Fast Ethernet
and
Gigabit Ethernet

Fast/Gigabit Ethernet Outline

- Fast Ethernet
  - 100 BASE T4
    - 8B/6T encoding
  - 100 BASE TX
  - 100 BASE FX
  - Collision domains
- Gigabit Ethernet
  - 1000 BASE SX
    - 8B/10B encoding
    - Fiber Channel

Fast/Gigabit Ethernet Outline

- Gigabit Ethernet (continued)
  - 1000 BASE LX
  - 1000 BASE T
  - Carrier Extension
  - Frame Bursting
  - Buffered Distributor
- 10 Gbps Ethernet
- 100 Gbps Ethernet

High-Speed LAN Characteristics

	Fast Ethernet	Gigabit Ethernet	Fibre Channel	Wireless LAN
Data Rate	100 Mbps	1 Gbps, 10 Gbps, 100 Gbps	100 Mbps - 3.2 Gbps	1 Mbps - 54 Mbps
Transmission Media	UTP, STP, optical fiber	UTP, shielded cable, optical fiber	Optical fiber, coaxial cable, STP	2.4-GHz, 5-GHz microwave
Access Method	CSMA/CD	Switched	Switched	CSMA/Polling
Supporting Standard	IEEE 802.3	IEEE 802.3	Fibre Channel Association	IEEE 802.11

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100 Mbps Fast Ethernet

	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

Fast Ethernet concept facilitated by 10Mbps/100Mbps Adapter Cards

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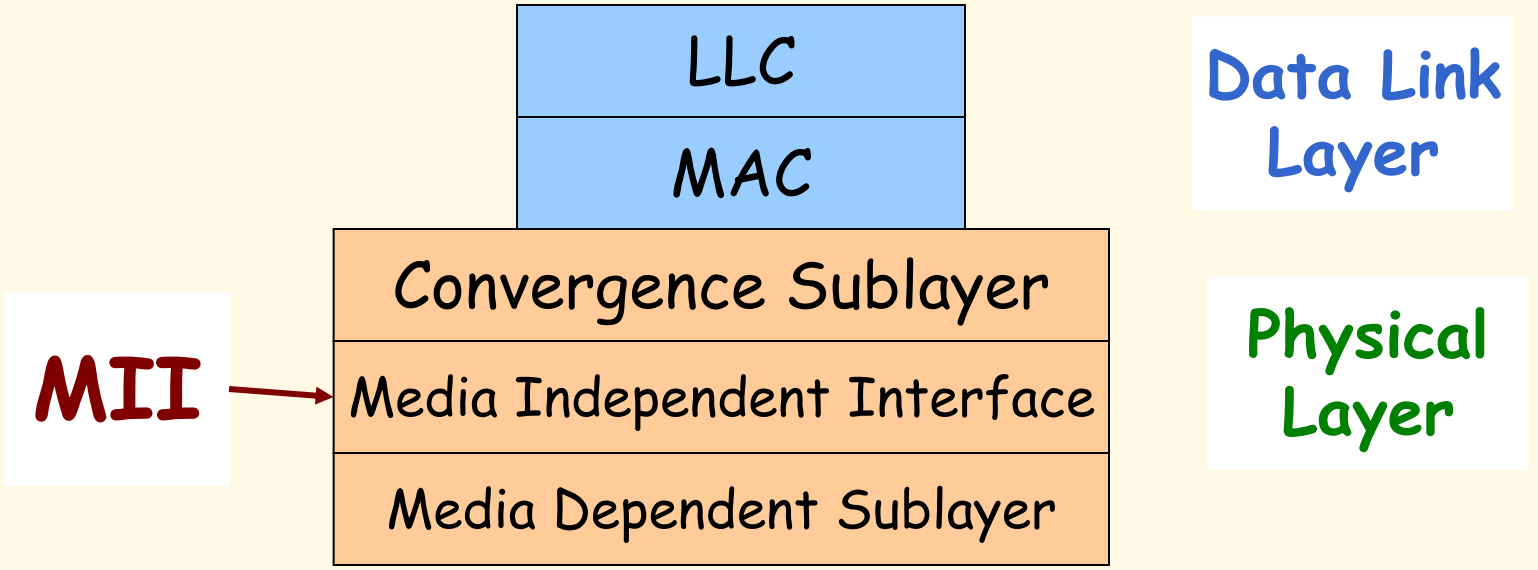
Fast Ethernet (100BASE-T)

How to achieve 100 Mbps capacity?



Media Independent Interface provides three choices.

Fast Ethernet Details

- UTP Cable has a 30 MHz limit.

  ➔Not feasible to use clock encoding (i.e., cannot use Manchester encoding)

- Instead use bit encoding schemes with sufficient transitions for receiver to maintain clock synchronization.

100 BASE T4

- Spec says can use four separate twisted pairs of Cat 3 UTP (now Cat 5e).
- Utilize three pair in both directions (at 33 1/3 Mbps) with other pair for carrier sense/collision detection.
- Three-level ternary code is used 8B/6T::

  Prior to transmission each set of 8 bits is converted into 6 ternary symbols.

8B6T Transmissions

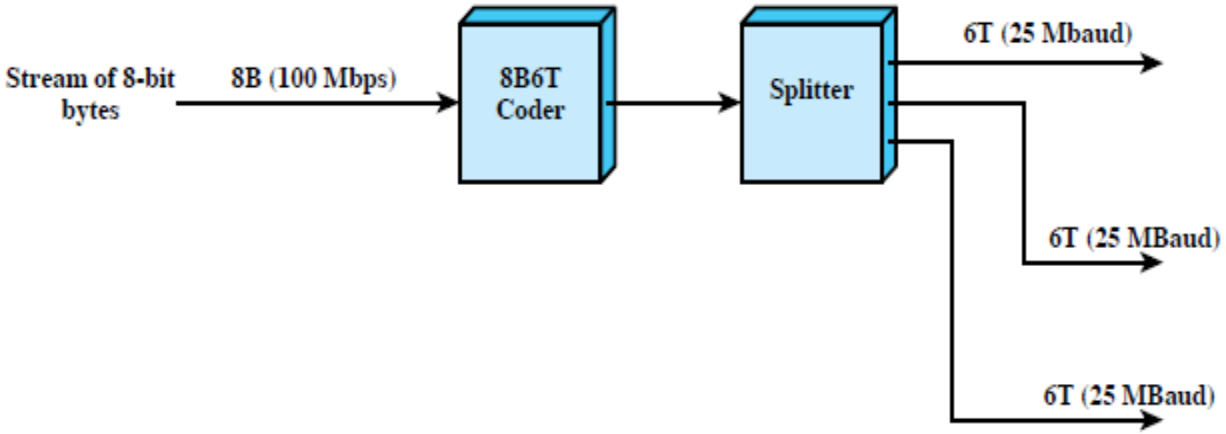


Figure 16.12 8B6T Transmission Scheme

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100 BASE T4

- The signaling rate becomes

$$\frac{100 \times 6/8}{3} = 25 \text{ MHz}$$

- Three signal levels : +V, 0, -V
- Codewords are selected such that line is d.c. balanced.
- All codewords have a combined weight of 0 or 1.

100 BASE T4

- $3^6 = 729$ possible codewords.
- Only 256 codewords are required, hence they are selected:
  - To achieve d.c. balance.
  - To have at least two signal transitions within them (for receiver clock synchronization).
- To solve d.c. 'wander', whenever a string of codewords with +1 are sent, alternate codewords (inverted before transmission) are used.
- To reduce latency, ternary symbols are sent staggered on the three lines.

8B6T Codes

Table 16.6 Portion of 8B6T Code Table

Data Octet	6T Code Group	Data Octet	6T Code Group	Data Octet	6T Code Group	Data Octet	6T Code Group
00	+−00+−	10	+0+−−0	20	00−++−	30	+−00−+
01	0+−+−0	11	++0−0−	21	−−+00+	31	0+−−+0
02	+−0+−0	12	+0+−0−	22	++−0+−	32	+−0−+0
03	−0++−0	13	0++−0−	23	++−0−+	33	−0+−+0
04	−0+0+−	14	0++−−0	24	00+0−+	34	−0+0−+
05	0+−−0+	15	++00−−	25	00+0+−	35	0+−+0−
06	+−0−0+	16	+0+0−−	26	00−00+	36	+−0+0−
07	−0+−0+	17	0++0−−	27	−−+++−	37	−0++0−
08	−+00+−	18	0+−0+−	28	−0−++0	38	−+00−+
09	0−++−0	19	0+−0−+	29	−−0+0+	39	0−+−+0
0A	−+0+−0	1A	0+−++−	2A	−0−+0+	3A	−+0−+0
0B	+0−+−0	1B	0+−00+	2B	0−−+0+	3B	+0−−+0
0C	+0−0+−	1C	0−+00+	2C	0−−++0	3C	+0−0−+
0D	0−+−0+	1D	0−+++−	2D	−−00++	3D	0−++0−
0E	−+0−0+	1E	0−+0−+	2E	−0−0++	3E	−+0+0−
0F	+0−−0+	1F	0−+0+−	2F	0−−0++	3F	+0−+0−

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100 BASE T4

- Ethernet Interframe gap of 9.6 microseconds becomes 960 nanoseconds in Fast Ethernet.
- 100 meters - max distance to hub
- 200 meters max between stations.
- Maximum of two Class II repeaters.

