Local Area Networks (LANs)

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- IEEE 802 Architecture
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- Ethernet Addressing

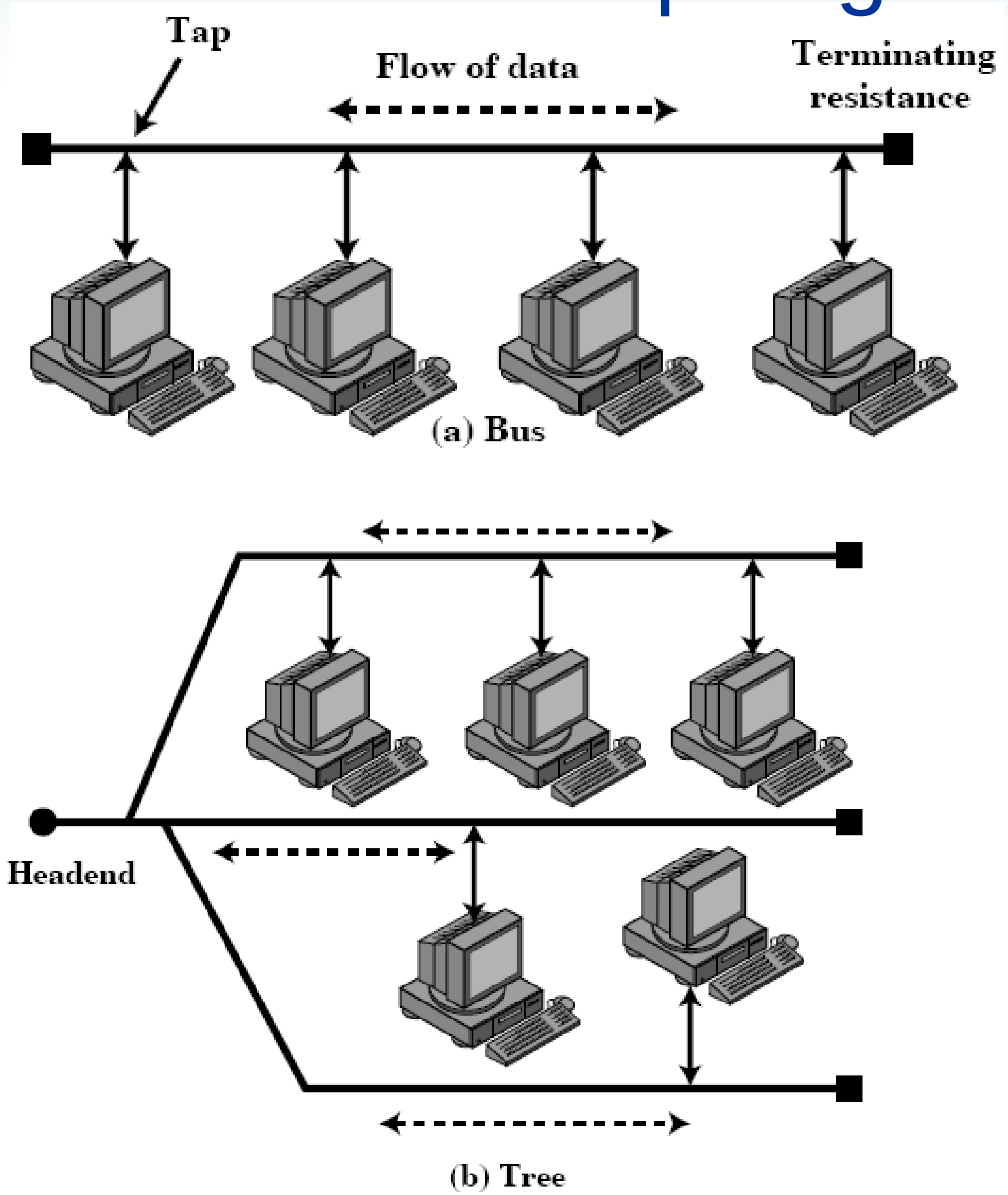
LAN Design Elements

- Four key elements of a LAN:
  - Topology
  - Transmission medium
  - Wiring layout
  - Medium access control

