Data and Computer Communications

Tenth Edition

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CHAPTER 12

Ethernet

"Congratulations. I knew the record would stand until it was broken."

- Yogi Berra

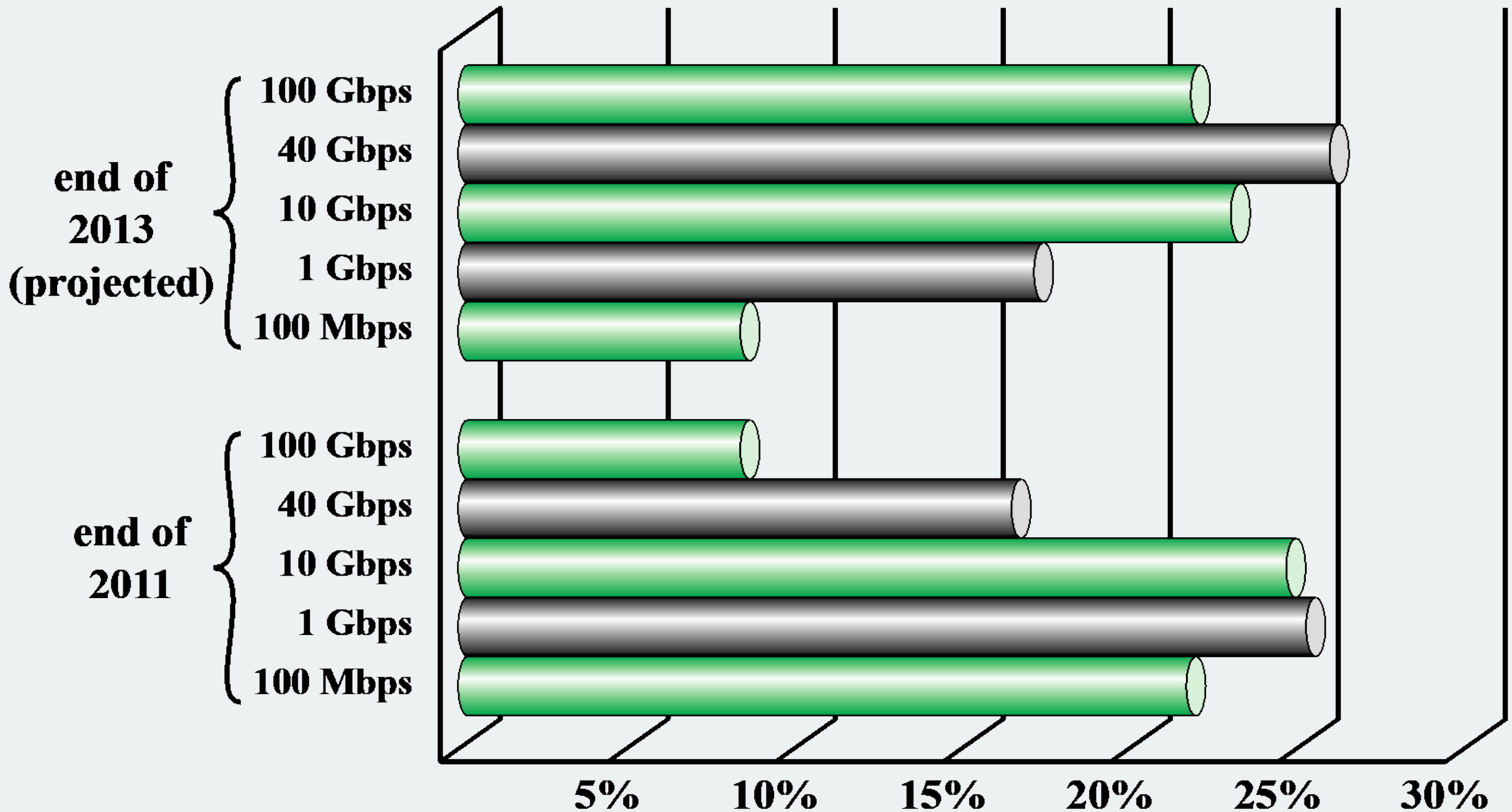


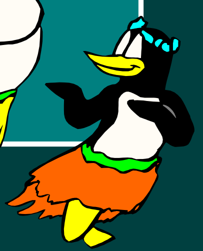
Figure 12.1 Data Center Study—Percentage of Ethernet Links by Speed

Traditional Ethernet

Earliest was ALOHA

- Developed for packet radio networks
- Station may transmit a frame at any time
- If frame is determined invalid, it is ignored
- Maximum utilization of channel about 18%

Next came slotted ALOHA



- Organized slots equal to transmission time
- Increased utilization to about 37%

CSMA/CD Precursors

- Carrier Sense Multiple Access (CSMA)
  - Station listens to determine if there is another transmission in progress
  - If idle, station transmits
  - Waits for acknowledgment
  - If no acknowledgment, collision is assumed and station retransmits
  - Utilization far exceeds ALOHA