100 BASE TX

- Uses two pair of twisted pair, one pair for transmission and one pair for reception.
- Uses either STP or Cat 5e UTP.
- Starts from 4B/5B NRZI encoding.
- Converts to MLT-3 signaling scheme that involves three voltages.

MLT-3 Encoder

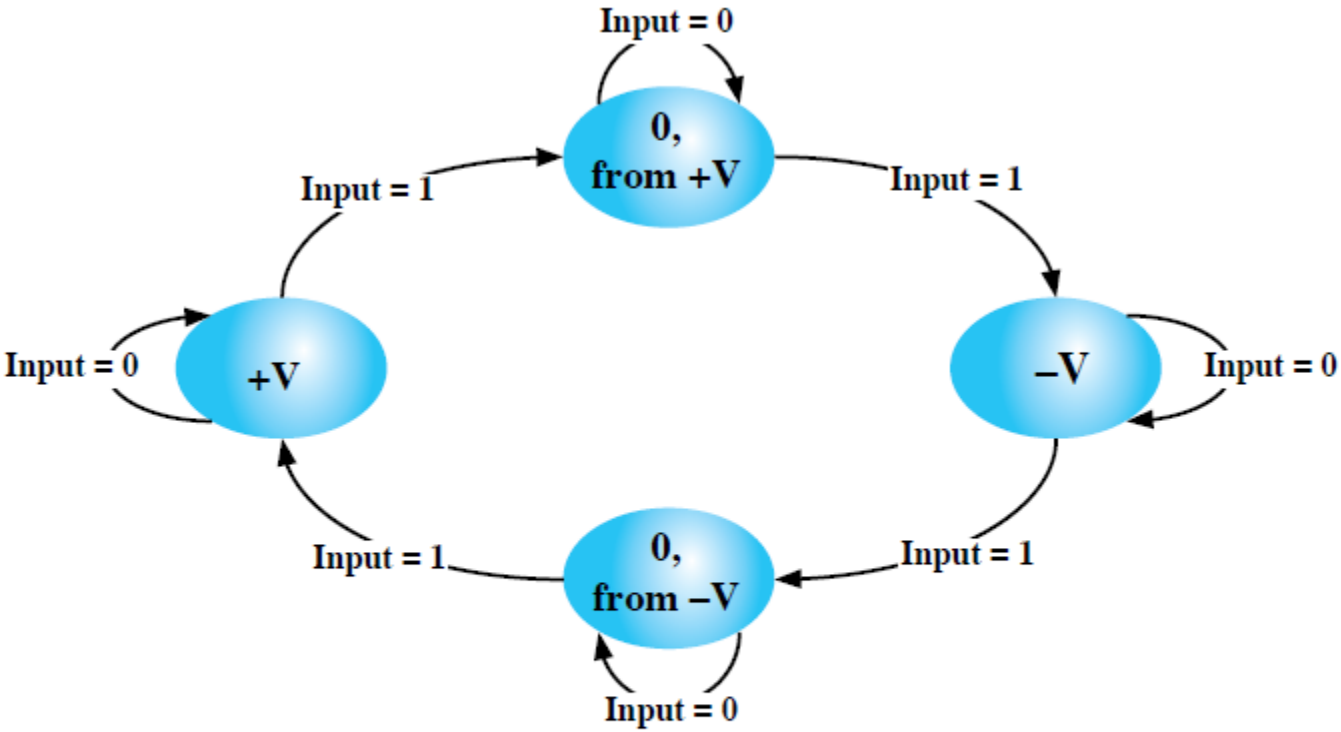

Figure 16.10 MLT-3 Encoder State Diagram

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MLT-3 Encoder

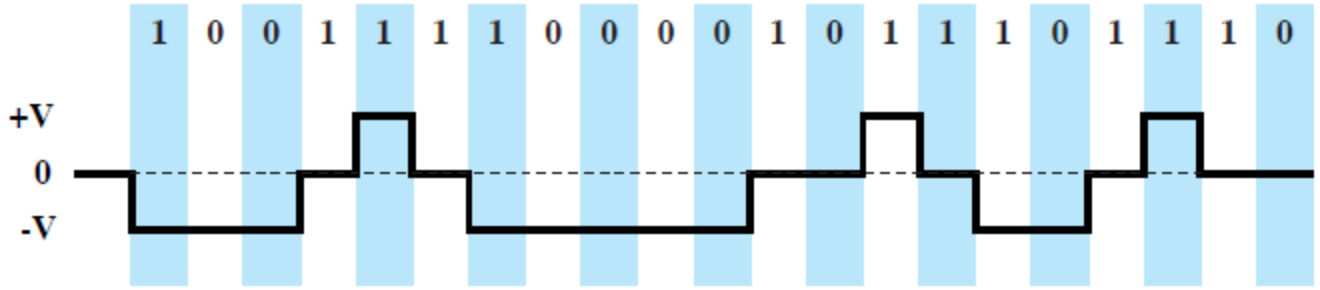

Figure 16.11 Example of MLT-3 Encoding

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100 BASE FX

- Uses two optical fibers, one for transmission and one for reception.
- Uses FDDI technology of converting 4B/5B to NRZI code group streams into optical signals.

Fast Ethernet Repeaters and Switches

- Class I Repeater – supports unlike physical media segments (only one per collision domain).
- Class II Repeater – limited to single physical media type (there may be two repeaters per collision domain).
- Switches – to improve performance can add full-duplex and have auto-negotiation for speed mismatches.

