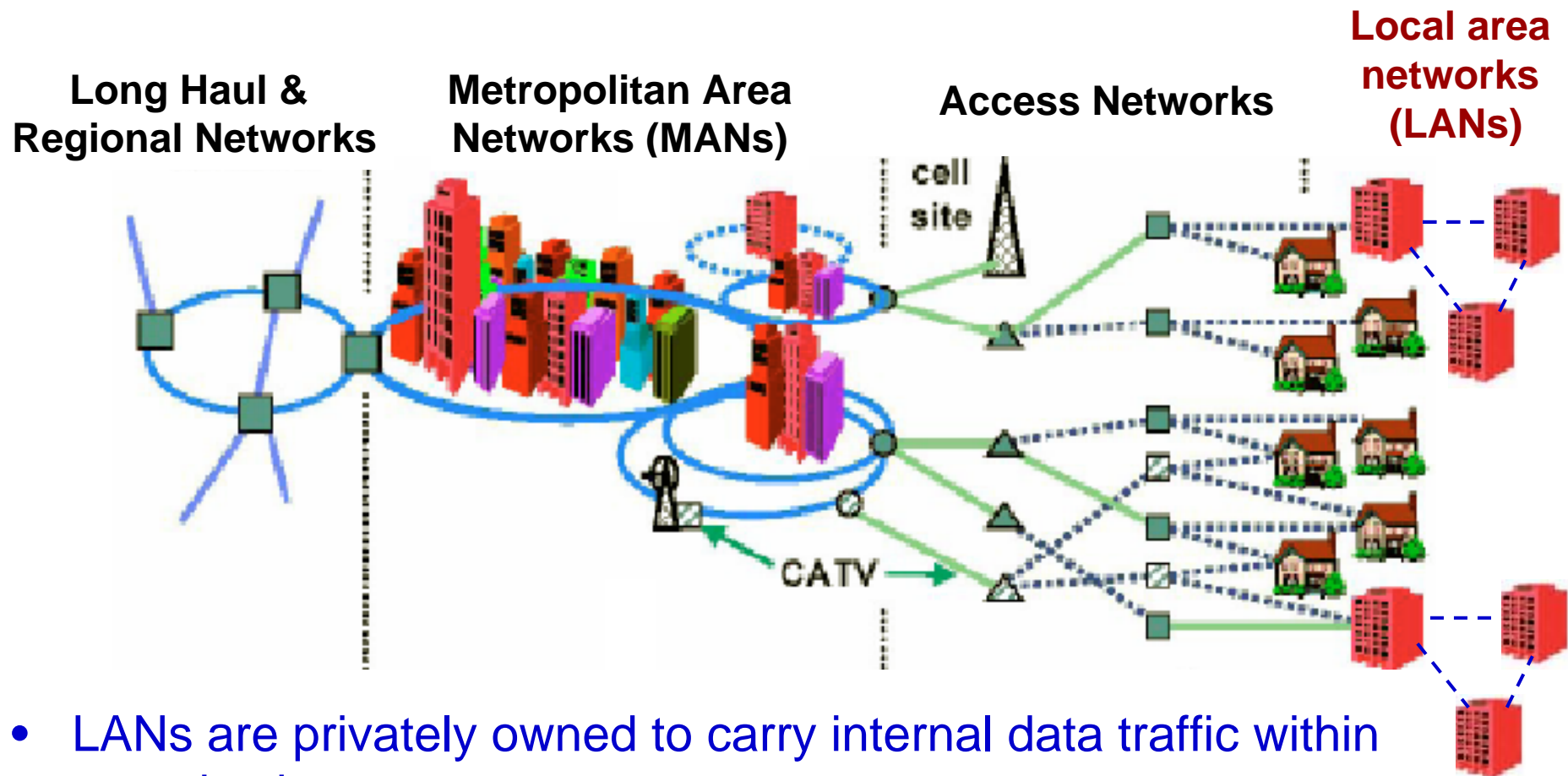
Guest Instructor  
Elaine Wong

# Outline

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- **Introduction to Local Area Networks (LANs)**
  - Network architecture
  - Geographical area
  - LAN applications
- **LAN Technologies**
  - Ethernet
  - Fiber Distributed Data Interface (FDDI)