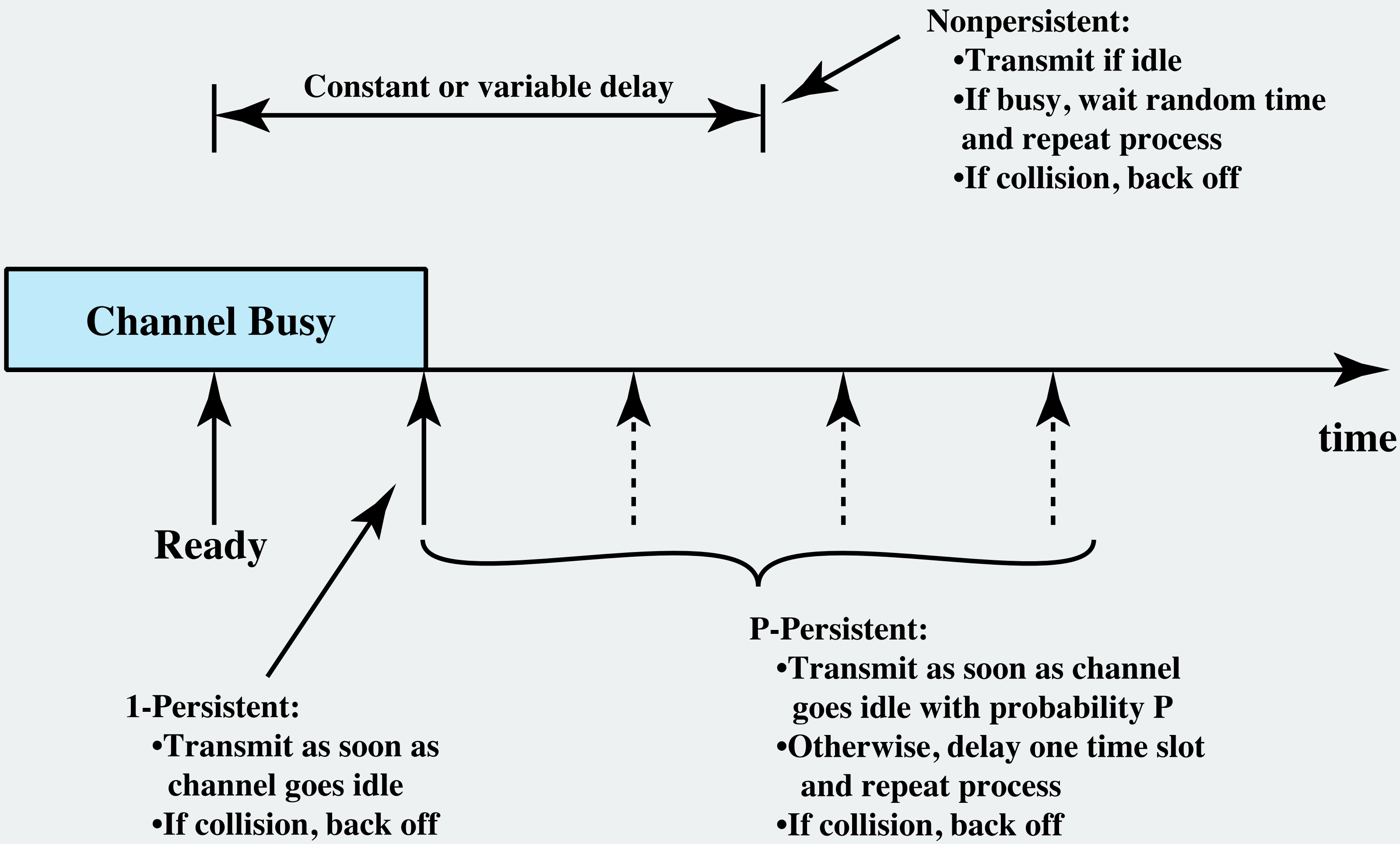


Figure 12.2 CSMA Persistence and Backoff

Nonpersistent CSMA

If the medium is idle, transmit; otherwise, go to step 2

If the medium is busy, wait an amount of time drawn from a probability distribution and repeat step 1

Disadvantage:

Capacity is wasted because the medium will generally remain idle following the end of a transmission even if there are one or more stations waiting to transmit

1-Persistent CSMA

- Avoids idle channel time
- Rules:
  1. If medium is idle, transmit
  2. If medium is busy, listen until idle; then transmit immediately
- Stations are selfish
- If two or more stations are waiting, a collision is guaranteed

P-Persistent CSMA

- A compromise to try and reduce collisions and idle time
- P-persistent CSMA rules:
  1. If medium is idle, transmit with probability *p*, and delay one time unit with probability (1–*p*)
  2. If medium is busy, listen until idle and repeat step 1
  3. If transmission is delayed one time unit, repeat step 1
- Issue of choosing effective value of *p* to avoid instability under heavy load

Value of *p*?

- Have *n* stations waiting to send
- At end of transmission, expected number of stations is *np*
  - If $np>1$ on average there will be a collision
- Repeated transmission attempts mean collisions are likely
- Eventually all stations will be trying to send, causing continuous collisions, with throughput dropping to zero
- To avoid catastrophe $np<1$ for expected peaks of *n*
  - If heavy load expected, *p* must be small
  - Smaller *p* means stations wait longer

Description of CSMA/CD

1. If the medium is idle, transmit; otherwise, go to step 2

2. If the medium is busy, continue to listen until the channel is idle, then transmit immediately

3. If a collision is detected, transmit a brief jamming signal to assure that all stations know that there has been a collision and cease transmission

4. After transmitting the jamming signal, wait a random amount of time, referred to as the ***backoff***, then attempt to transmit again