Collision Domains

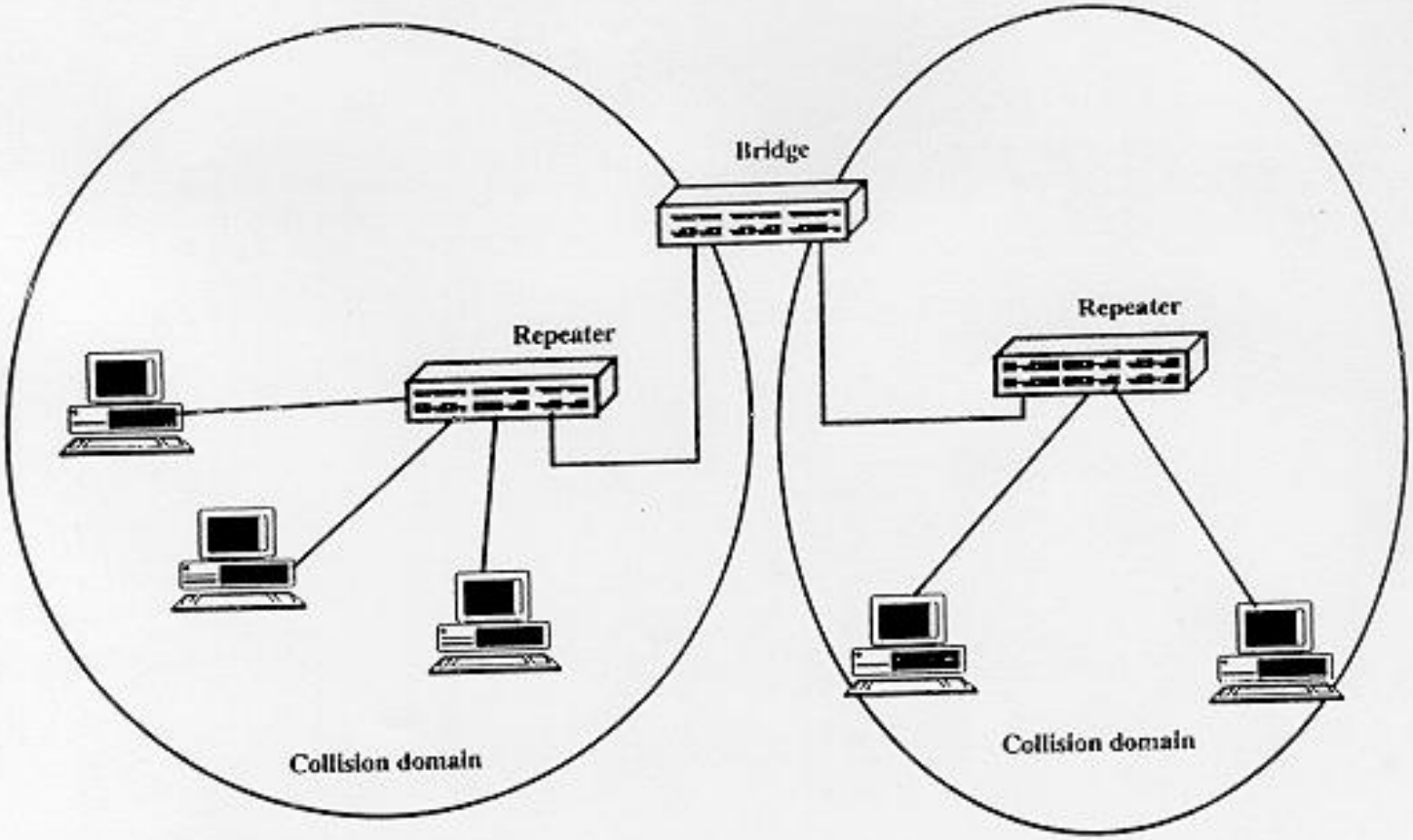

Figure 7.9 Collision Domains

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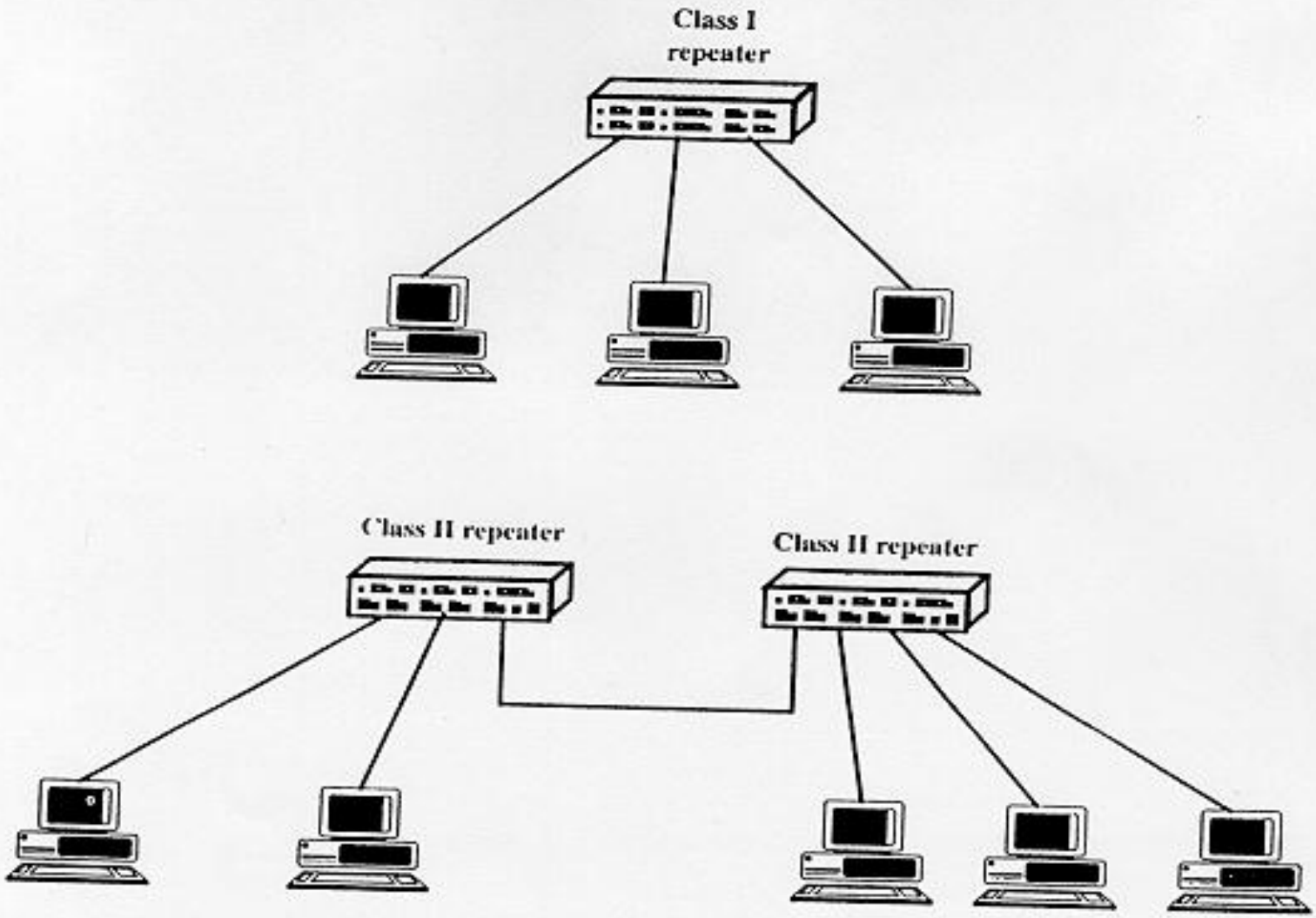

Figure 7.10 100BASE-T Repeater Types

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Full Duplex Operation

- Traditional Ethernet is half duplex.
- Using full-duplex, a station can transmit and receive simultaneously.
- 100 Mbps Ethernet (in full-duplex mode) gives a theoretical transfer rate of 200 Mbps.
- Stations must have full-duplex adapter cards.
- Stations must use switching hub.

Gigabit Ethernet History

- In February 1997 the Gigabit Ethernet Alliance announced that IEEE802.3z Task Force met to review the first draft of the Gigabit Ethernet Standard.
- According to IDC by the end of 1997 85% of all network connections used Ethernet.
- → Higher capacity Ethernet was appealing because network managers can leverage their investment in staff skills and training.
- 1000 BASE X (IEEE802.3z) was ratified in June 1998.

Gigabit Ethernet (1000 BASE X)

- Provides speeds of 1000 Mbps (i.e., one billion bits per second capacity) for half-duplex and full-duplex operation.
- Uses Ethernet frame format and MAC technology
  - CSMA/CD access method with support for one repeater per collision domain.
  - Backward compatible with 10BASE-T and 100BASE-T.
- Uses 802.3 full-duplex Ethernet technology.
- Uses 802.3x flow control.
- All Gigabit Ethernet configurations are point-to-point!

Gigabit Ethernet

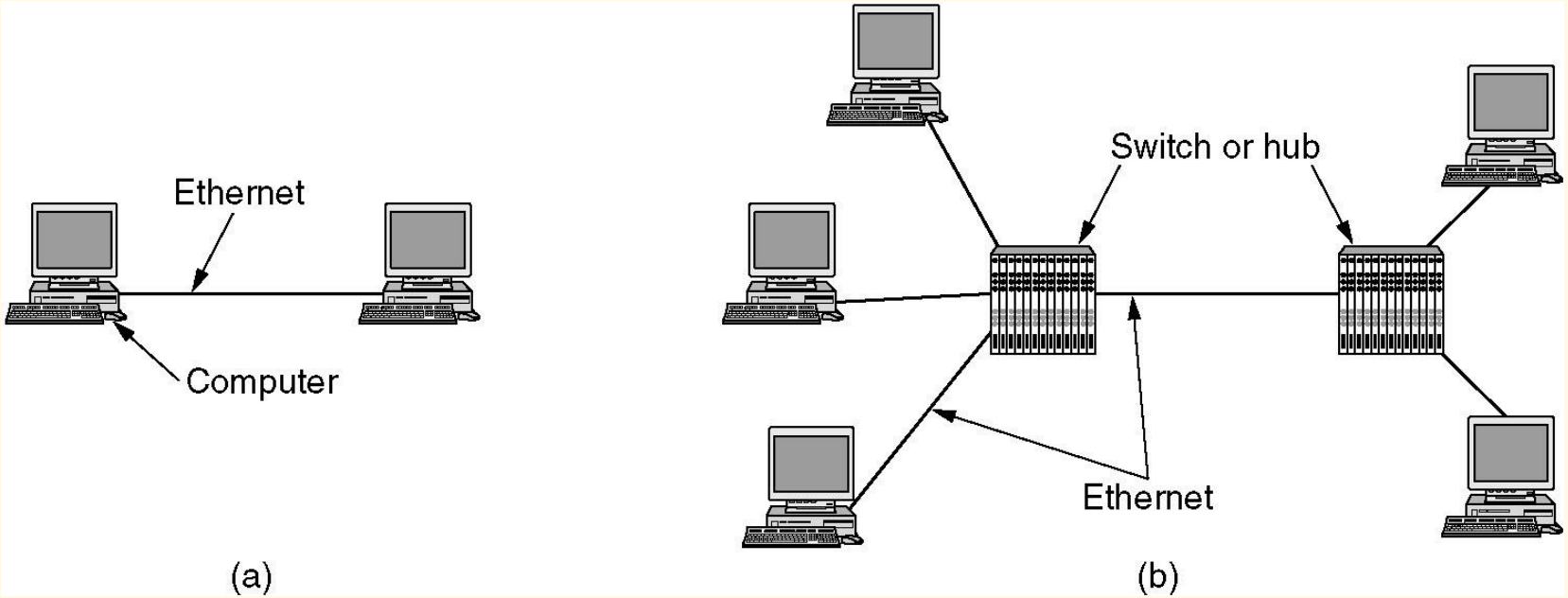

Figure 4-22. (a) A two-station Ethernet. (b) A multistation Ethernet.