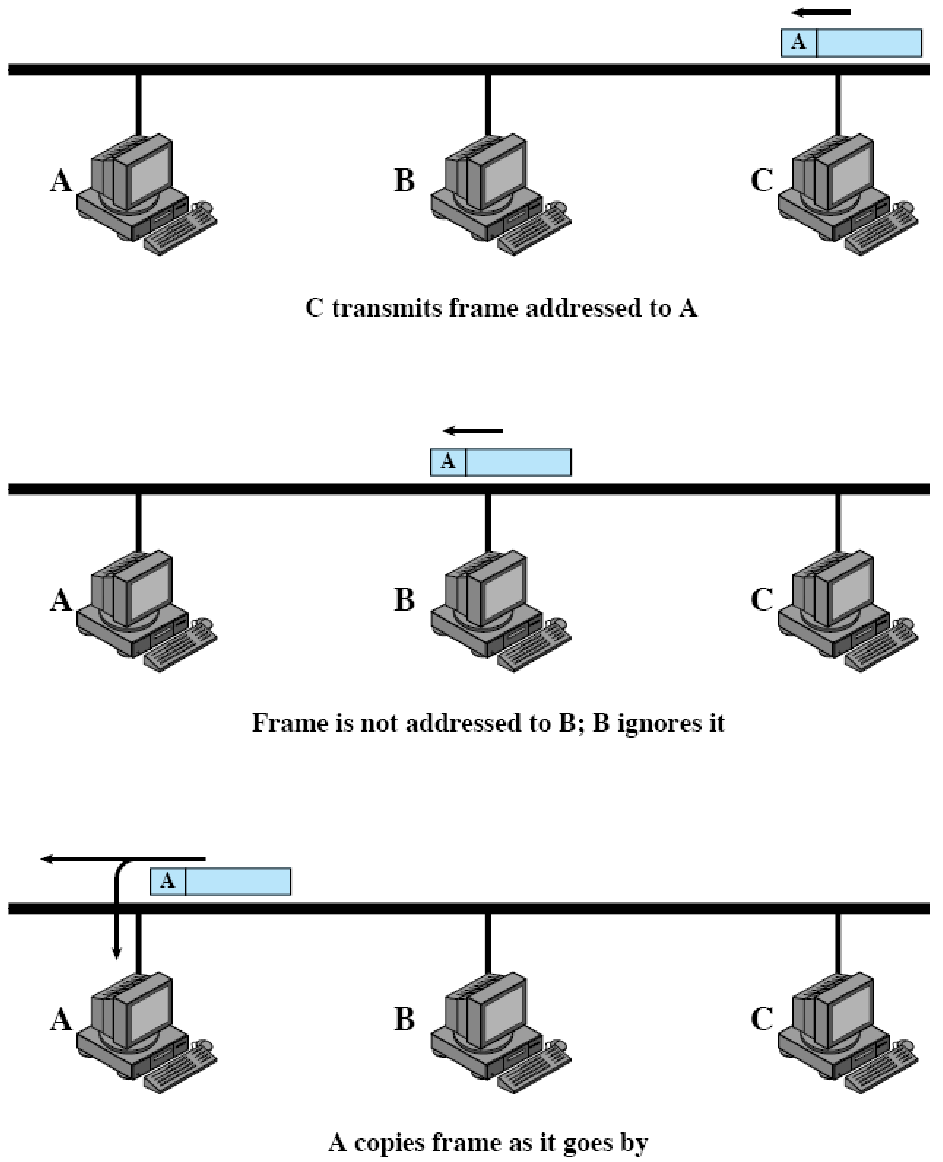
Topologies

- Bus and Tree Topologies
  - Used with multipoint medium
  - Transmission propagates throughout medium and is heard by all stations
  - Stations attach to the bus via a *tap*
  - Full duplex connection between station and tap allows for transmission (“put on the bus”) and reception (“take off the bus”)
  - Need to regulate transmission to avoid collisions and hogging
  - Terminator absorbs frames at end of medium/cable
  - Tree topology is a generalization of bus topology
    - Headend connected to branching cables