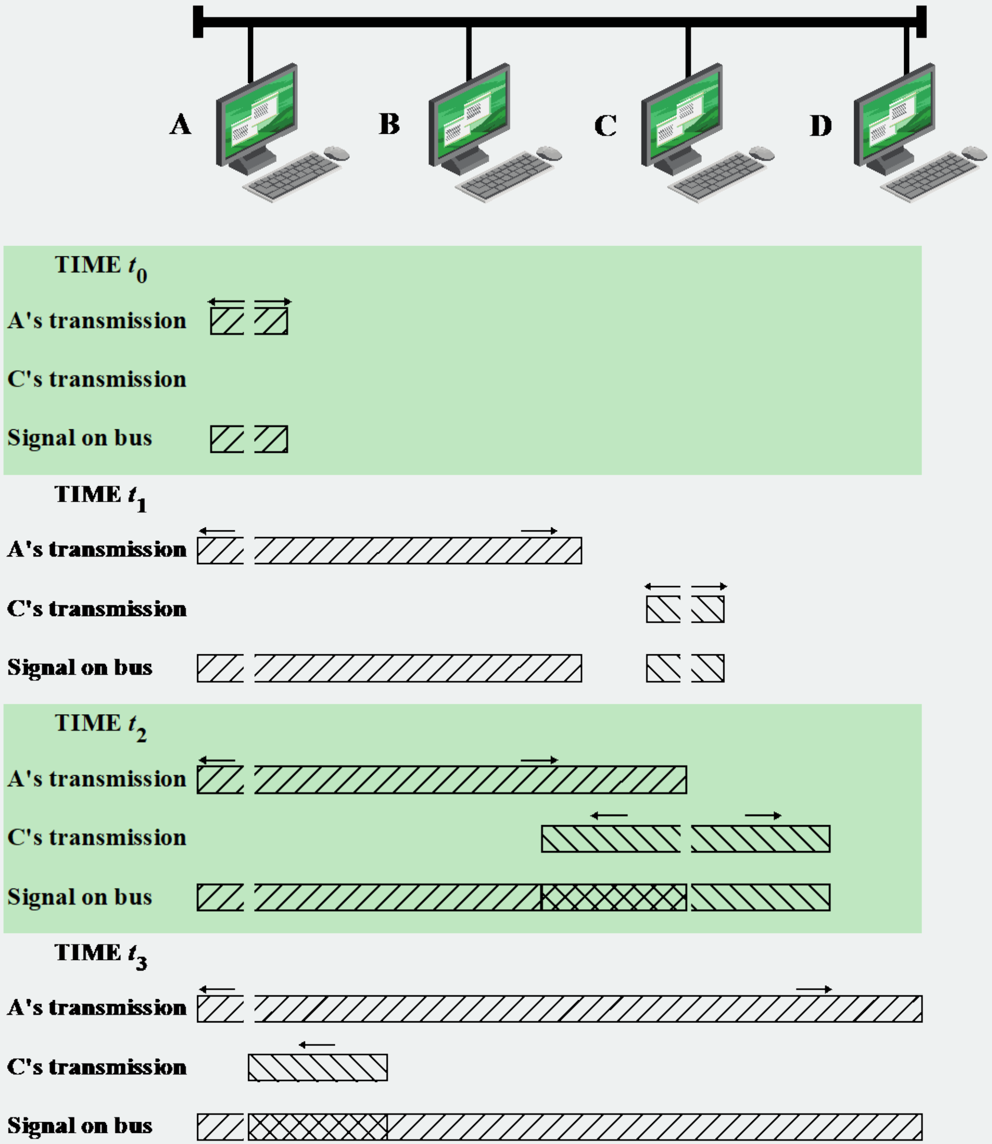


Figure 12.3 CSMA/CD Operation

Which Persistence Algorithm?

- IEEE 802.3 uses 1-persistent
- Both nonpersistent and p-persistent have performance problems

1-persistent seems more unstable than p-persistent

- **Because of greed of the stations**
- **Wasted time due to collisions is short**
- **With random backoff unlikely to collide on next attempt to send**

Binary Exponential Backoff

- IEEE 802.3 and Ethernet both use binary exponential backoff
- A station will attempt to transmit repeatedly in the face of repeated collisions
  - On first 10 attempts, mean random delay doubled
  - Value then remains the same for 6 further attempts
  - After 16 unsuccessful attempts, station gives up and reports error
- 1-persistent algorithm with binary exponential backoff is efficient over wide range of loads
- Backoff algorithm has last-in, first-out effect

Collision Detection

On baseband bus

- Collision produces higher signal voltage
- Collision detected if cable signal is greater than single station signal
- Signal is attenuated over distance
- Limit to 500m (10Base5) or 200m (10Base2)

On twisted pair (star-topology)

- Activity on more than one port is collision
- Use special collision presence signal