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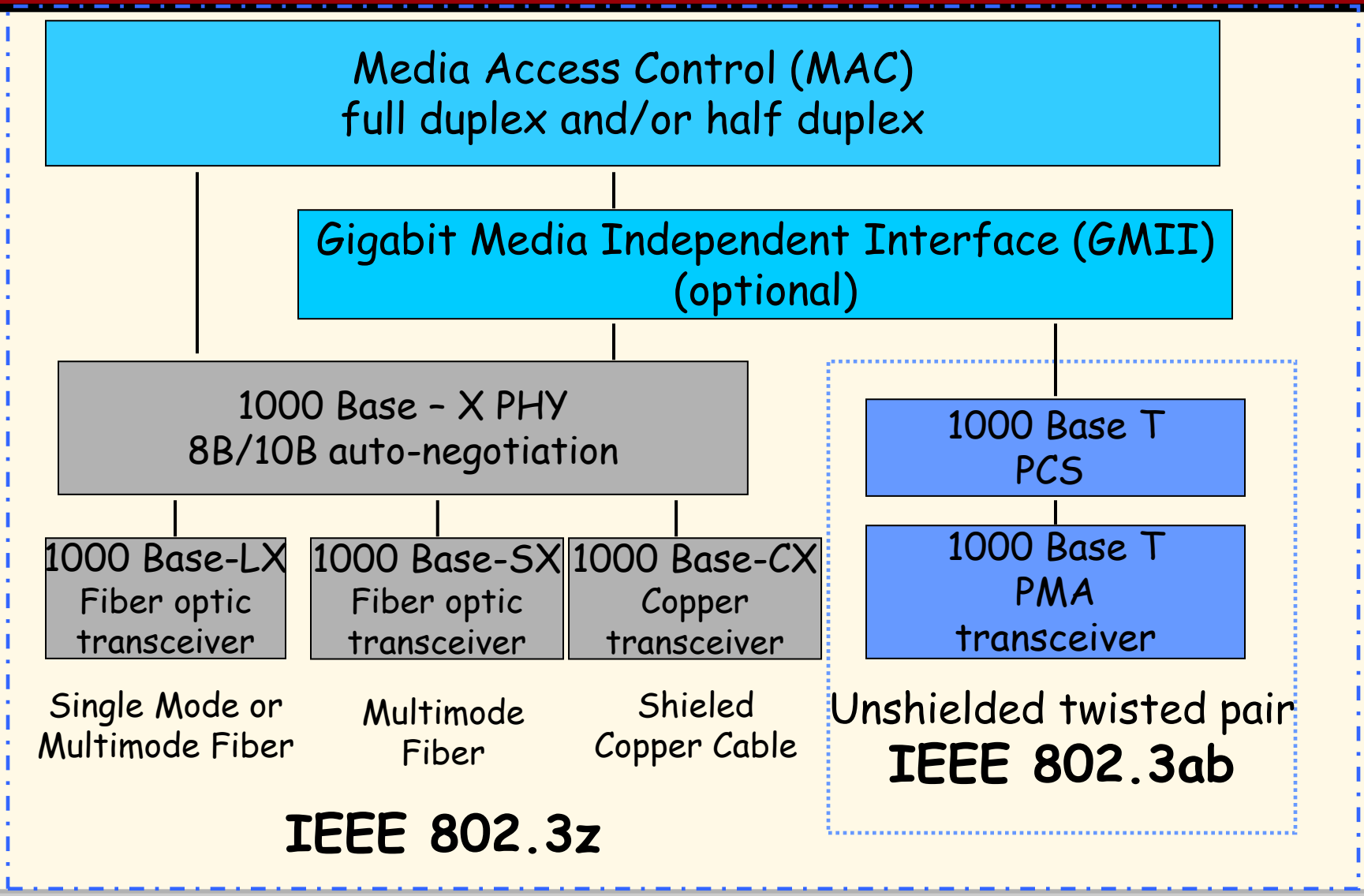
Gigabit Ethernet Architecture Standard

Source - IEEE



Gigabit Ethernet Technology

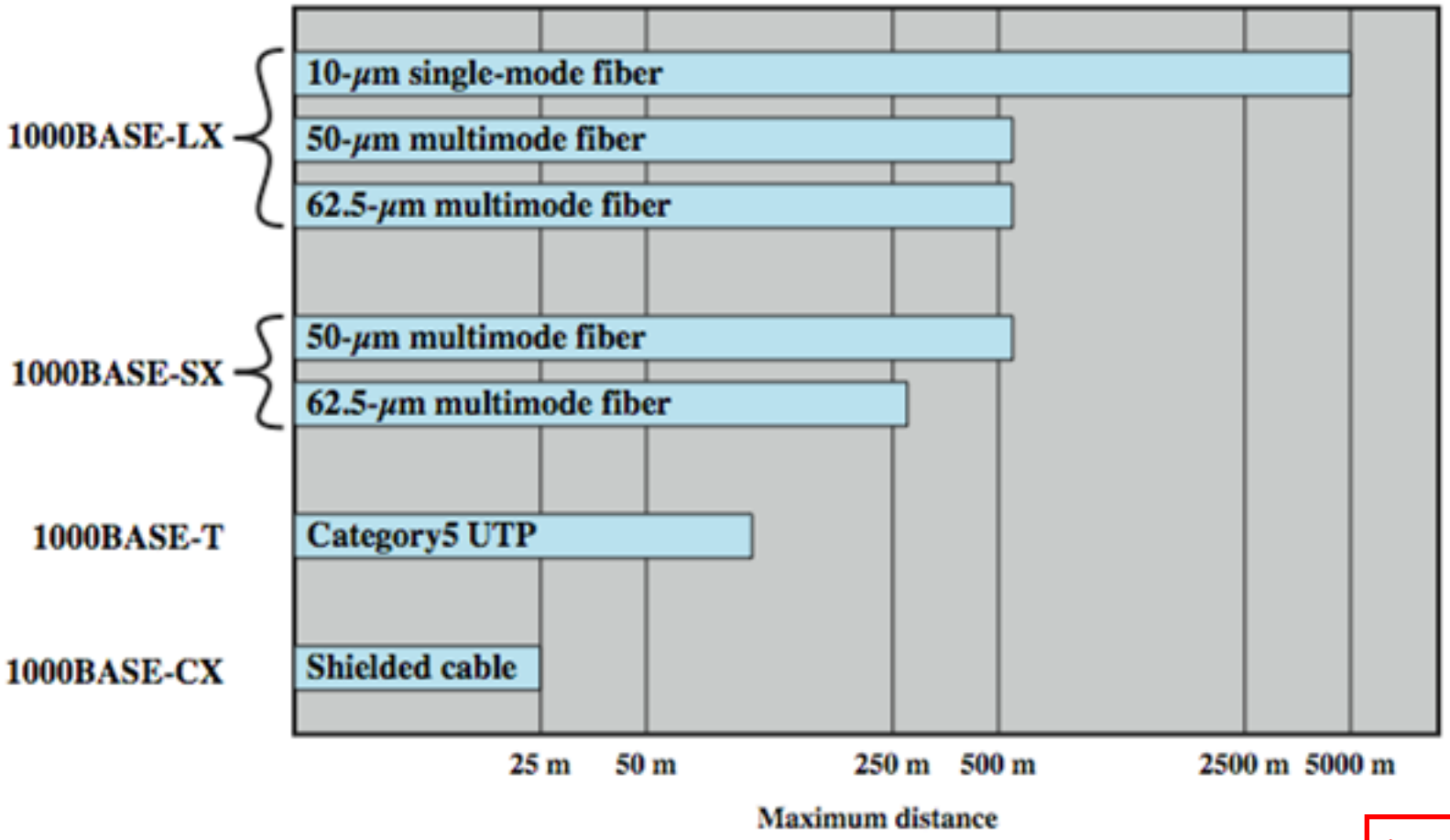
Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 μ) or multimode (50, 62.5 μ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

Figure 4-23.Gigabit Ethernet cabling.

1000 BASE LX fiber - long wavelength
1000 BASE SX fiber - short wavelength
1000 BASE T copper - unshielded twisted pair
1000 BASE CX copper - shielded twisted pair

* Based on Fiber Channel physical signaling technology.

