LECTURE 6

LOCAL AREA NETWORK (ETHERNET)

Topics

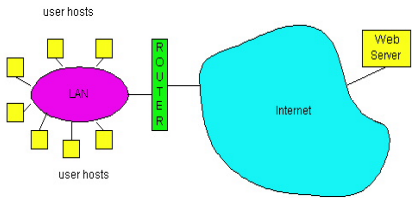
- LAN: characteristics, basic principles
- Protocol architecture
- Topologies
- LAN Systems: Ethernet
- Extending LANs: repeater, bridge, router
- Virtual LANs

LAN technologies

Data link layer so far:
– services, error detection/correction, multiple access

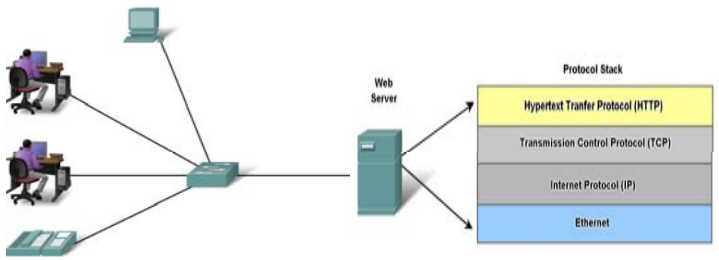
Next: LAN technologies

– Ethernet
– addressing
– hubs, bridges, switches
– 802.11
– PPP
– ATM



What is LAN

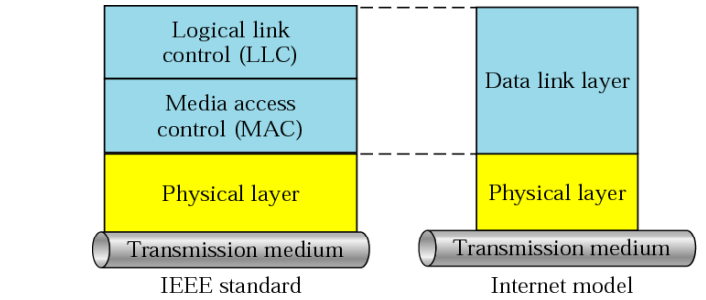
- Define Local Area Networks (LANs)
  - - A network serving a home, building or campus is considered a Local Area Network (LAN)

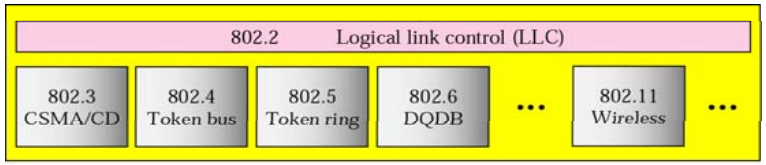


Ethernet

- History
  - Developed by Bob Metcalfe and others at Xerox PARC in mid-1970s
  - Roots in Aloha packet-radio network
  - Standardized by Xerox, DEC, and Intel in 1978
  - LAN standards define MAC and physical layer connectivity
    - IEEE 802.3 (CSMA/CD - Ethernet) standard – originally 2Mbps
    - IEEE 802.3u standard for 100Mbps Ethernet
    - IEEE 802.3z standard for 1,000Mbps Ethernet
- CSMA/CD: Ethernet's Media Access Control (MAC) policy
  - CS = carrier sense (Send only if medium is idle)
  - MA = multiple access
  - CD = collision detection (Stop sending immediately if collision is detected
- LAN standardization in IEEE Project 802
  - Data link layer subdivision
    - Logical Link Control (LLC)
    - Medium Access Control (MAC)