# System Architectures

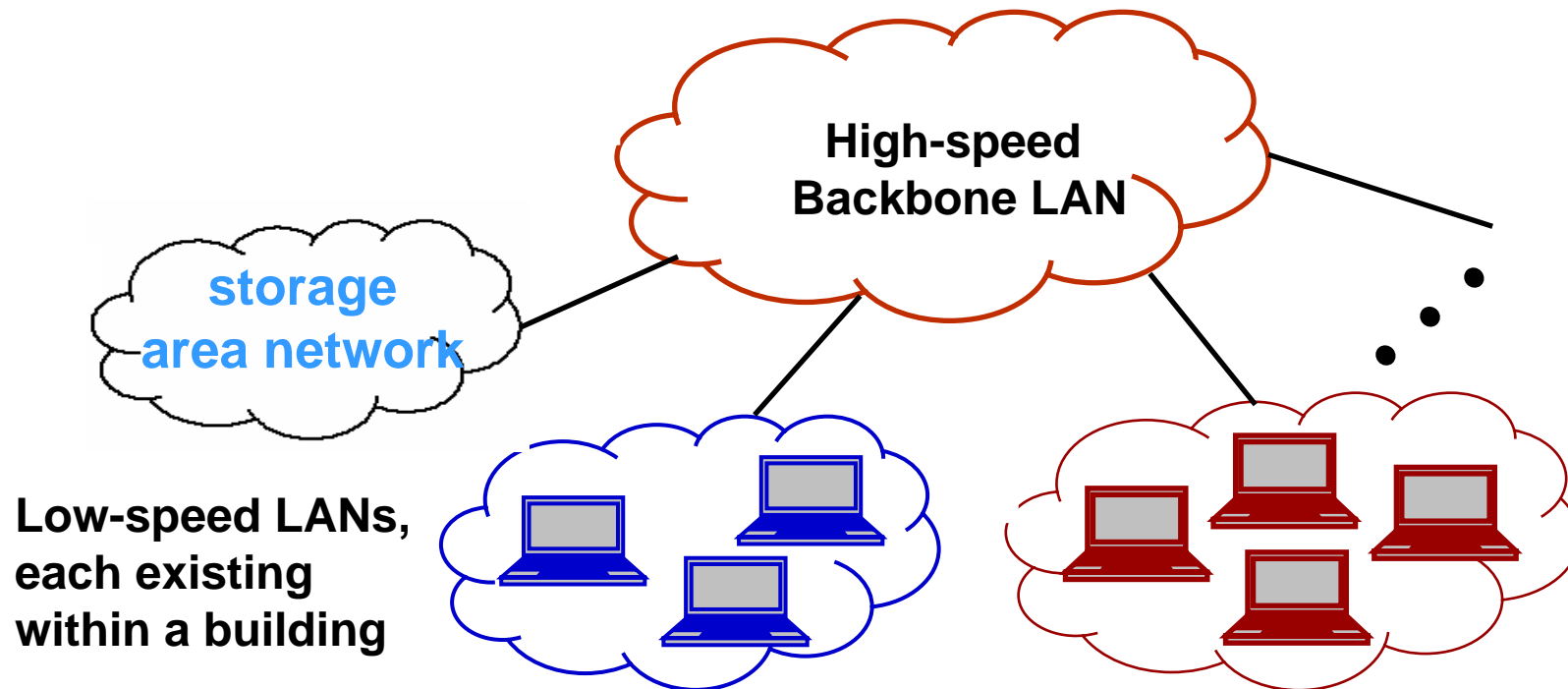


- LANs are privately owned to carry internal data traffic within organisation
- Coverage area < 10 km

# Interconnection of LANs

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- LANs may exist on many levels categorized by speed and application



# Ethernet

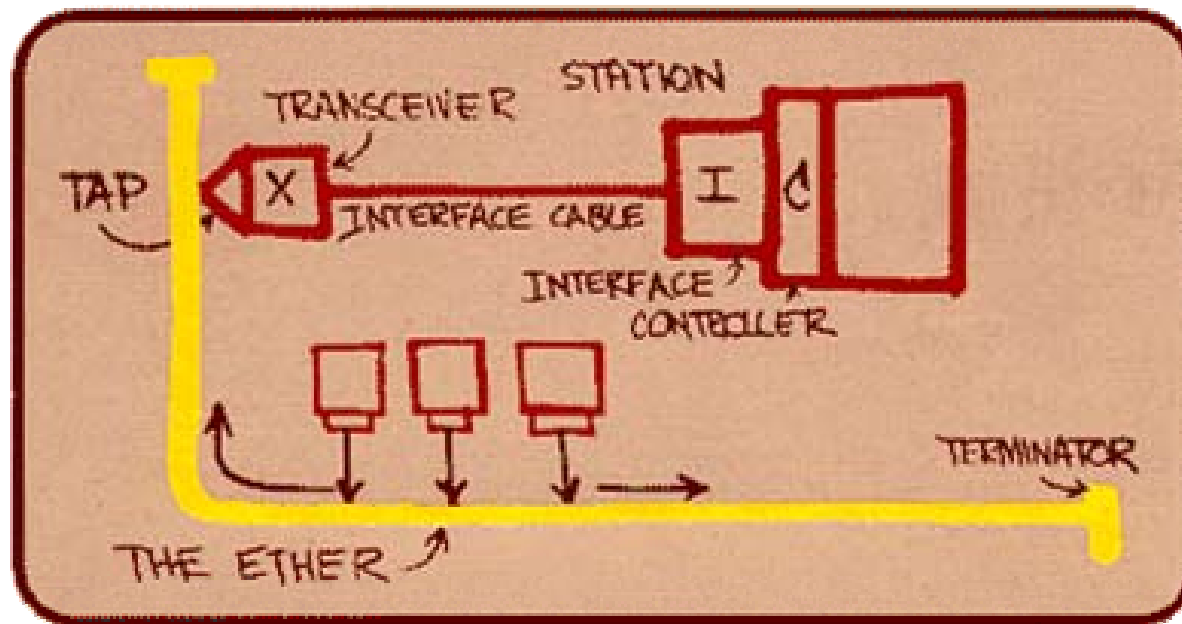
# Overview

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- Ethernet is the most popular LAN technology
  - large installed base (500 million Ethernet nodes)
  - more than 95% of LAN traffic is Ethernet based
- Ethernet supports 10 Mb/s, 100 Mb/s (Fast Ethernet), 1 Gb/s (Gigabit Ethernet) and 10 Gb/s (10GbE)
- Ethernet standardized by IEEE (802.3 standard series)
- Widespread popularity
  - **Specifications and rights** to build and install Ethernet made easily **available to everyone**
  - Design goals: create a **simple network topology** with efficient shared resources, **easy to configure and maintain**, **compatible** across many manufacturers and systems
  - Ethernet is competitively priced