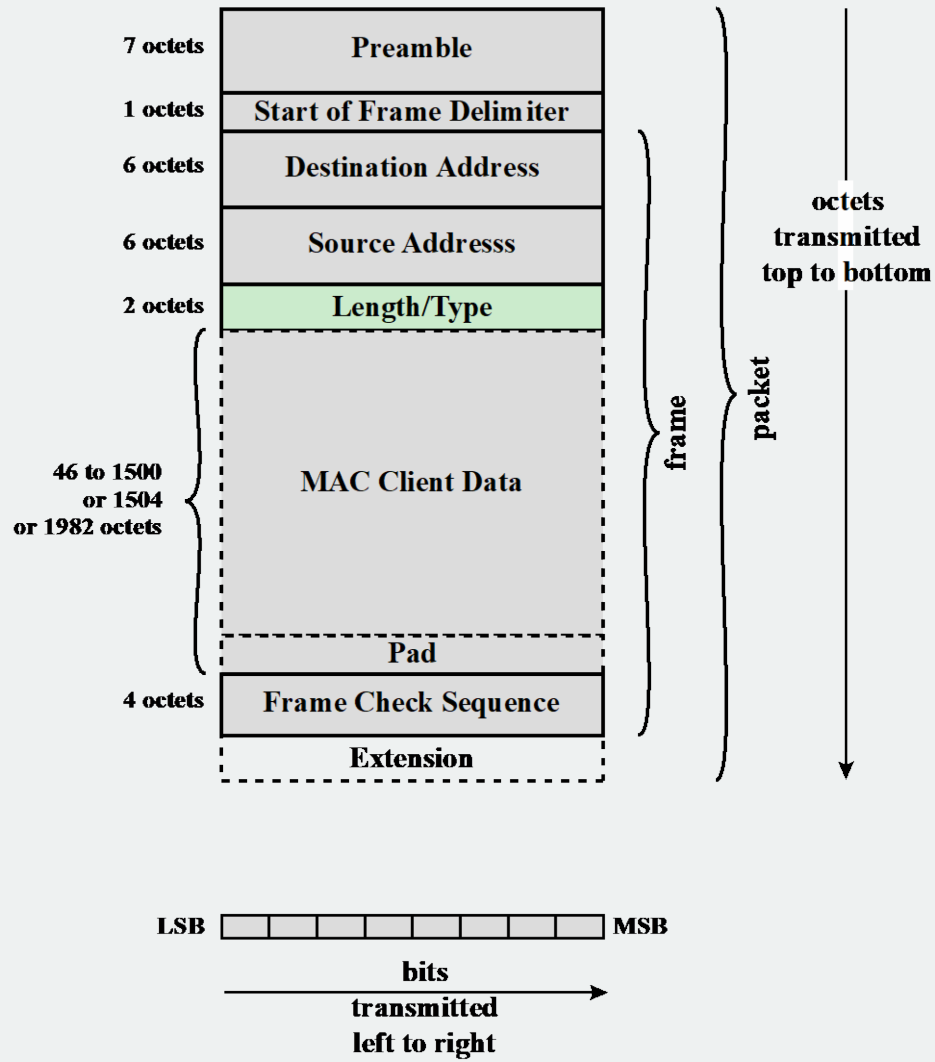


Figure 12.4 IEEE 802.3 MAC Frame Format

Table 12.1
IEEE 802.3 10-Mbps Physical Layer Medium Alternatives

	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

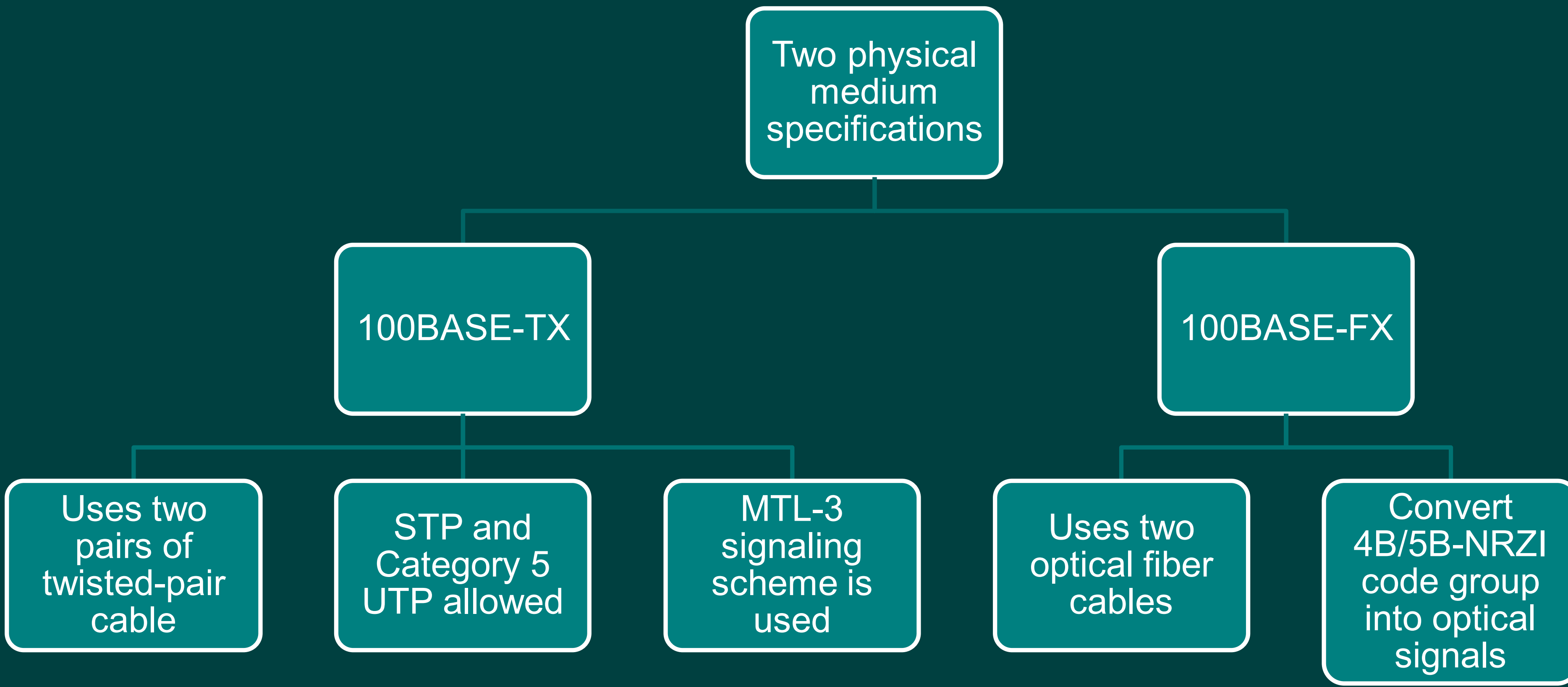
Table 12.2

IEEE 802.3 100BASE-T Physical Layer Medium Alternatives

	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

100BASE-X

- Uses a unidirectional data rate 100 Mbps over single twisted pair or optical fiber link
- Encoding scheme same as FDDI
  - 4B/5B-NRZI



100BASE-T4

- 100-Mbps over lower-quality Cat 3 UTP
  - Takes advantage of large installed base
  - Does not transmit continuous signal between packets
  - Useful in battery-powered applications
- Can not get 100 Mbps on single twisted pair
  - So data stream split into three separate streams
  - Four twisted pairs used
  - Data transmitted and received using three pairs
  - Two pairs configured for bidirectional transmission
- Use ternary signaling scheme (8B6T)

Full Duplex Operation

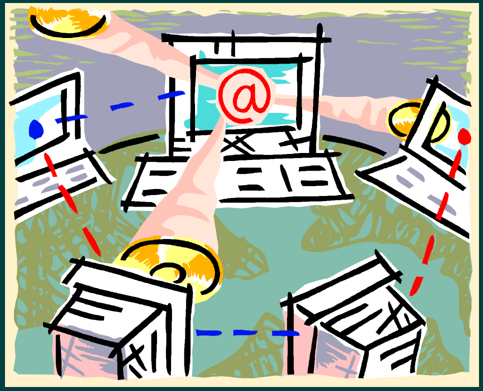
- Traditional Ethernet half duplex
- Using full-duplex, station can transmit and receive simultaneously
- 100-Mbps Ethernet in full-duplex mode, giving a theoretical transfer rate of 200 Mbps
- Stations must have full-duplex adapter cards
- And must use switching hub
  - Each station constitutes separate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

Mixed Configurations

- Fast Ethernet supports mixture of existing 10-Mbps LANs and newer 100-Mbps LANs
- Supporting older and newer technologies
  - Stations attach to 10-Mbps hubs using 10BASE-T
  - Hubs connected to switching hubs using 100BASE-T
  - High-capacity workstations and servers attach directly to 10/100 switches
  - Switches connected to 100-Mbps hubs use 100-Mbps links
  - 100-Mbps hubs provide building backbone
  - Connected to router providing connection to WAN

Gigabit Ethernet - Differences

- Carrier extension
  - At least 4096 bit-times long (512 for 10/100)
- Frame bursting
- Not needed if using a switched hub to provide dedicated media access