IEEE Project 802



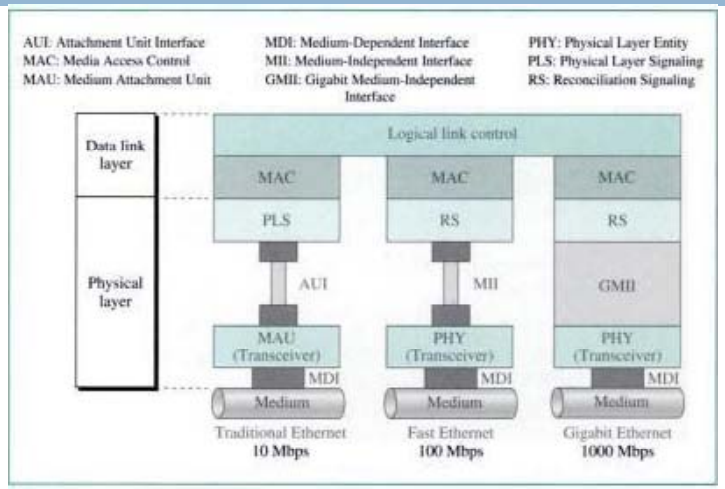


Ethernet

Why Ethernet:

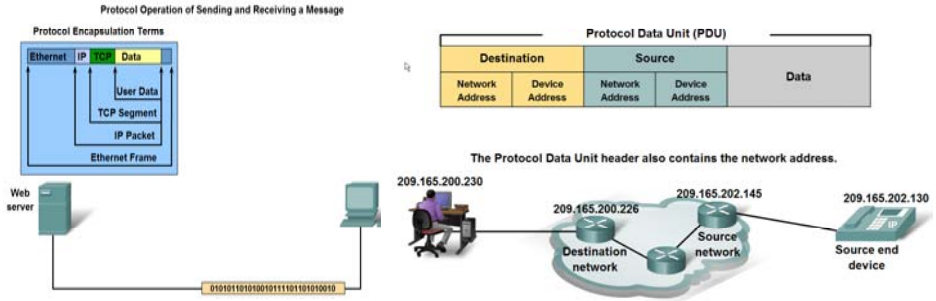
– cheap, high speed shared bus – widely used (Most popular packet-switched LAN technology)
– multiple access protocol: CSMA/CD
– medium independent (i.e., can run over coaxial cable, twisted pair, or fiber optics - any medium that supports collision detection)
– Bandwidths: 10Mbps, 100Mbps, 1Gbps
– Max bus length: 2500m
500m segments with 4 repeaters
– Bus and Star topologies are used to connect hosts
– Problem: Distributed algorithm that provides fair access

Generations of Ethernet



LAN

- Explain protocol data units (PDU) and encapsulation



Framing

Frame: (Protocol Data Unit – PDU) on the physical link

• Manageable unit of transmission (Slice raw bit stream up into frames)

• Sample Issues:

– how big is a frame? what demarks the end of the frame?

– how to control access to a shared channel?

Ethernet by definition is a broadcast protocol

Framing

- Framing, link access:
  - encapsulate datagram into frame, adding header, trailer
  - implement channel access if shared medium,
  - 'physical addresses' used in frame headers to identify source, destination
    - different from IP address!

• How do we know when a frame ends?

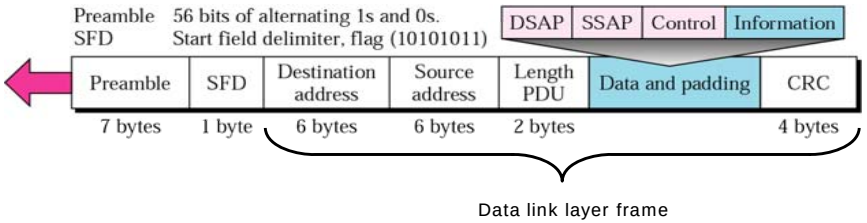
– Character count for frame boundary

• header can indicate number of bytes

• what if header is corrupt? Use special bit pattern to indicate end of frame (Preamble).