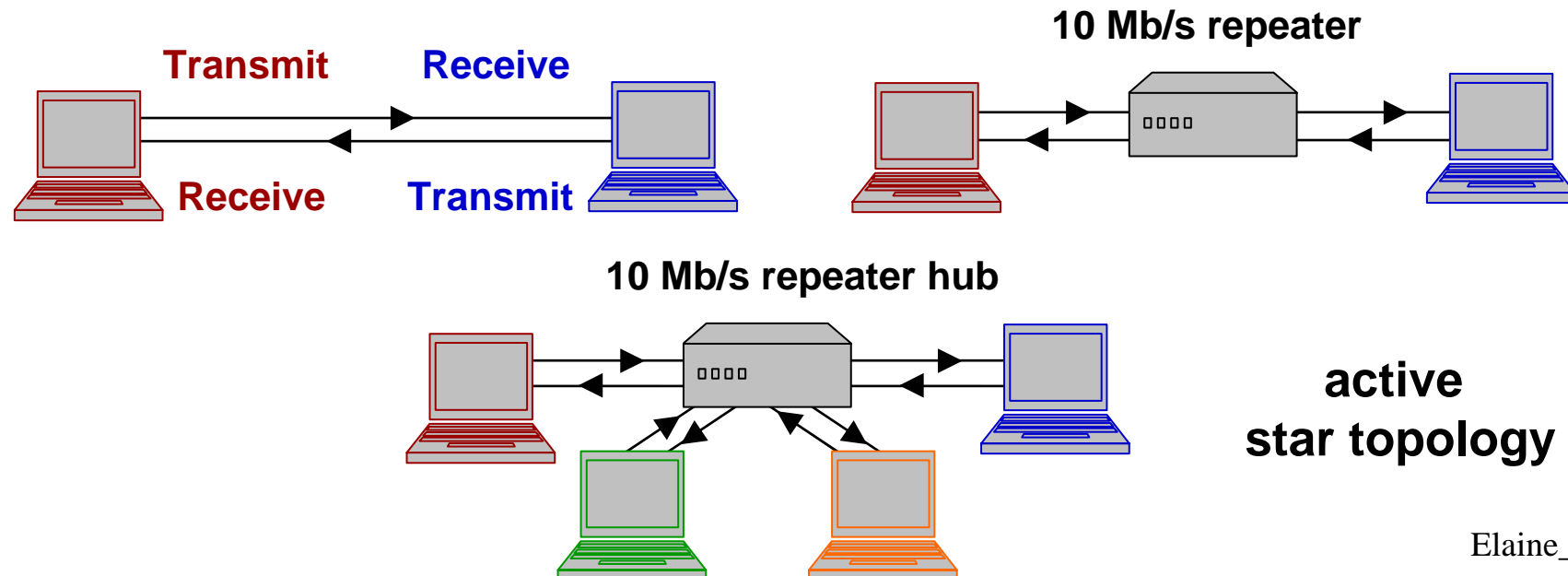
# Invention of Ethernet

- Invented in 1976 by Dr. Robert M. Metcalfe at the Xerox Palo Alto Research Center
- Asked to build a networking system for computers → “office of the future”
- First demonstration of Ethernet (2.94 Mb/s data rate)



# Standardization of Ethernet

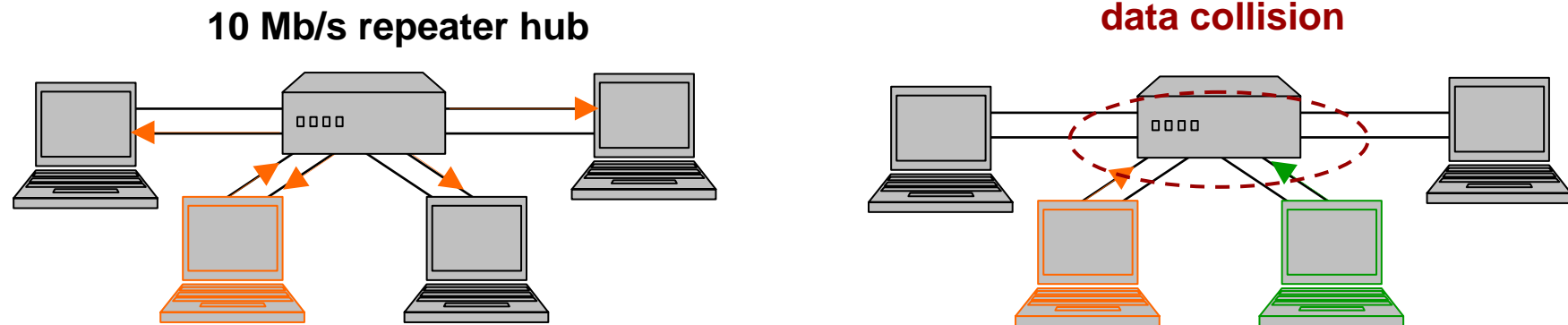
- In 1983, IEEE released first Ethernet standard (10 Mb/s) based on 50  $\Omega$  thick coaxial cable in bus topology
- In 1990, major advancement with unshielded twisted pair (UTP) copper transmission medium (IEEE 802.3 10BASE-T)
- Only point-to-point connections allowed in 10BASE-T
- Repeater regenerates data received from one cable and retransmit signal at all output cables to all users





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

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- CSMA/CD protocol minimizes data collision
  1. Listen for activity on medium (carrier-sense)
  2. If no activity, send data frame immediately (multiple access)
  3. While transmitting, listen to medium for collision (collision detect)
  4. If collision is detected, stop transmission and send jamming signal
  5. After random time period, retransmit data by repeating step 1.
- Half-duplex operation