Gigabit Ethernet – Physical



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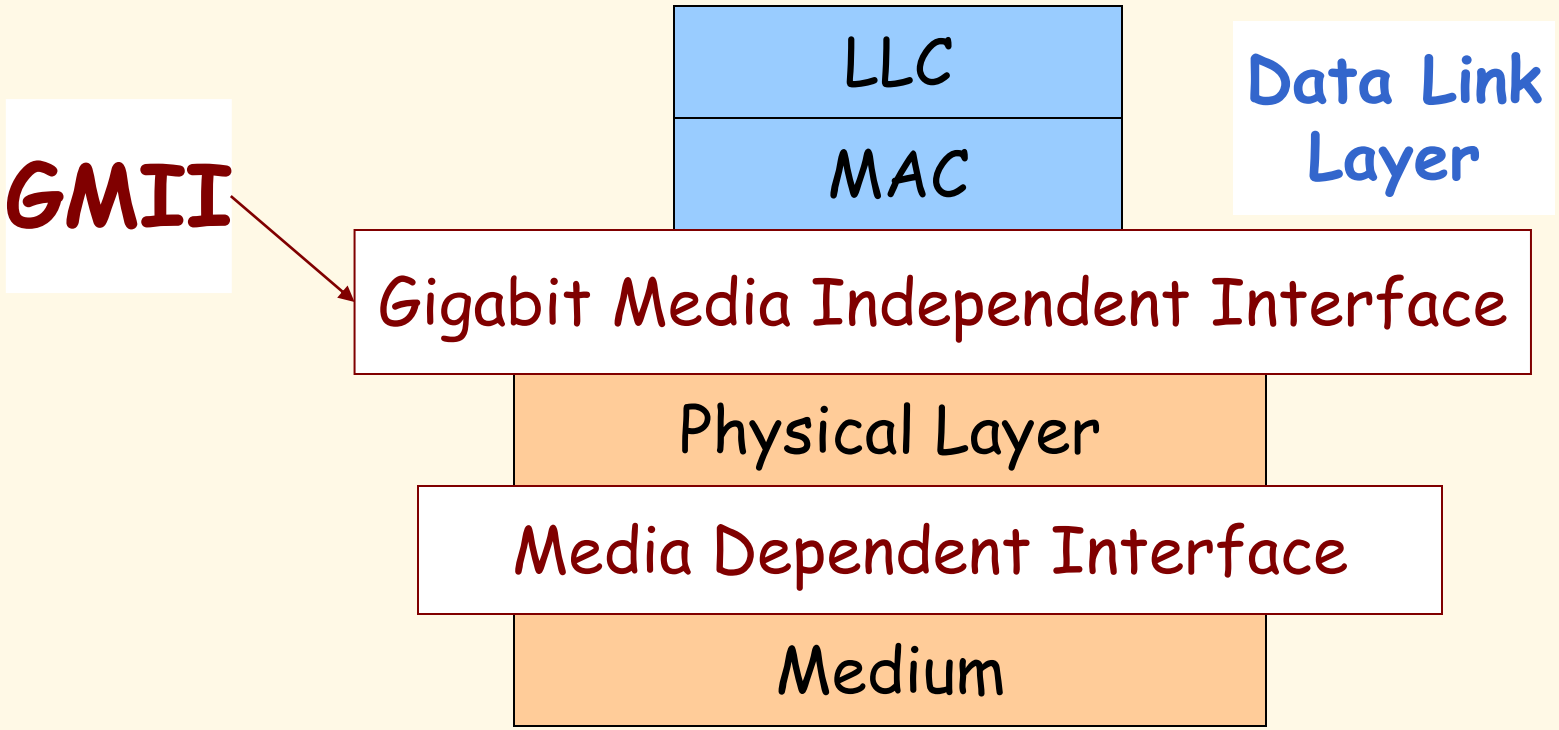
Gigabit Ethernet (1000 BASE-T)



Gigabit Media Independent Interface (GMII)

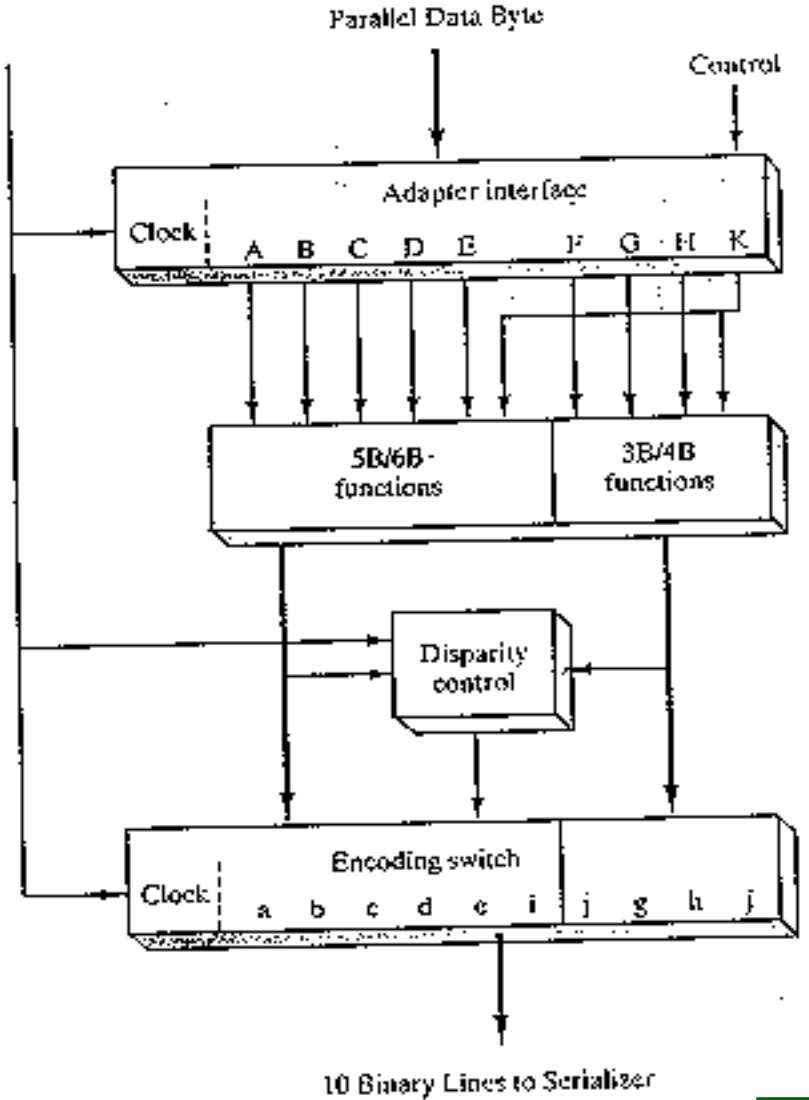
- Allows any physical layer to be used with a given MAC.
- Namely, Fiber Channel physical layer can be used with CSMA/CD.
- Permits both full-duplex and half-duplex.

1000 BASE LX

Long wavelength

- Supports duplex links up to 5000 meters.
- 1270-1355 nm range; 1300 nm wavelength using lasers.
- Fiber Channel technology
- PCS (Physical Code Sublayer) includes 8B/10B encoding with 1.25 Gbps line.
- Either single mode or multimode fiber.

8B/10B Encoder



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8B/10B Encoding Issues

EXAMPLES OF EIGHT-BIT CODE GROUPS

Code Group Name	Actual Byte Being Encoded	RD- Encoding Value	RD+ Encoding Value	Effect on RD after Sending
D1.0	000 00001	011101 0100	100010 1011	same
D4.1	001 00100	110101 1001	001010 1001	flip
D28.5	101 11100	001110 1010	001110 1010	same
D28.5	101 11100	001111 1010	110000 0101	flip

- When the encoder has a choice for codewords, it always chooses the codeword that moves in the direction of balancing the number of 0s and 1s. This keeps the DC component of the signal as low as possible.

1000 BASE SX

Short wavelength

- Supports duplex links up to 275 meters.
- 770-860 nm range; 850 nm laser wavelength
- (FC) *Fiber Channel technology*
- PCS (Physical Code Sublayer) includes 8B/10B encoding with 1.25 Gbps line.
- Only multimode fiber
- Cheaper than LX.

1000 BASE CX

'Short haul' copper jumpers

- Shielded twisted pair.
- 25 meters or less *typically within wiring closet.*
- PCS (Physical Code Sublayer) includes 8B/10B encoding with 1.25 Gbps line.
- Each link is composed of a separate shielded twisted pair running in each direction.

1000 BASE T

Twisted Pair

- Four pairs of Category 5 UTP.
- IEEE 802.3ab ratified in June 1999.
- Category 5, 6 and 7 copper up to 100 meters.
- This requires extensive signal processing.

Gigabit Ethernet compared to Fiber Channel

- Since Fiber Channel (FC) already existed, the idea was to *immediately* leverage physical layer of FC into Gigabit Ethernet.
- The difference is that fiber channel was viewed as *specialized* for high-speed I/O lines. Gigabit Ethernet is general purpose and can be used as a high-capacity switch.