• Preamble used to synchronize receiver, sender clock rates

IEEE 802.3 MAC Frame Format



- 6 bytes (48-bit) addresses
  - Written as 00:90:27:25:3c:4e or 00-90-27-25-3c-4e
  - Multicast (8th bit is 1), unicast, or broadcast (all 1s)
- Type: indicates the higher layer protocol, mostly IP (Novell IPX and AppleTalk)
- Length/PDU
  - Length if less than 1518
    - IEEE 802.3 format
  - Otherwise PDU type
    - DIX (DEC, Intel, Xerox) Ethernet format
- CRC-32: checked at receiver, if error is detected, the frame is simply dropped

Note

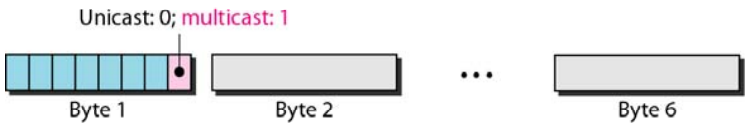
Frame length:
Minimum: 64 bytes (512 bits)
Maximum: 1518 bytes (12,144 bits)

Figure 13.6 *Example of an Ethernet address in hexadecimal notation*

06 : 01 : 02 : 01 : 2C : 4B

6 bytes = 12 hex digits = 48 bits

Figure 13.7 *Unicast and multicast addresses*



Note

The least significant bit of the first byte defines the type of address.
If the bit is 0, the address is unicast;
otherwise, it is multicast.

Note

The broadcast destination address is a special case of the multicast address in which all bits are 1s.

Traditional Ethernet

- 10 Mb/s
- CSMA/CD access
- Manchester coding
- Several different physical layers
  - Bus
    - 10Base5 (thick coax)
    - 10Base2 (thin coax)
  - Star
    - 10Base-T (twister pair)
    - 10Base-FL (fiber link)

Ethernet - Network Media

- 10 Base 5
  - "Thick Ethernet"
  - heavily shielded, expensive
- 10 Base 2
  - "Thin Ethernet"
  - coax cable
  - cheap
  - 10: 10Mbps; 2: under 185 (~200) meters cable length
  - Thin coaxial cable in a bus topology
- 10 Base T
  - "Twisted Pair Ethernet"
  - cable: twisted pair

High-speed Ethernet:

- 100 Base T
  - transmits at 100 Mbps
  - requires CAT5 twisted pair (higher quality spec.)
  - more efficient encoding
- Gigabit Ethernet
  - transmits at 1 Gbps
  - www.gigabit-ethernet.org