# 10 Mb/s Ethernet

- In 1993, IEEE extended Ethernet to operate over optical fiber transmission medium (IEEE 802.3j 10BASE-F)
- Three types of physical layer specifications: 10BASE-FP (fiber passive), 10BASE-FL (fiber link), 10BASE-FB (fiber backbone)

	<b>10BASE-FP</b>	<b>10BASE-FL</b>	<b>10BASE-FB</b>
<b>Data Rate</b>	10 Mb/s	10 Mb/s	10 Mb/s
<b>Transmission Wavelength</b>	850 nm	850 nm	850 nm
<b>Transmission medium</b>	62.5 $\mu$ m MMF pair	62.5 $\mu$ m MMF pair	62.5 $\mu$ m MMF pair
<b>Topology</b>	Passive star	Point-to-point link	Point-to-point link
<b>Max. distance</b>	500 m	2 km	2 km

# 100 Mb/s Ethernet (Fast Ethernet)

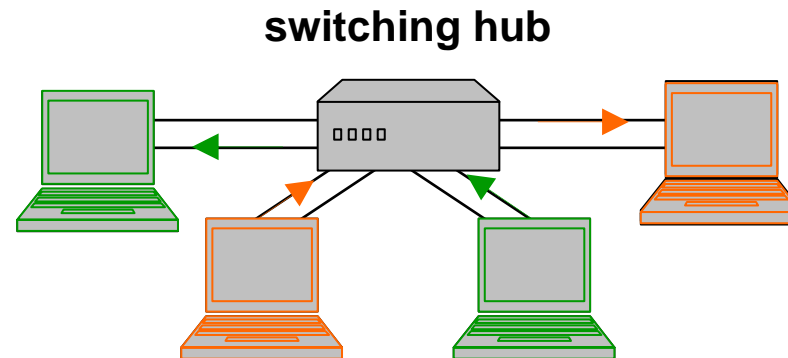
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- In 1995, IEEE improved performance of Ethernet by a factor of 10 with 100 Mb/s standard (Fast Ethernet)
- One physical layer specification for the optical fiber transmission medium: 100BASE-FX

	<b>100BASE-FX</b>
<b>Data Rate</b>	100 Mb/s
<b>Transmission wavelength</b>	850 nm
<b>Transmission medium</b>	62.5 $\mu$ m MMF pair
<b>Max distance</b>	412 m (half-duplex) 2 km (full-duplex)

# Switched Ethernet

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- Data frames switched from one input link to one output link
- Simultaneously switching can be performed on multiple input-output links without collision
- Switching hub can support mixed capacity links, i.e. 10 Mbps / 100 Mbps
- Fast Ethernet can operate in one of two modes
  - half-duplex (CSMA/CD MAC protocol)
  - full duplex (switched Ethernet protocol)

# 1 Gb/s Ethernet (Gigabit Ethernet)

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- In 1998, IEEE improved performance of Ethernet by a factor of 10 with 1 Gb/s standard (Gigabit Ethernet, GbE)
- Target application: backbone LAN
- Half-duplex and full-duplex operation
- Two GbE physical layer specifications for optical fiber transmission: 1000BASE-SX, 1000BASE-LX

	<b>1000BASE-SX</b>	<b>1000BASE-LX</b>
<b>Data Rate</b>	1 Gb/s	1 Gb/s
<b>Transmission wavelength</b>	850 nm	1310 nm
<b>Transmission medium</b>	50 $\mu\text{m}$ or 62.5 $\mu\text{m}$ MMF pair	10 $\mu\text{m}$ SMF pair, 50 $\mu\text{m}$ or 62.5 $\mu\text{m}$ MMF pair
<b>Max distance</b>	550 m (50 $\mu\text{m}$ ) or 275 m (62.5 $\mu$ )	5 km for SMF, 550 m for MMF

# 10 Gb/s Ethernet (10GbE)

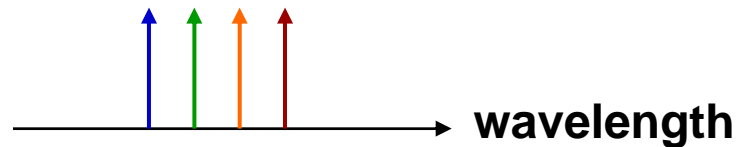
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- In June 2002, IEEE 802.3 standard extended to include 10 Gb/s transmission
- 10GbE expected to be deployed in LAN, MAN and WAN
  - Seamless transport of Ethernet frames across entire network
  - Simplifies network management, minimizes operational costs
- 10GbE specifies full duplex operation and optical fiber transmission medium
- 10GbE media types: 10GBASE-S, 10GBASE-L, 10GBASE-E and 10GBASE-LX4

	<b>10GBASE-S</b>	<b>10GBASE-L</b>	<b>10GBASE-E</b>
<b>Data Rate</b>	10 Gb/s	10 Gb/s	10 Gb/s
<b>Transmission wavelength</b>	850 nm	1310 nm	1550 nm
<b>Transmission medium</b>	62.5 $\mu$ m MMF pair	10 $\mu$ m SMF pair	10 $\mu$ m SMF pair
<b>Max distance</b>	300 m	10 km	40 km

# 10GbE: 10GBASE-LX4

- 10GBASE-LX4 designed for wavelength division multiplexed (WDM) network
- Transmission of four simultaneous 2.5 Gb/s wavelength channels



	<b>10GBASE-LX4</b>
<b>Data Rate</b>	4 × 2.5 Gb/s
<b>Transmission wavelength</b>	1270 nm to 1355 nm
<b>Transmission medium</b>	10 μm SMF or 50 μm, 62.5 μm MMF pair
<b>Max transmission distance</b>	300 m (MMF) and 10 km (SMF)