Gigabit Ethernet

- Initially viewed as LAN solution while ATM is now a WAN solution.
- Gigabit Ethernet can be shared (hub) or switched.
- Shared Hub
  - Half duplex: CSMA/CD with MAC changes:
  - Carrier Extension
  - Frame Bursting
- Switch
  - Full duplex: Buffered repeater *called* {Buffered Distributor}

Gigabit Ethernet

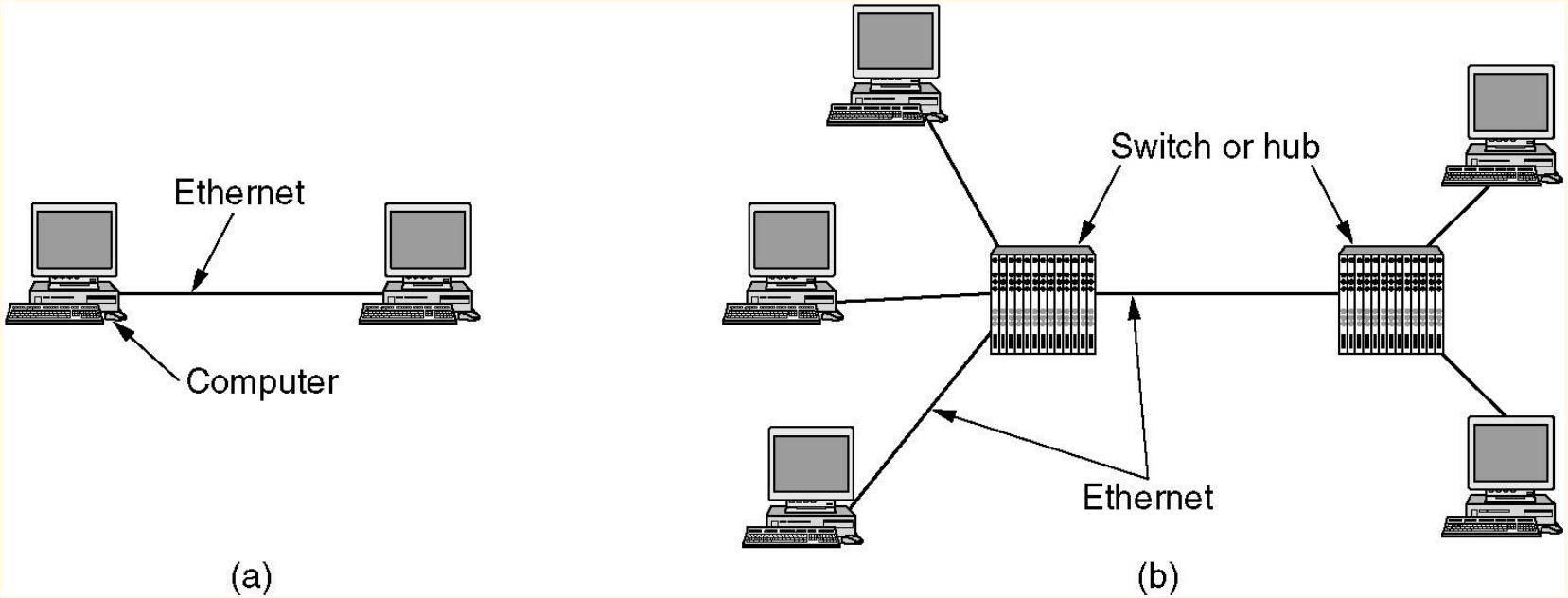

Figure 4-22. (a) A two-station Ethernet. (b) A multistation Ethernet.

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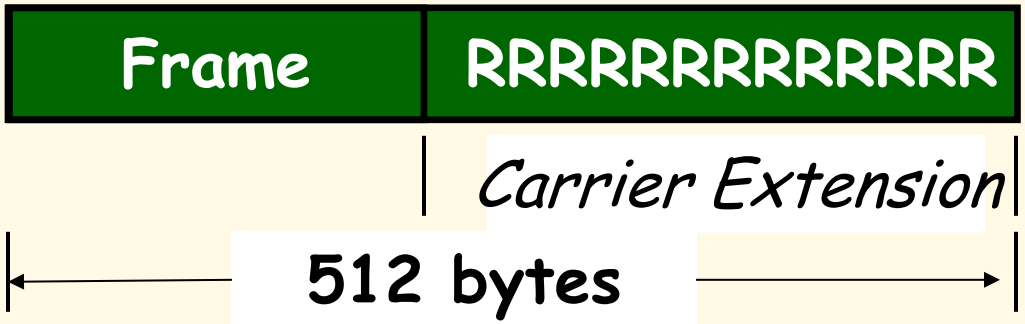
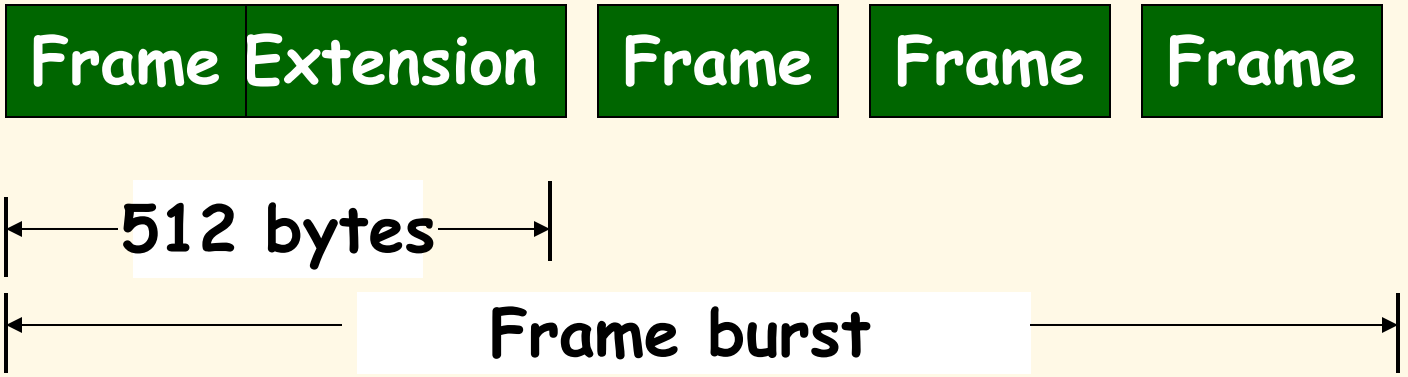
Carrier Extension



- For 10BaseT : 2.5 km max; slot time = 64 bytes
- For 1000BaseT: 200 m max; slot time = 512 bytes
- **Carrier Extension** :: continue transmitting control.
- This permits minimum 64-byte frame to be handled.
- Control characters discarded at destination.
- For small frames, LAN throughput is only slightly better than Fast Ethernet.

Based on Raj Jain's slide

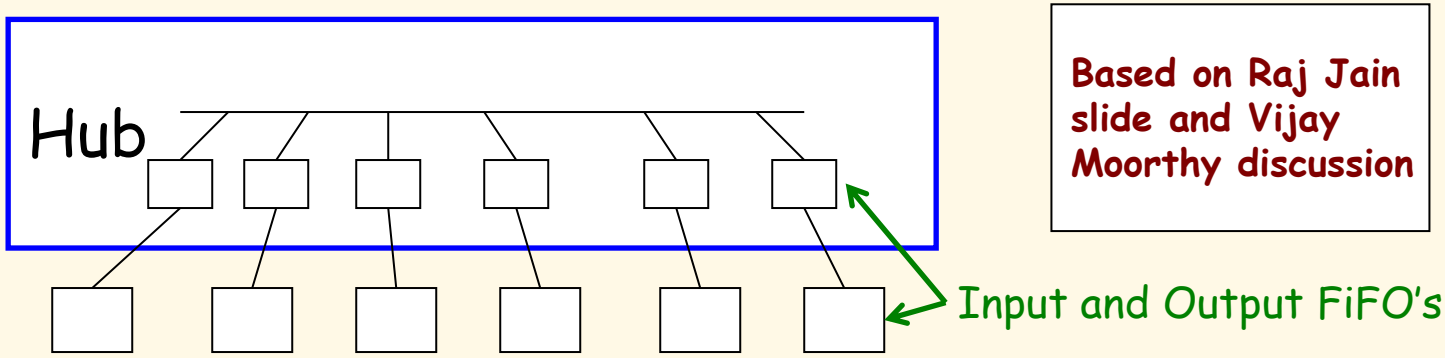
Frame Bursting



- Source sends out burst of frames without relinquishing control of the network.
- Uses Ethernet Interframe gap filled with extension bits (96 bits).
- Maximum frame burst is 8192 bytes.
- Three times more throughput for small frames.

Based on Raj Jain's slide

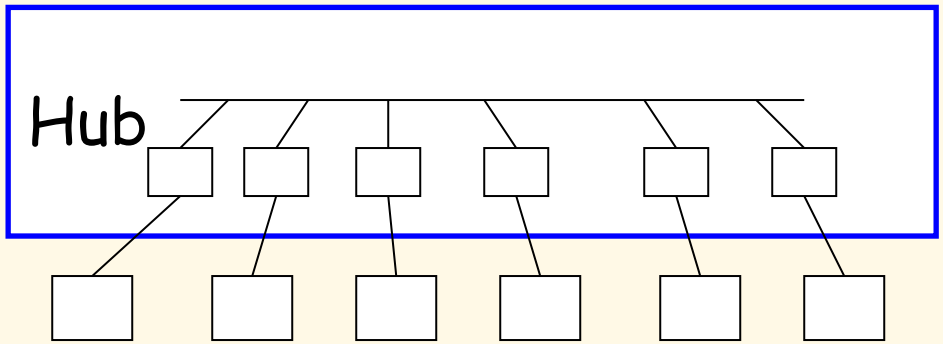
Buffered Distributor



Based on Raj Jain slide and Vijay Moorthy discussion

- A buffered distributor is a new type of 802.3 hub where incoming frames are buffered in FIFO queues.
  - Each port has an input FIFO queue and an output FIFO queue.
  - A frame arriving at an input queue is forwarded to all output queues, except the one on the incoming port.
- CSMA/CD arbitration is done inside the distributor to forward the frames to the output FIFOs.