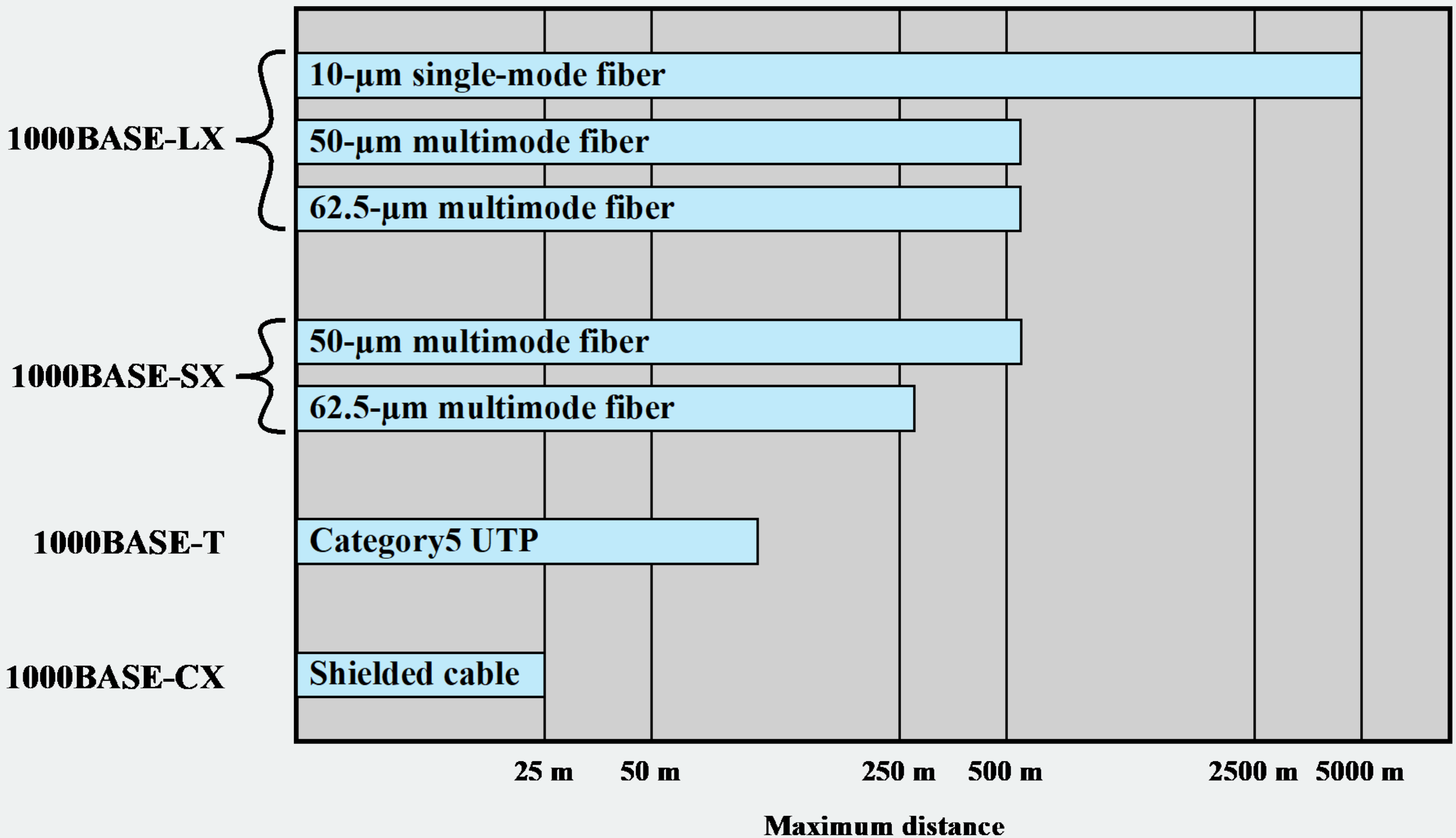


Figure 12.5 Gigabit Ethernet Medium Options (log scale)

10Gbps Ethernet

- Growing interest in 10Gbps Ethernet
  - High-speed backbone use
  - Future wider deployment
- Alternative to ATM and other WAN technologies
- Uniform technology for LAN, MAN, or WAN
- Advantages of 10Gbps Ethernet
  - No expensive, bandwidth-consuming conversion between Ethernet packets and ATM cells
  - IP and Ethernet together offers QoS and traffic policing approach ATM
  - Have a variety of standard optical interfaces