# **Fiber Distributed Data Interface (FDDI)**



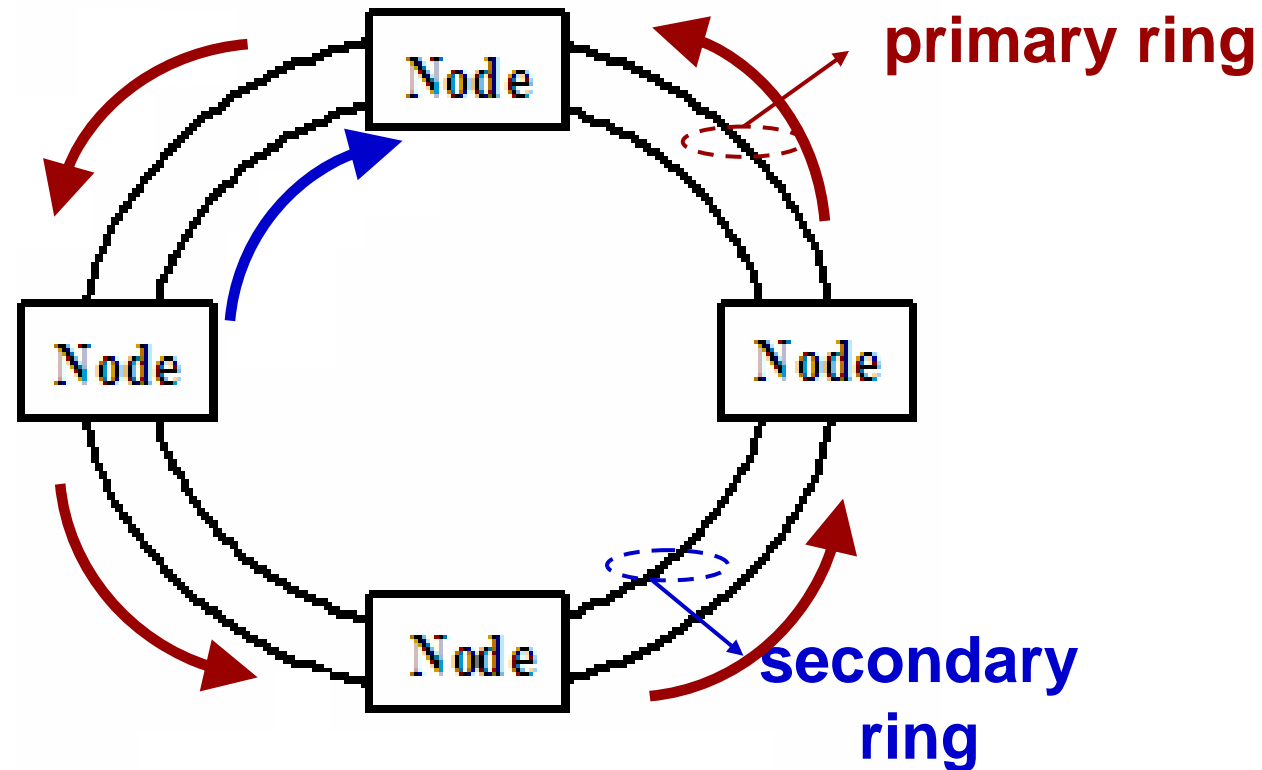
# Overview

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- FDDI developed and standardized by American National Standards Institute (ANSI) and later the International Organization of Standardization (ISO) in mid-80s
- Target installations: high-speed workstation interconnections and backbone LANs, where network reliability is important
- Now not as widely deployed as the Ethernet family but remains as one of the first to be standardized for high-speed fiber-optic LAN applications
- Physical statistics:
  - **Transmission medium** → multimode fiber (connectivity within building, single-mode fiber (connectivity between buildings))
  - **Network architecture** → dual counter-propagating rings
  - **Maximum ring size** → 100 km per ring
  - **Data rate** → 100 Mb/s