Buffered Distributor



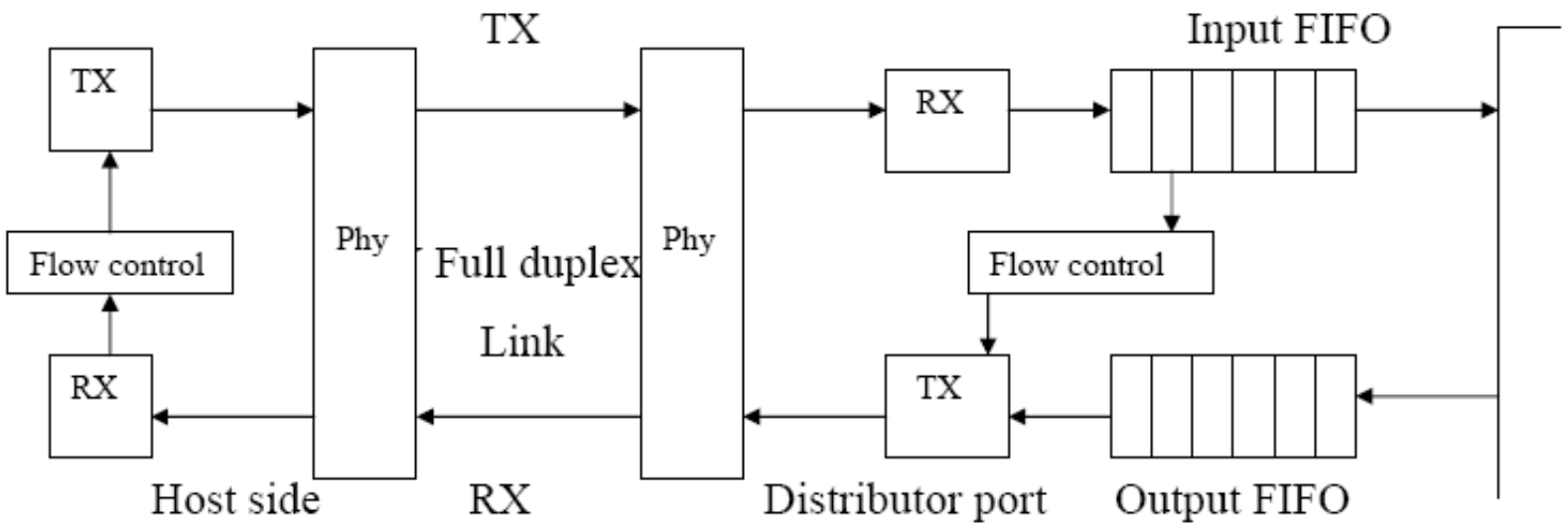
Based on Raj Jain slide and Vijay Moorthy discussion

- Since collisions can no longer occur external to the distributor on the links, the distance restrictions no longer apply.
- Since the sender can flood an input FIFO, 802.3x frame-based flow control is used to handle congestion between the sending station and the input port.
- All links are full-duplex.

Buffered Distributor

Buffered/Full duplex Distributor:

This is a multi-port repeater with full-duplex links.



White Paper
By
McIntyre and Arora

Gigabit Ethernet Example

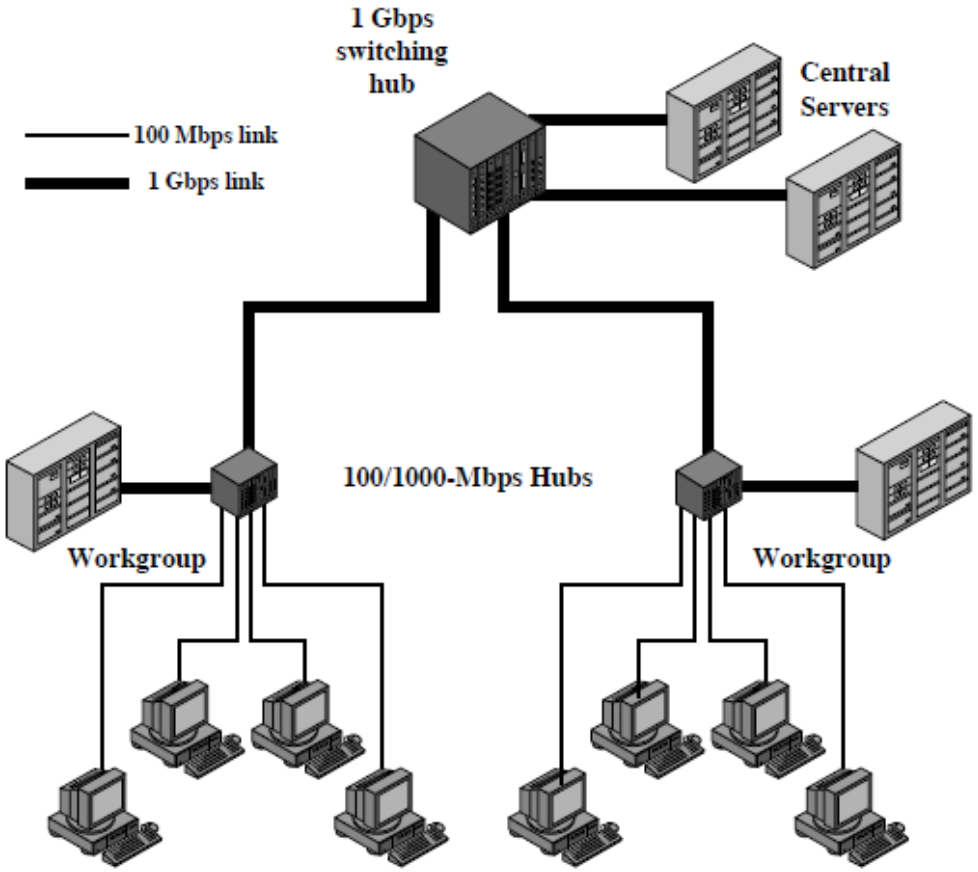


Figure 16.4 Example Gigabit Ethernet Configuration

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10 Gbps Ethernet

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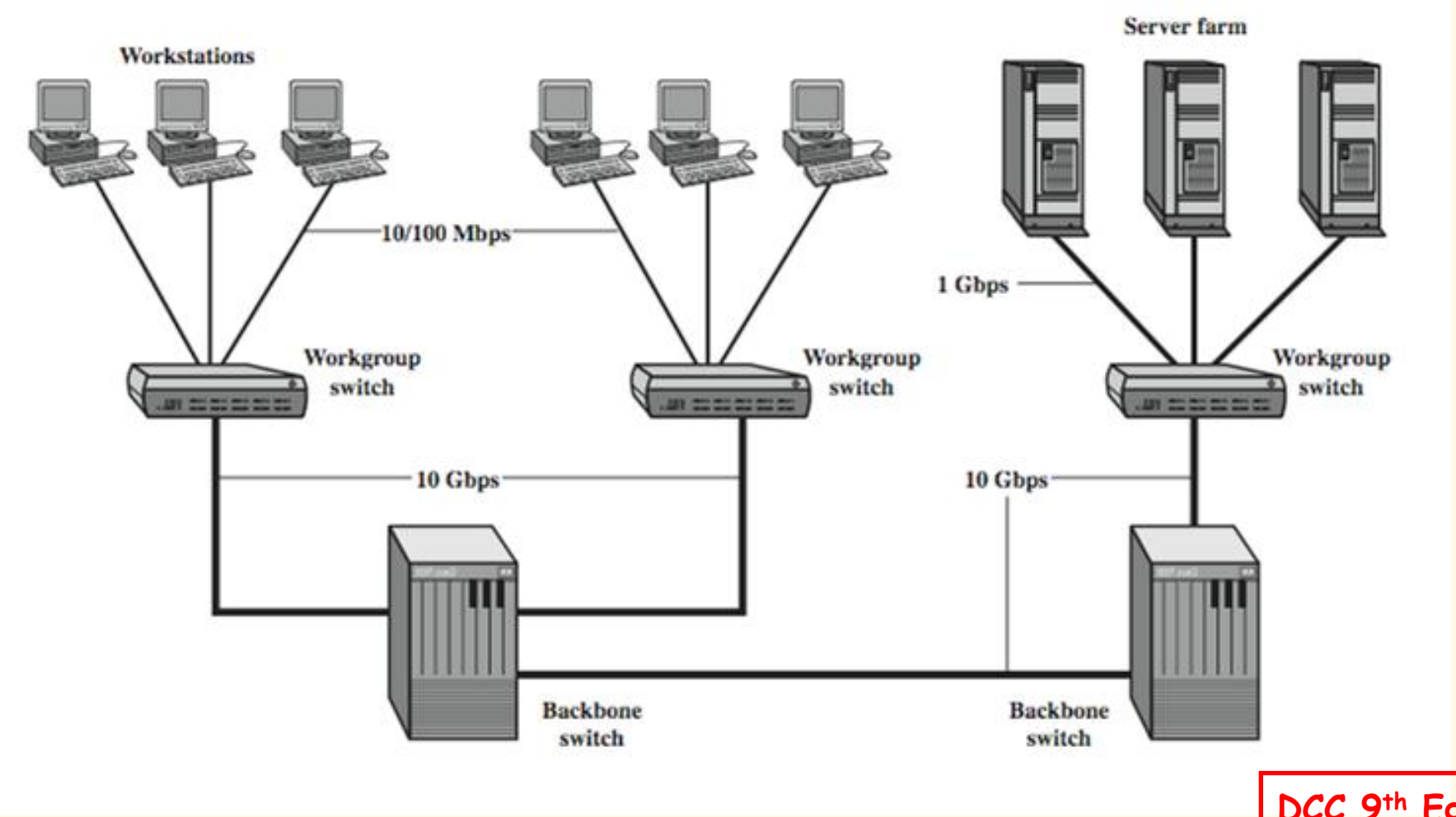
- Growing interest in 10 Gbps Ethernet.
  - high-speed backbone use
  - future wider deployment
- Provides an alternative to ATM and other WAN technologies.
- Viewed as a uniform technology for LAN, MAN, or WAN.
- advantages of 10 Gbps Ethernet
  - no expensive, bandwidth-consuming conversion between Ethernet packets and ATM cells.
  - IP and Ethernet together offers QoS and traffic policing that approach ATM.
  - have a variety of standard optical interfaces.