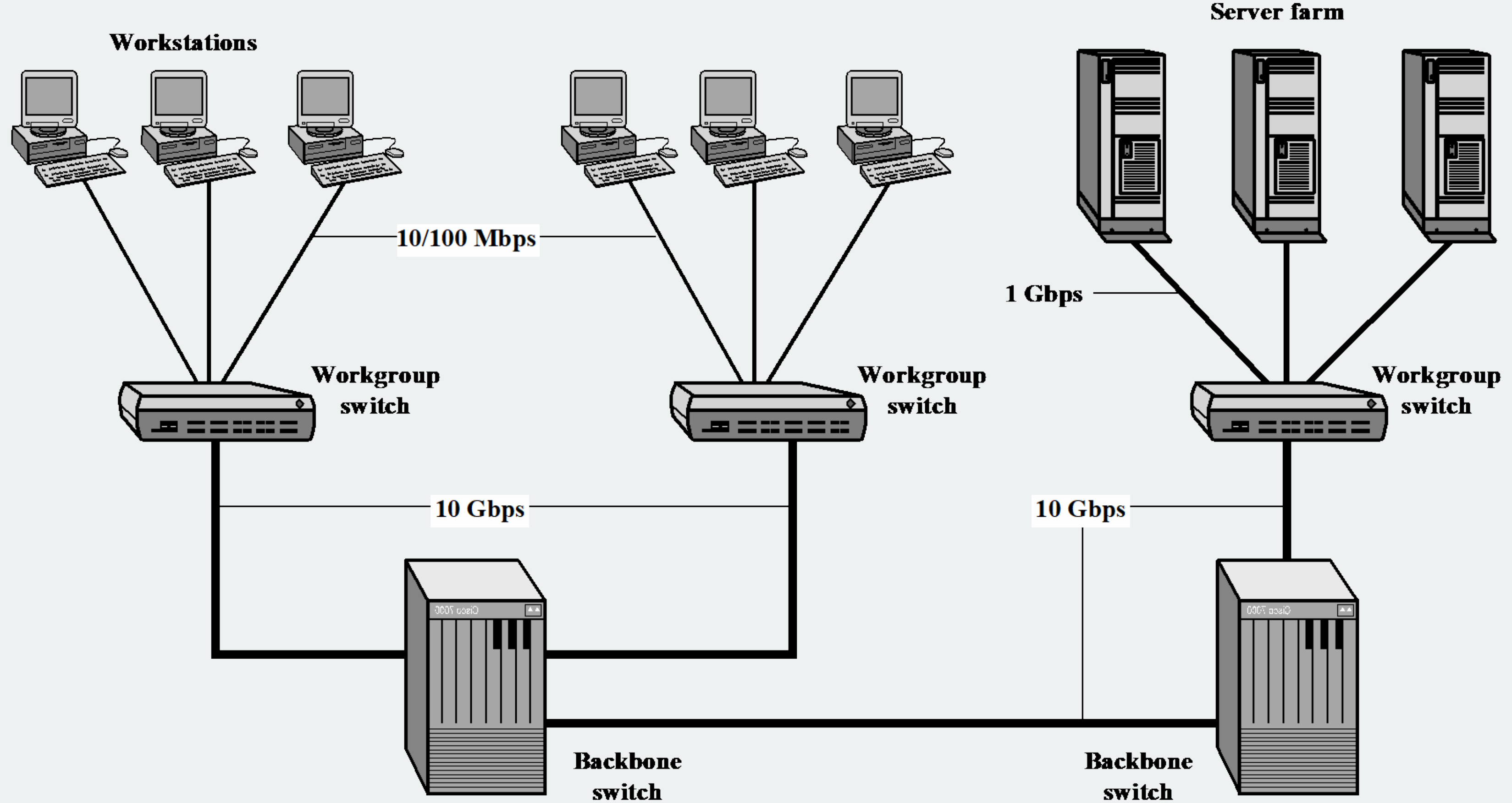


Figure 12.6 Example 10 Gigabit Ethernet Configuration

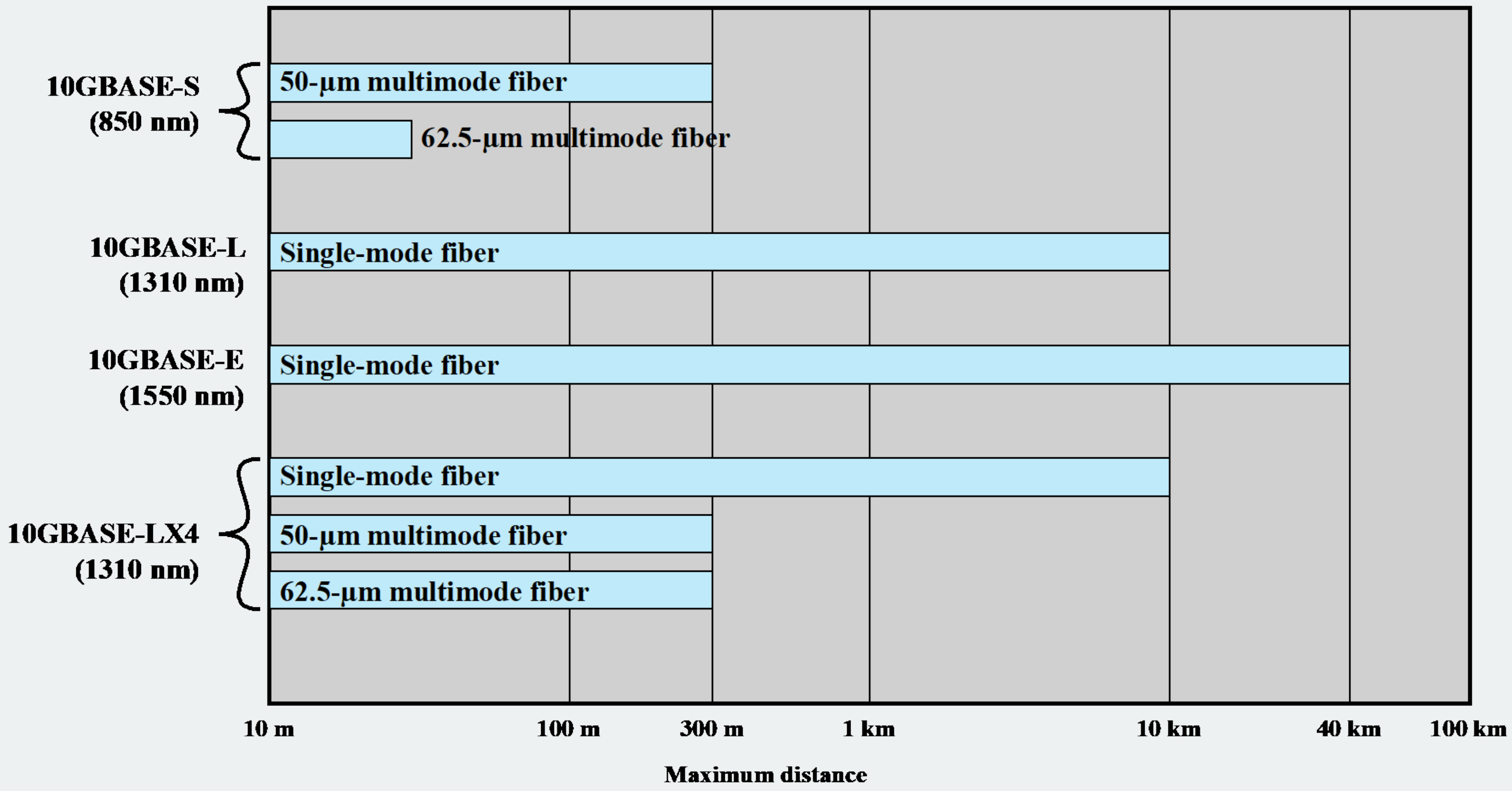


Figure 12.7 10-Gbps Ethernet Distance Options (log scale)