# FDDI: Network Architecture

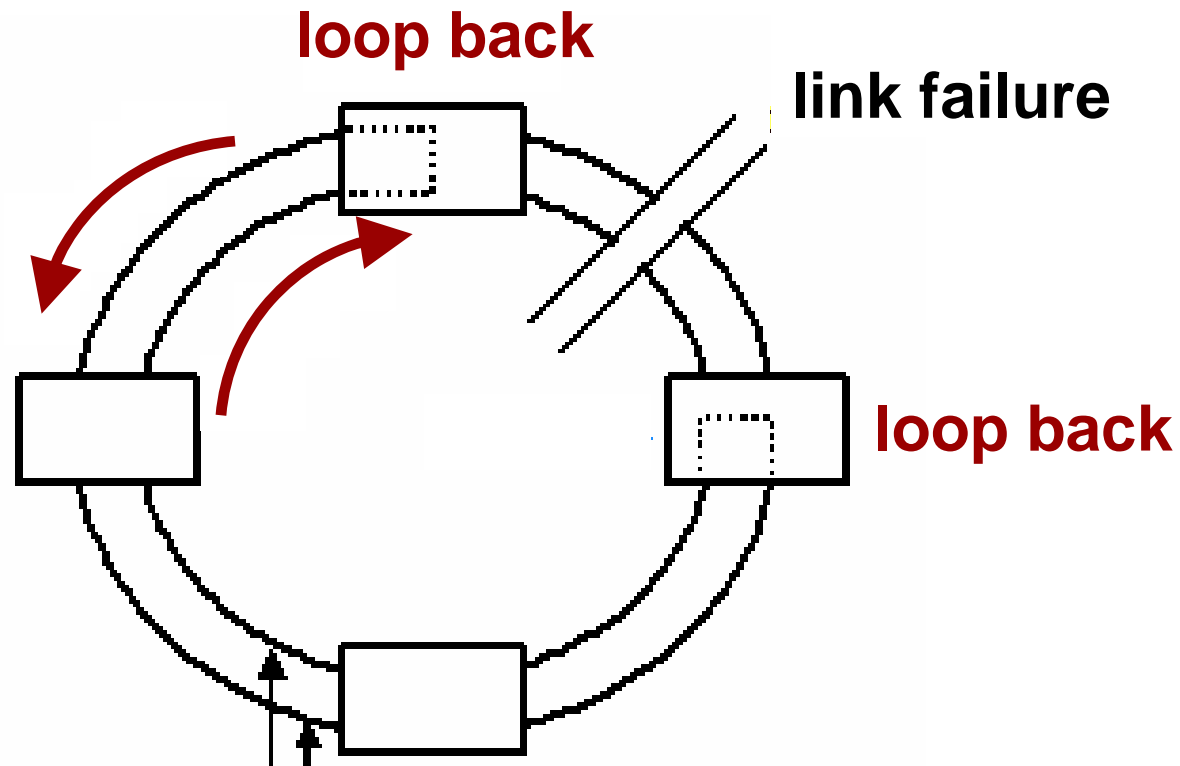
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- Each node connected to two rings via four fibers
- During normal operation, data transmitted and received on primary ring
- Data frames passed from one node to another

# FDDI: Self-Healing Network

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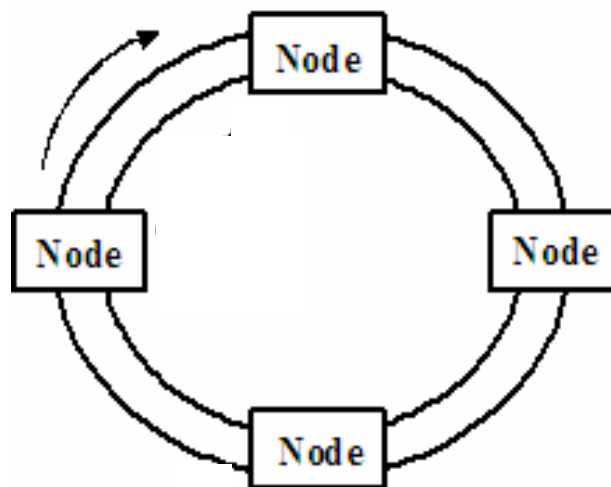
both primary and secondary rings in use

- During node or link failure, secondary ring closes loop to restore all traffic transport
- Self-healing network is fault tolerate and increases network reliability

# Timed Token Rotation Protocol (TTRP)

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- FDDI uses TTRP to control network access between nodes that share the network
- During network initialization or power up, pre-assigned node transmits special frame “TOKEN” onto the ring
- TOKEN circulates ring network from one node to the next
- TOKEN → “passport” to transmit data



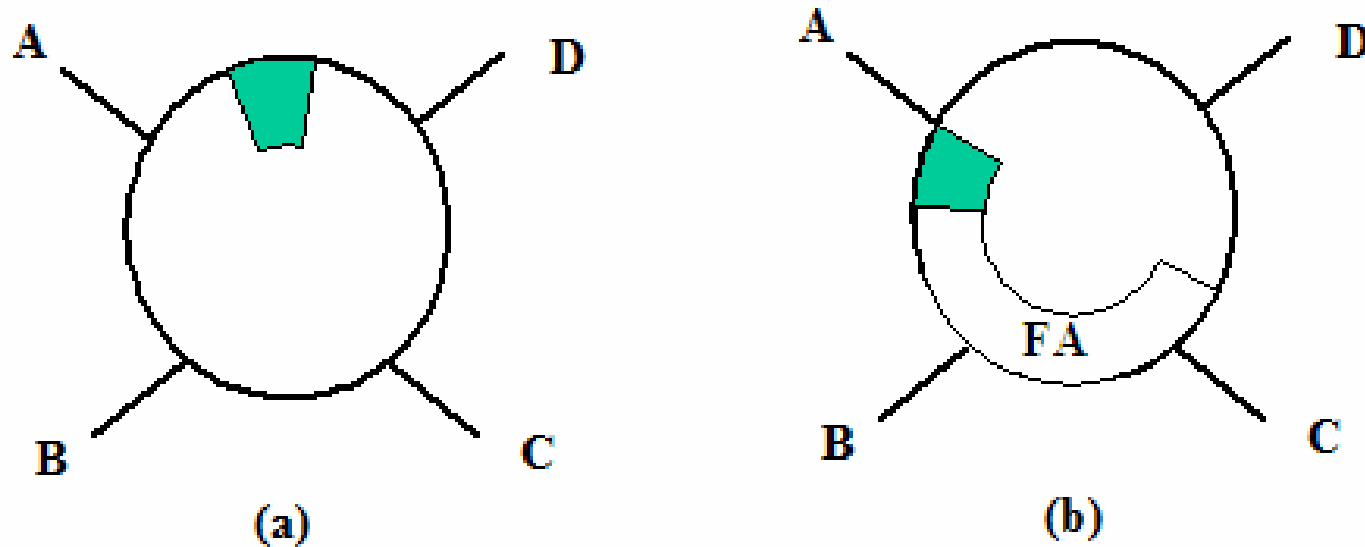
# TTRP (cont.)