Figure 13.10 *10Base5 implementation*

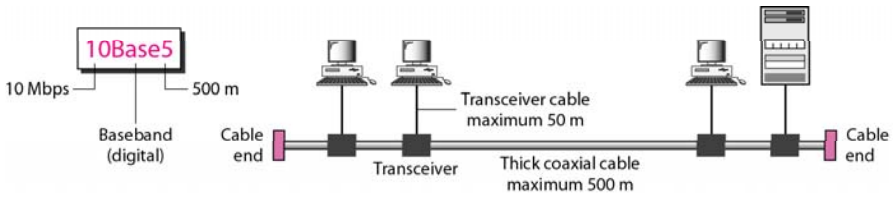


Figure 13.11 *10Base2 implementation*

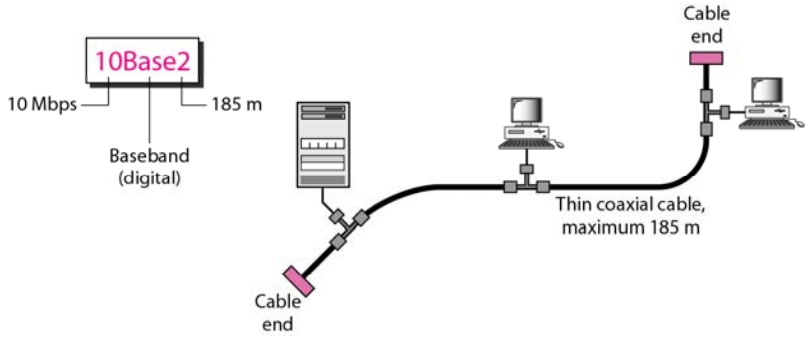


Figure 13.12 *10Base-T implementation*

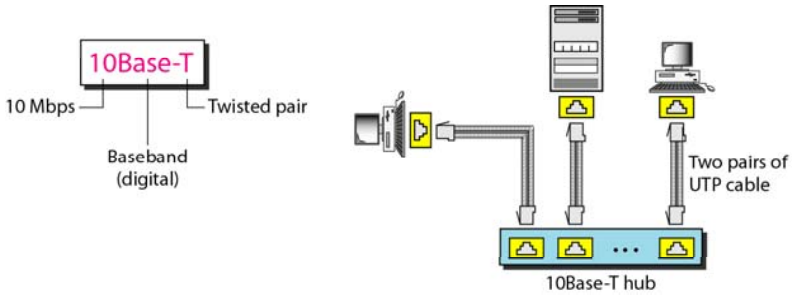


Figure 13.13 *10Base-F implementation*

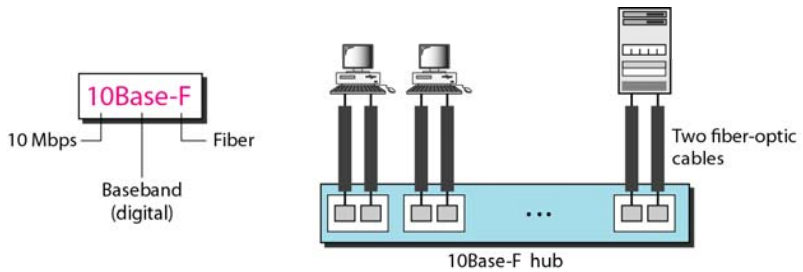


Table 13.1 *Summary of Standard Ethernet implementations*

Characteristics	*10Base5*	*10Base2*	*10Base-T*	*10Base-F*
Media	Thick coaxial cable	Thin coaxial cable	2 UTP	2 Fiber
Maximum length	500 m	185 m	100 m	2000 m
Line encoding	Manchester	Manchester	Manchester	Manchester

CHANGES IN THE STANDARD

The 10-Mbps Standard Ethernet has gone through several changes before moving to the higher data rates. These changes actually opened the road to the evolution of the Ethernet to become compatible with other high-data-rate LANs.