10Gbps Ethernet Configurations



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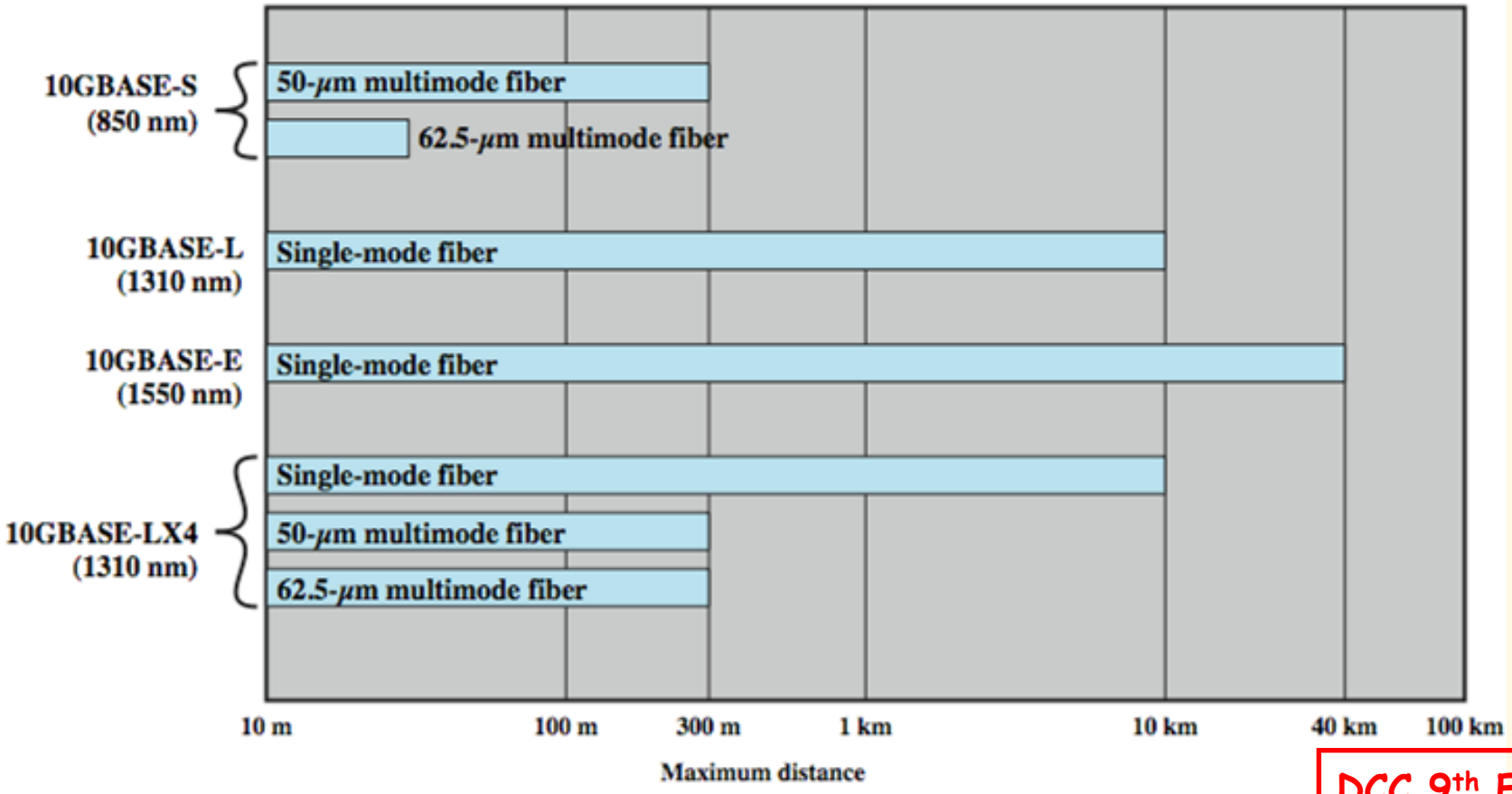
10Gbps Ethernet Options



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100 Gbps Ethernet

- preferred technology for wired LAN.
- preferred carrier for bridging wireless technologies into local Ethernet networks.
- cost-effective, reliable and interoperable.
- popularity of Ethernet technology:
  - availability of cost-effective products
  - reliable and interoperable network products
  - variety of vendors

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100 Gbps Ethernet

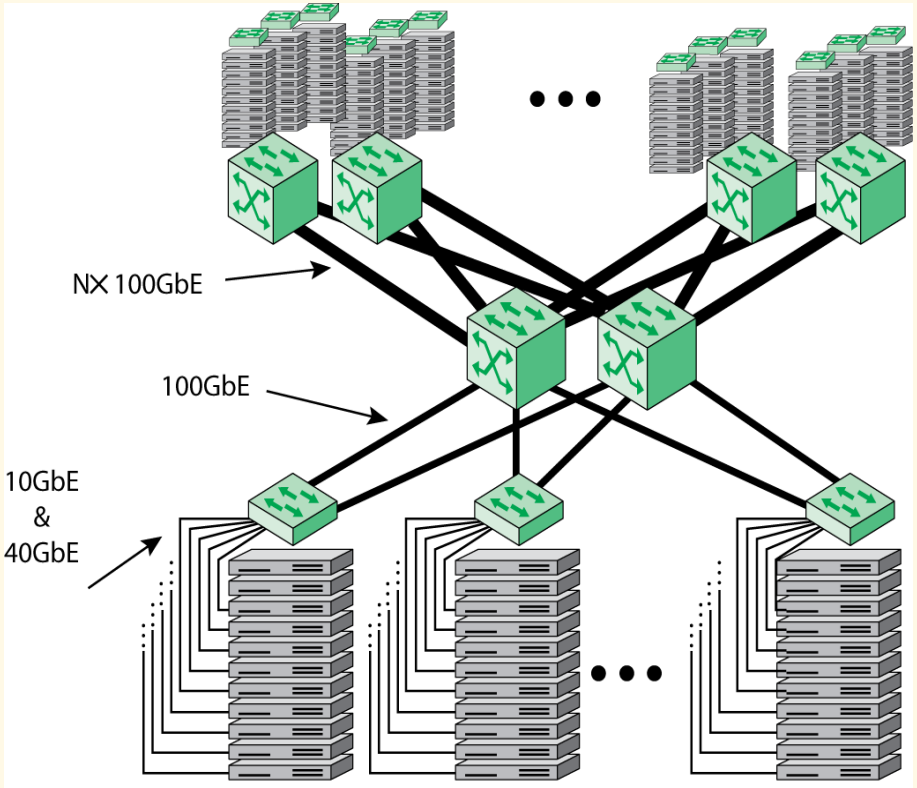

Figure 16.8 Example 100-Gbps Ethernet Configuration for Massive Blade Server Site

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Fast/Gigabit Ethernet Summary

- Fast Ethernet
  - 100 BASE T4
    - 8B/6T encoding
  - 100 BASE TX
  - 100 BASE FX
  - Collision domains
- Gigabit Ethernet
  - 1000 BASE SX
    - 8B/10B encoding
    - Fiber Channel

Fast/Gigabit Ethernet Summary

- Gigabit Ethernet (continued)
  - 1000 BASE LX
  - 1000 BASE T
  - 1000 BASE CX
  - Carrier Extension
  - Frame Bursting
  - Buffered Distributor
- 10 Gbps Ethernet
- 100 Gbps Ethernet