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- To transmit, a node
  - waits for TOKEN
  - captures TOKEN (without retransmitting back into the network)
  - immediately transmits data frames
  - release TOKEN (append TOKEN to end of data frame)
- Transmitting (source) node removes data frame from network after one roundtrip propagation around the ring

# Transmissions from Node A-C, and B-A

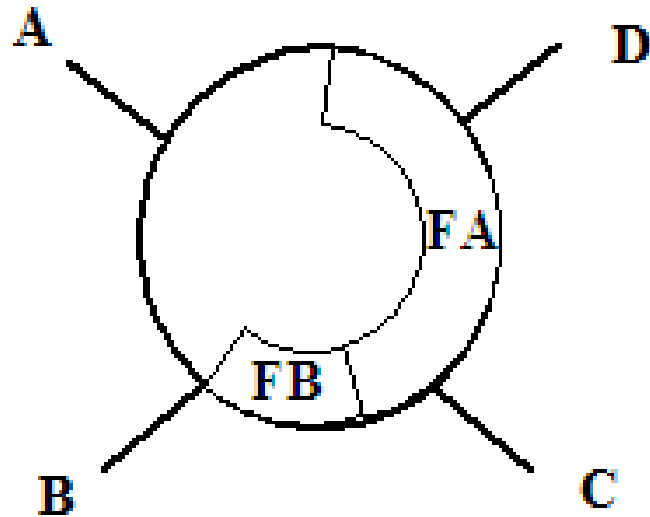
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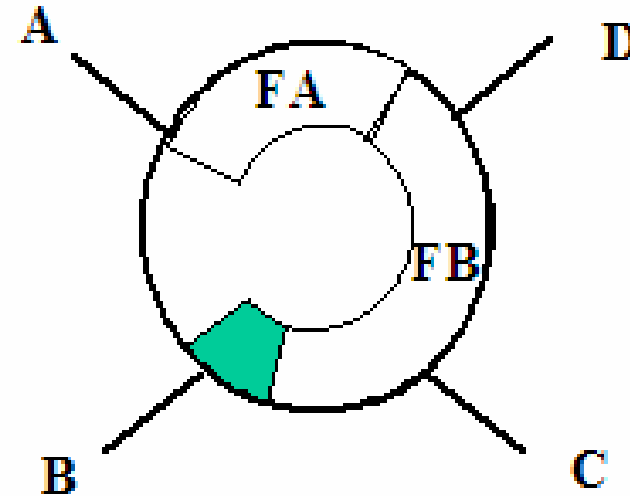
- Node A waits and captures TOKEN
- Node A transmits frame FA addressed to Node C
- Node B regenerates and retransmits frame FA as it circulates past
- Destination Node C copies and retransmits frame FA as it circulates past
- Node A appends TOKEN at the end of FA

# Transmissions from Node A-C, and B-A

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(c)

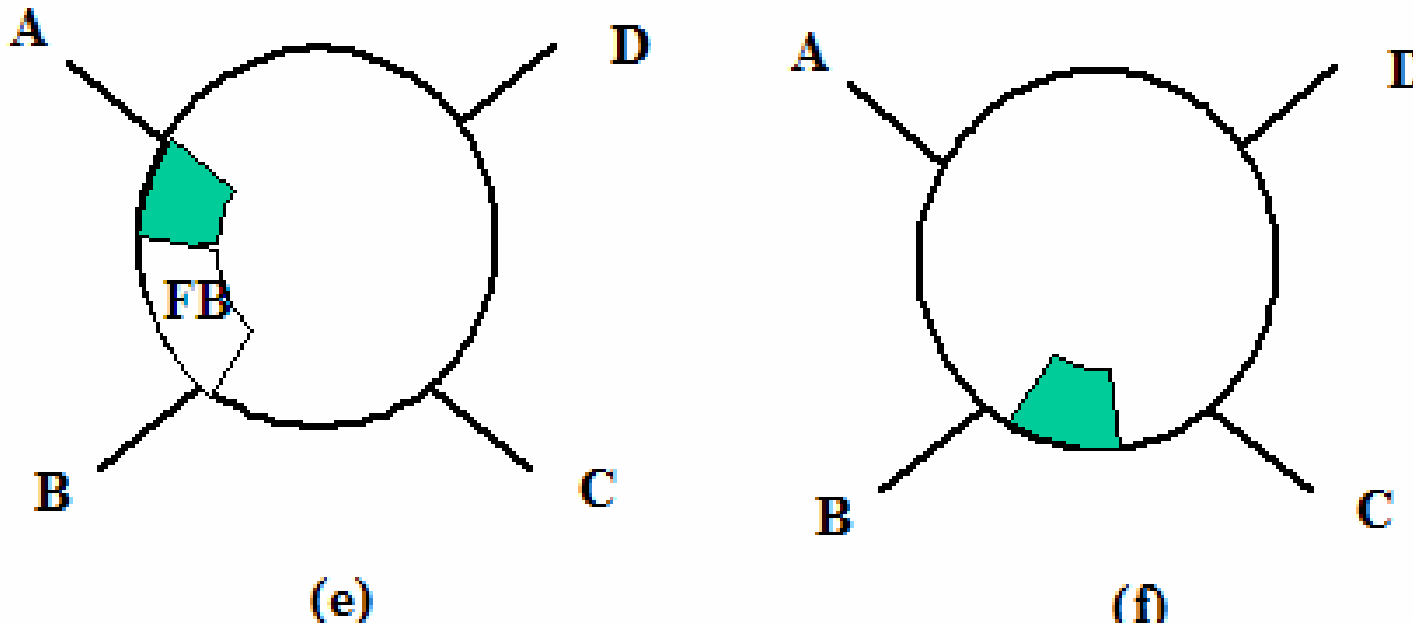


(d)