Bridged Ethernet
Switched Ethernet
Full-Duplex Ethernet

Figure 13.14 *Sharing bandwidth*

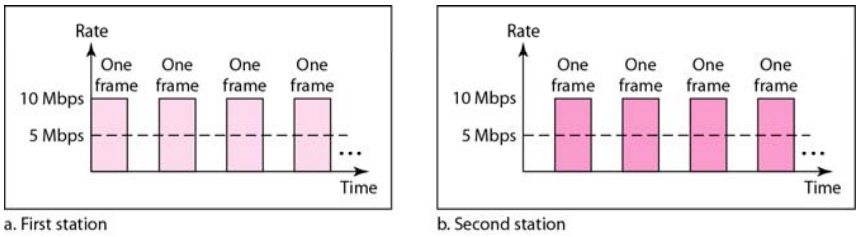


Figure 13.15 *A network with and without a bridge*

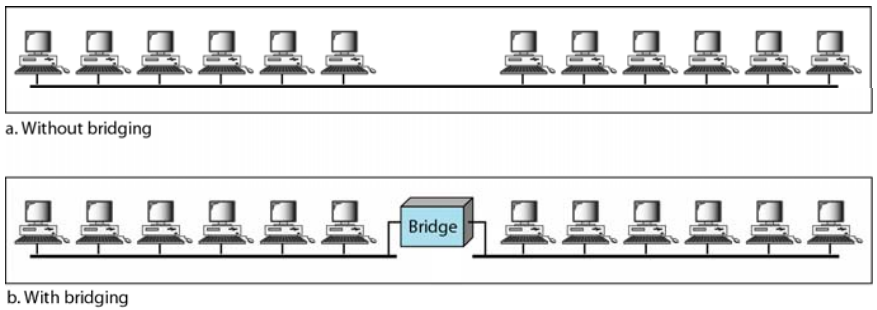


Figure 13.16 *Collision domains in an unbridged network and a bridged network*

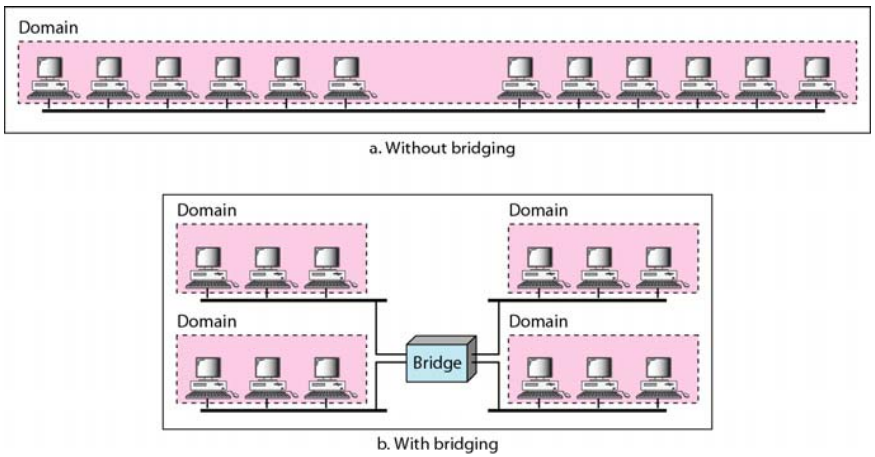


Figure 13.17 *Switched Ethernet*

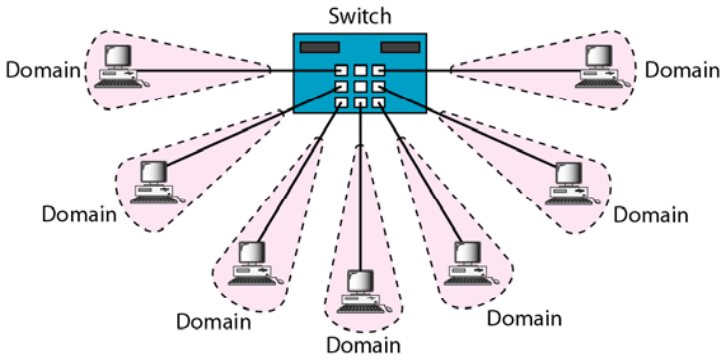
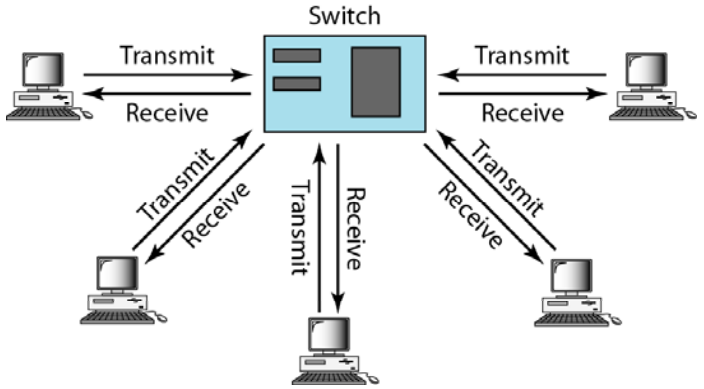


Figure 13.18 *Full-duplex switched Ethernet*



FAST ETHERNET

Fast Ethernet was designed to compete with LAN protocols such as FDDI or Fiber Channel. IEEE created Fast Ethernet under the name 802.3u. Fast Ethernet is backward-compatible with Standard Ethernet, but it can transmit data 10 times faster at a rate of 100 Mbps.