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

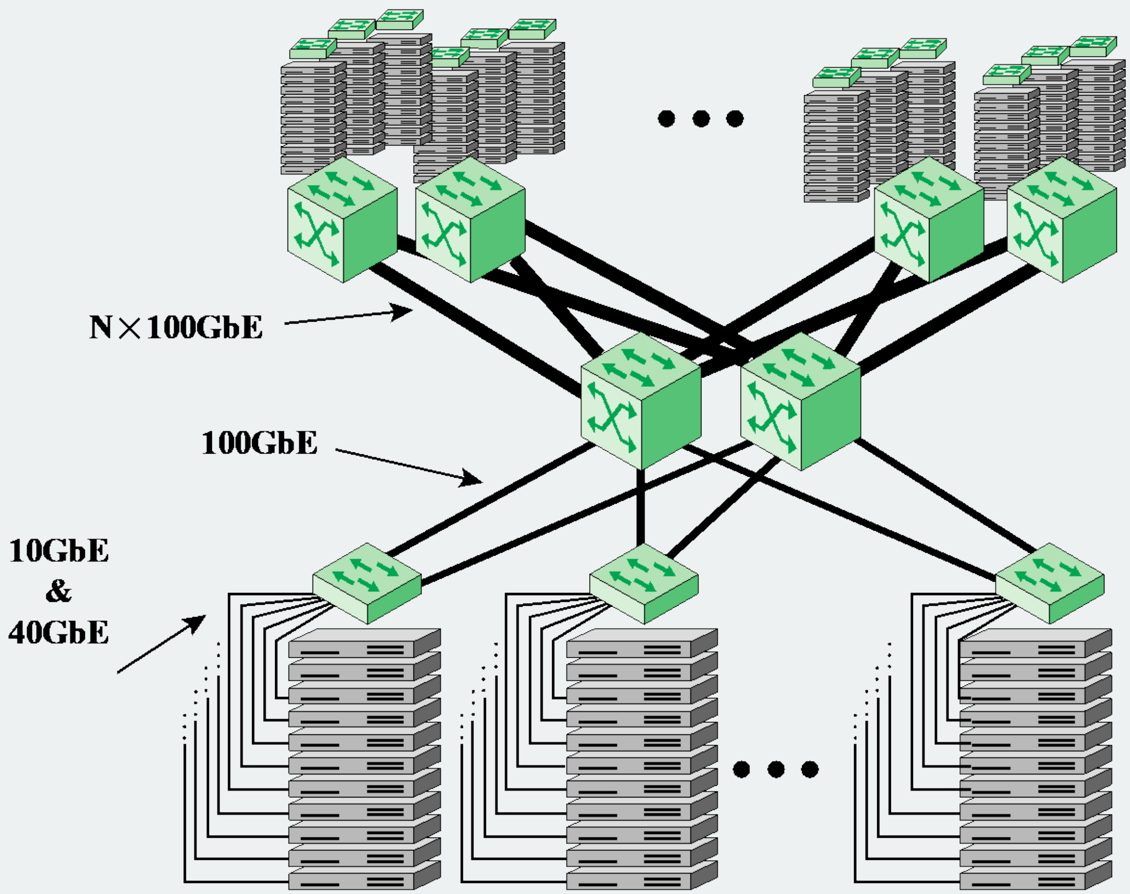


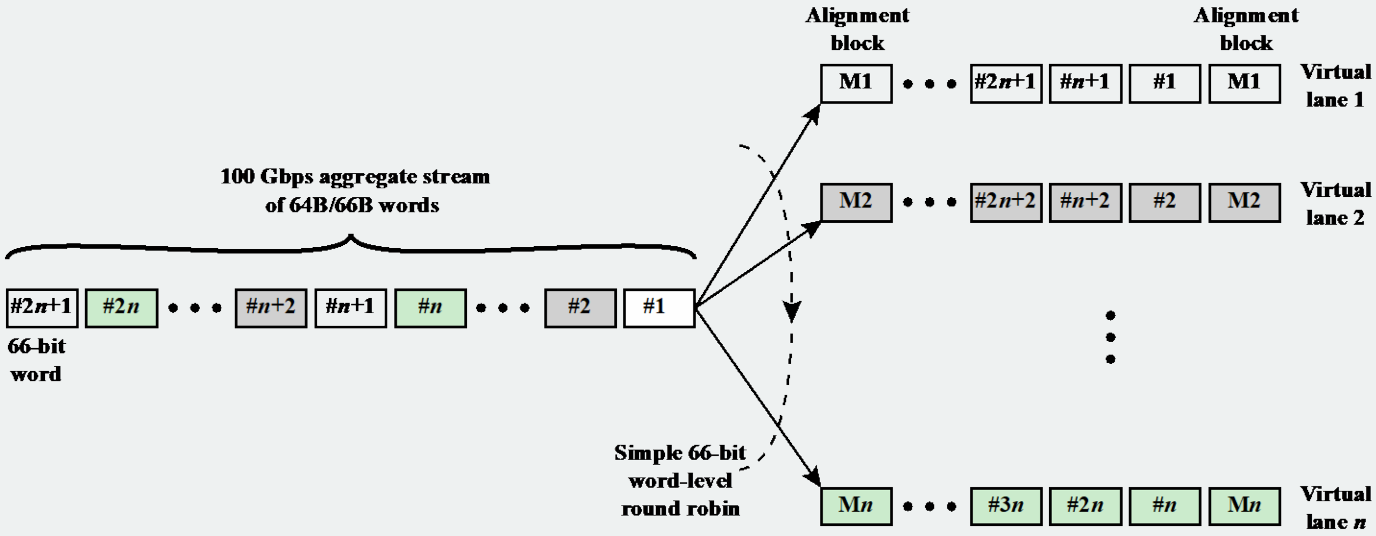
Figure 12.8 Example 100-Gbps Ethernet Configuration for Massive Blade Server Site

Multilane Distribution

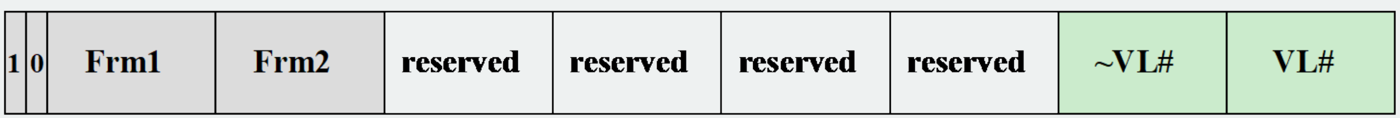
used to achieve the required data rates

- Multilane distribution:
  - Switches implemented as multiple parallel channels
    - Separate physical wires

- Virtual lanes:
  - If a different number of lanes are actually in use, virtual lanes are distributed into physical lanes in the PMD sublayer
  - Form of inverse multiplexing



(a) Virtual lane concept



(b) Alignment block

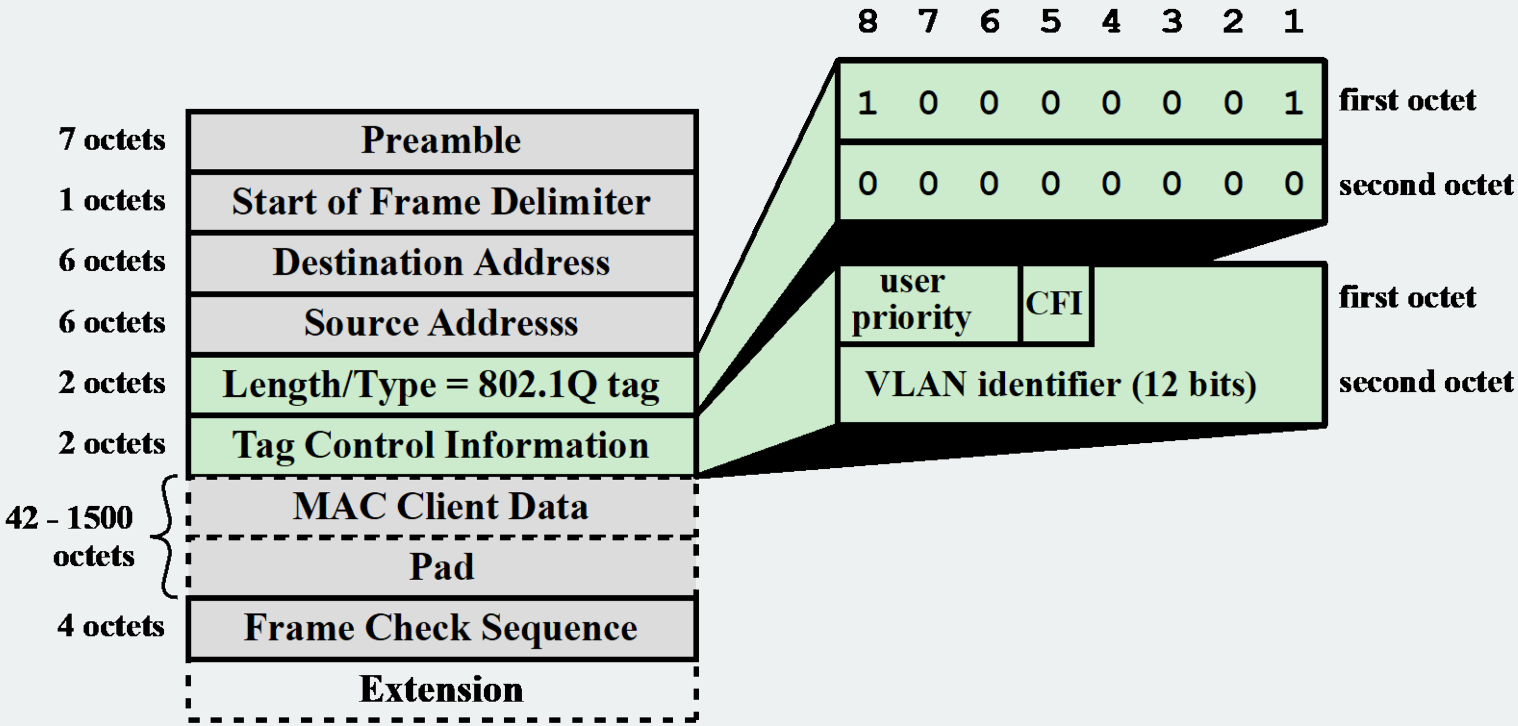
Figure 12.9 Multilane Distribution for 100-Gbps Ethernet