- Node B captures TOKEN issued by Node A
- Node B transmits frame FB addressed to Node A
- Eventually, frame FA recirculates back to its source, Node A, and is removed by Node A (no retransmission)
- Meanwhile, Node B finishes transmitting FB and appends TOKEN to FB

# Transmissions from Node A-C, and B-A

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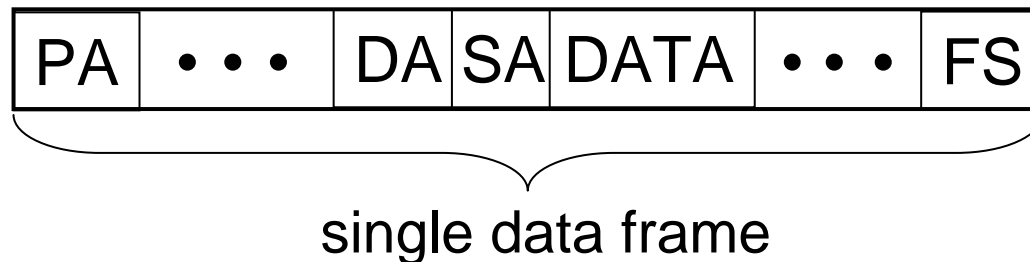
- Destination Node A copies FB, and regenerates FB and TOKEN at end of FB
- Frame FB is removed by its source, Node B, from the ring
- Node B regenerates TOKEN
- TOKEN will remain circulating around the ring until a node wanting to transmit data frames will capture it for the right to transmit



# Data Frame Format

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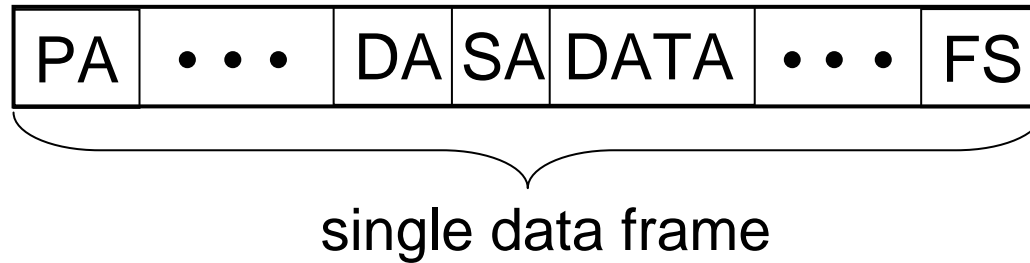
- Each node in the ring network is assigned a unique MAC address
- MAC addresses used in data frames to distinguish between source and destination nodes



- FDDI data frame comprises nine different fields
- PA field – contains preamble
- DA field – contains destination address  
(MAC address of node that the data frame is intended for)

# Data Frame Format (cont.)

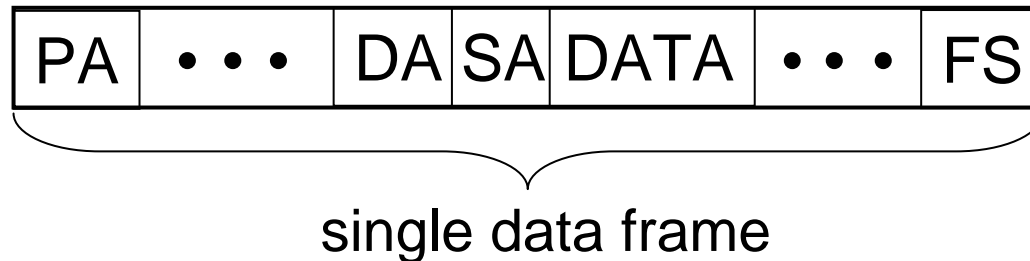
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- SA field – contains source address  
(MAC address of node transmitting data frame)
- DATA field – contains data information for destination node
- Each node checks the DA and SA fields of every incoming data frame
- If DA field matches node's own MAC address  
→ copy entire DATA field and pass on the upper networking layers
- If SA field matches node's own MAC address  
→ remove frame from the ring

# Frame Status

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- FS –frame status (for checking correct reception of data frame)
- Contains indicator bits – address recognized (A), and frame copied (C)
- Node sets A indicator to ‘1’ if DA field matches own MAC add
- Node sets C indicator to ‘1’ after copying entire DATA field
- FS field is checked when data frame recirculates back to source node
- If A and C are not set i.e. ‘0’, then destination node does not exist or is inactive
- If A = ‘1’ and C = ‘0’, DATA field not copied by active destination node → **issue retransmission**

# Time Controlled Mechanism

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- Prevent nodes from dominating network capacity
- During network initialization, each node negotiates a **guaranteed maximum capacity to transmit high priority frames**
- A **global target token rotation time (TTRT)** is stored at all nodes
- During network operation, each node measures successive arrivals of the TOKEN with a **token rotation time (TRT)**
- When TOKEN arrives and  $TRT < TTRT$ 
  - send both high and then low priority frames
- When TOKEN arrives and  $TRT > TTRT$ 
  - only send high priority frames

# Summary

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- Ethernet family remains the most prevalent
  - availability of low chip-sets
  - mature and familiar management and analysis tools
- Fiber-optic LANs will continue to grow
  - higher speeds and larger coverage areas
- Future beyond 10 Gb/s will depend on wavelength division multiplexing (WDM) technology