MAC Sublayer
Physical Layer

Fast Ethernet (IEEE 802.3u)

- Fast Ethernet has technology very similar to 10Mbps Ethernet
  - Uses different physical layer encoding (4B5B)
  - Many NIC's are 10/100 capable
    - Can be used at either speed
- 100 Mb/s
- CSMA/CD
  - Compatibility
- Autonegotiation
  - 10/100 Mb/s, full/half duplex, etc
- Two-wire and four-wire

Figure 13.19 *Fast Ethernet topology*

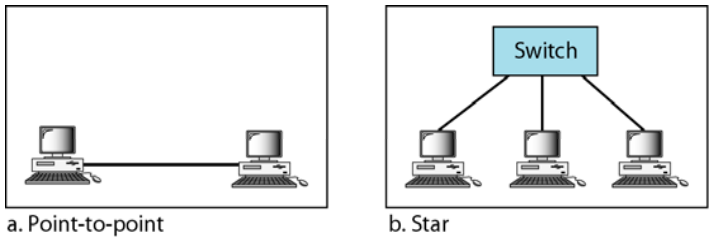


Figure 13.20 *Fast Ethernet implementations*

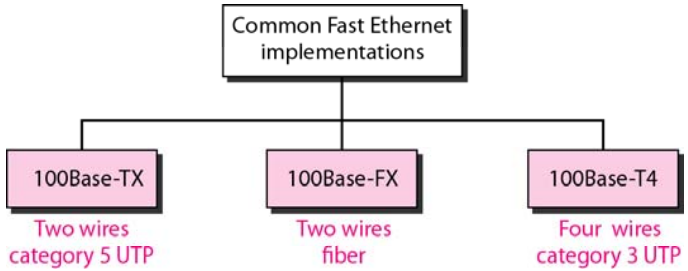


Table 13.2 *Summary of Fast Ethernet implementations*

Characteristics	*100Base-TX*	*100Base-FX*	*100Base-T4*
Media	Cat 5 UTP or STP	Fiber	Cat 4 UTP
Number of wires	2	2	4
Maximum length	100 m	100 m	100 m
Block encoding	4B/5B	4B/5B	
Line encoding	MLT-3	NRZ-I	8B/6T

GIGABIT ETHERNET

The need for an even higher data rate resulted in the design of the Gigabit Ethernet protocol (1000 Mbps). The IEEE committee calls the standard 802.3z.

MAC Sublayer
Physical Layer
Ten-Gigabit Ethernet

Gigabit Ethernet

- Compatible with lower speeds
- Uses standard framing and CSMA/CD algorithm
- Distances are severely limited
- Typically used for backbones and inter-router connectivity
- Becoming cost competitive
- How much of this bandwidth is realizable?

- 1 Gb/s
- Full duplex without CSMA/CD
  - Mostly used
- Half-duplex with CSMA/CD
- Two-wire and four-wire

Note

In the full-duplex mode of Gigabit Ethernet, there is no collision;
the maximum length of the cable is determined by the signal attenuation
in the cable.