Table 12.3
Media Options for 40-Gbps and 100-Gbps Ethernet

	40 Gbps	100 Gbps
1m backplane	40GBASE-KR4	
10 m copper	40GBASE-CR4	1000GBASE-CR10
100 m multimode fiber	40GBASE-SR4	1000GBASE-SR10
10 km single mode fiber	40GBASE-LR4	1000GBASE-LR4
40 km single mode fiber		1000GBASE-ER4

Naming nomenclature:

Copper: K = backplane; C = cable assembly
Optical: S = short reach (100m); L - long reach (10 km); E = extended long reach (40 km)
Coding scheme: R = 64B/66B block coding
Final number: number of lanes (copper wires or fiber wavelengths)



CFI = Canonical Format Indicator
VLAN = virtual local area network

Figure 12.10 Tagged IEEE 802.3 MAC Frame Format

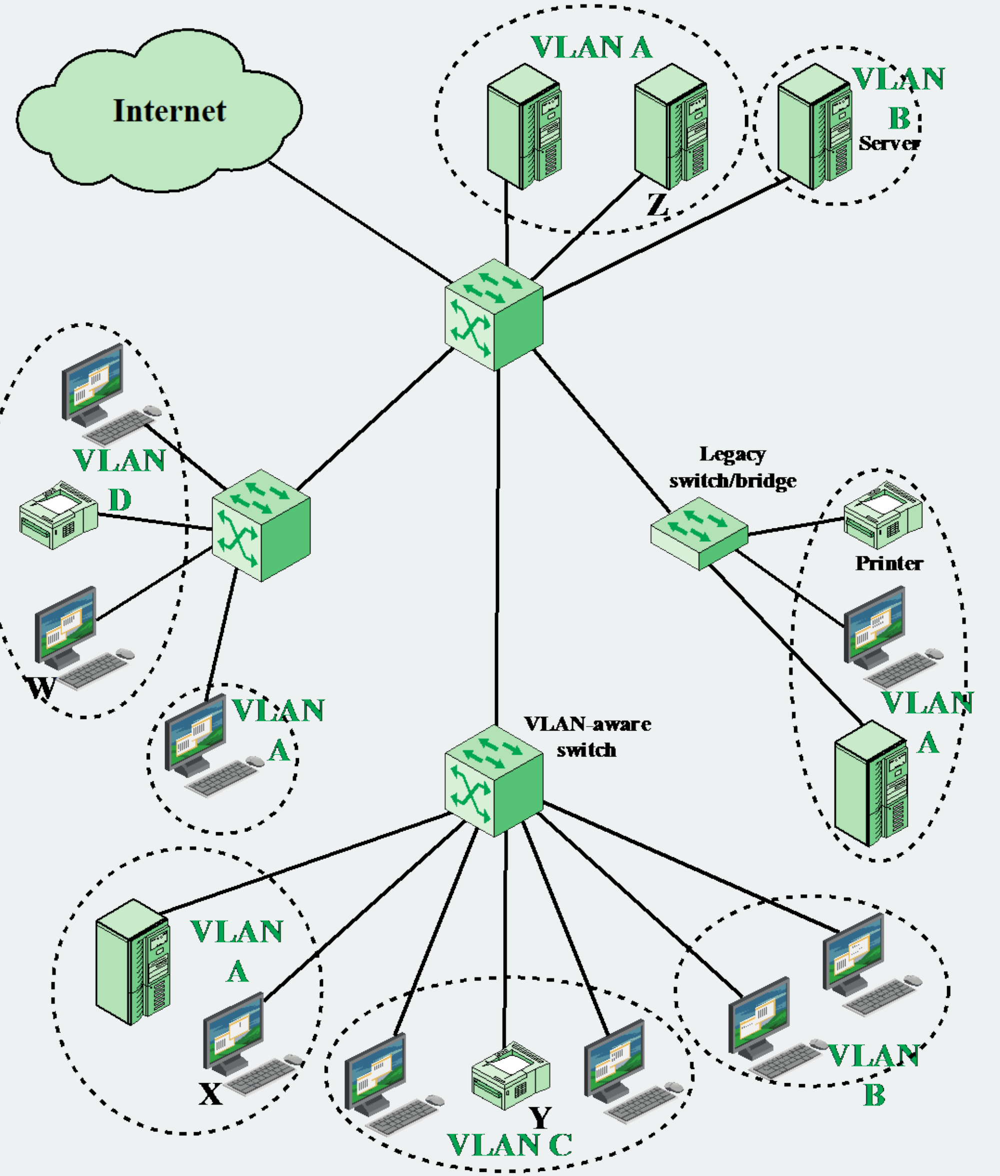


Figure 12.11 A VLAN Configuration

Summary

- Traditional Ethernet
  - IEEE 802.3 medium access control
  - IEEE 802.3 10-Mbps specifications (Ethernet)
- IEEE 802.1Q VLAN standard
- High-speed Ethernet
  - IEEE 802.3 100-Mbps specifications (Fast Ethernet)
  - Gigabit Ethernet
  - 10-Gbps Ethernet
  - 100-Gbps Ethernet