Figure 13.22 *Topologies of Gigabit Ethernet*

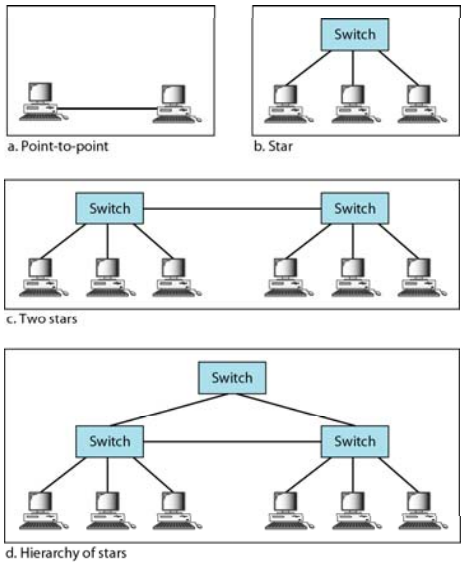


Figure 13.23 *Gigabit Ethernet implementations*

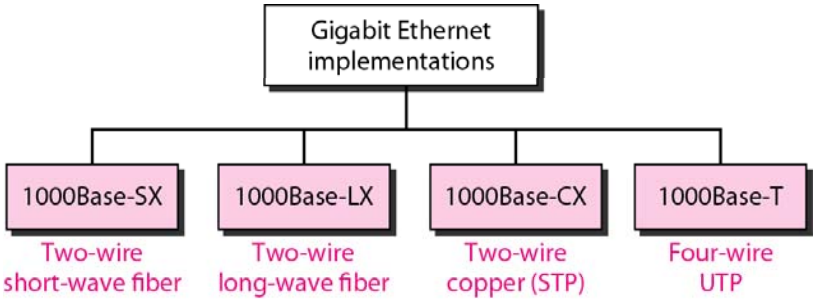


Table 13.3 *Summary of Gigabit Ethernet implementations*

Characteristics	*1000Base-SX*	*1000Base-LX*	*1000Base-CX*	*1000Base-T*
Media	Fiber short-wave	Fiber long-wave	STP	Cat 5 UTP
Number of wires	2	2	2	4
Maximum length	550 m	5000 m	25 m	100 m
Block encoding	8B/10B	8B/10B	8B/10B	
Line encoding	NRZ	NRZ	NRZ	4D-PAM5

10G Ethernet (IEEE802.3ae)

- Serial transmission
  - 10GBase-SR, 10GBase-SW, 10GBase-LR, 10GBase-LW, 10GBase-ER, 10GBase-EW
    - S: Short wavelength (850 nm multimode, 300 m)
    - L: Long wavelength (1310 nm singlemode, 10 km)
    - E: Extra long wavelength (1550 nm singlemode, 40 km)
  - WAN/LAN varieties
    - W: WAN interoperability (SONET/SDH scrambling, STS-192c framing)
    - R: LAN
  - 64B/66B coding
- Parallel transmission
  - 10GBase-LX4
  - 8B/10B coding
  - 4 × 3.125 Gb/s W-WDM (Wide Wave Division Multiplexing)

Table 13.4 *Summary of Ten-Gigabit Ethernet implementations*

Characteristics	*10GBase-S*	*10GBase-L*	*10GBase-E*
Media	Short-wave 850-nm multimode	Long-wave 1310-nm single mode	Extended 1550-mm single mode
Maximum length	300 m	10 km	40 km

Experiences with Ethernet

Ethernets work best under light loads (Utilization over 30% is considered heavy)
Network capacity is wasted by collisions
Most networks are limited to about 200 hosts while Specification allows for up to 1024
Most networks are much shorter (5 to 10 microsecond RTT)
Transport level flow control helps reduce load (number of back to back packets)
Ethernet is inexpensive, fast and easy to administer!

Ethernet Problems

Ethernet's peak utilization is pretty low (like Aloha)
Peak throughput worst with
- More hosts (More collisions needed to identify single sender)
- Smaller packet sizes (More frequent arbitration)
- Longer links (Collisions take longer to observe, more wasted bandwidth

Efficiency is improved by avoiding these conditions

Extending LANs

- Why not one LAN?
  - Signal quality and network performance
    - Declines with number of connected devices and network diameter
  - Reliability
    - Several self-contained units
  - Security
    - Separation of traffic
  - Geography
    - Connect LANs at different locations

Extending LANs

- Repeaters and hubs
  - Connects segments of the same LAN
    - Signal regeneration
- Bridges (two-layer switches)
  - Routing at the data link layer
    - Connects LANs that use same type of data link addresses
  - Traffic filtering
- Router (three-layer switches)
  - Routing at the network layer
  - Connects LANs (or links in general) of different technologies
- *Beware*: terminology is getting blurred!
  - "Smart switches", "dual-speed hubs", …