Bus and Tree Topologies

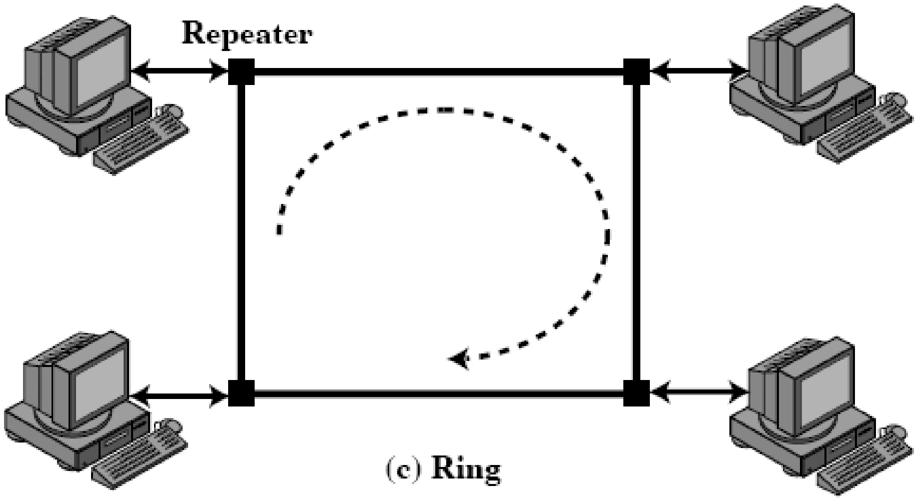


Frame Transmission on Bus Topology



Topologies

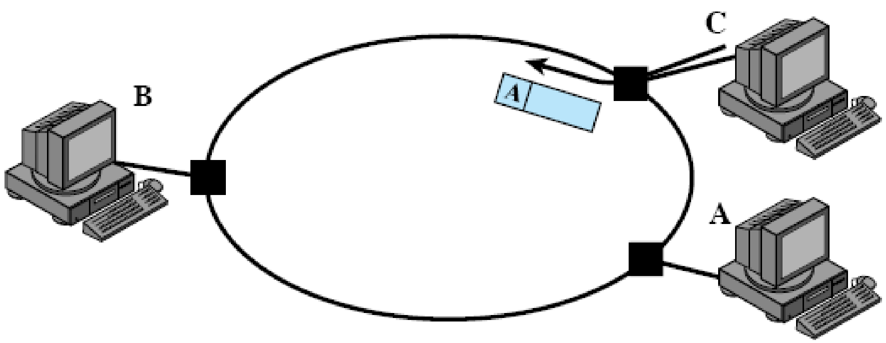
- Ring
  - Point-to-point links between stations to form a loop Receive data on one link and retransmit on another
    - Links unidirectional
    - Stations attach to repeaters
  - Data in frames
    - Circulate past all stations
    - Destination recognizes address and copies frame
    - Frame circulates back to source where it is removed
  - Media access control determines when a station can insert frame



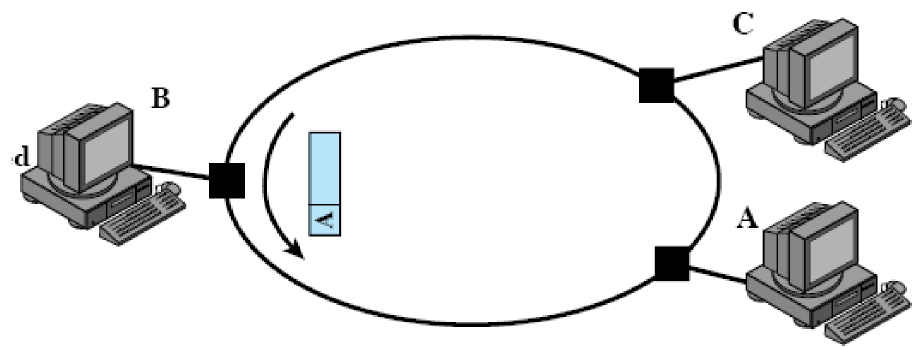
(c) Ring

Frame Transmission on Ring Topology

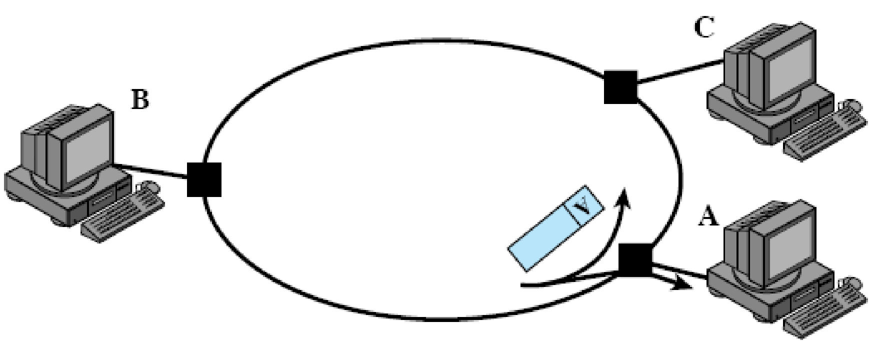
1. C transmits frame addressed to A



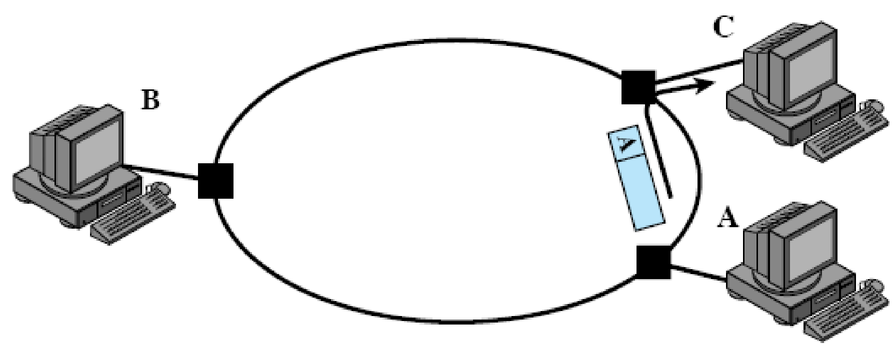
2. Frame is not addressed to B; B ignores it



3. A copies frame as it goes by

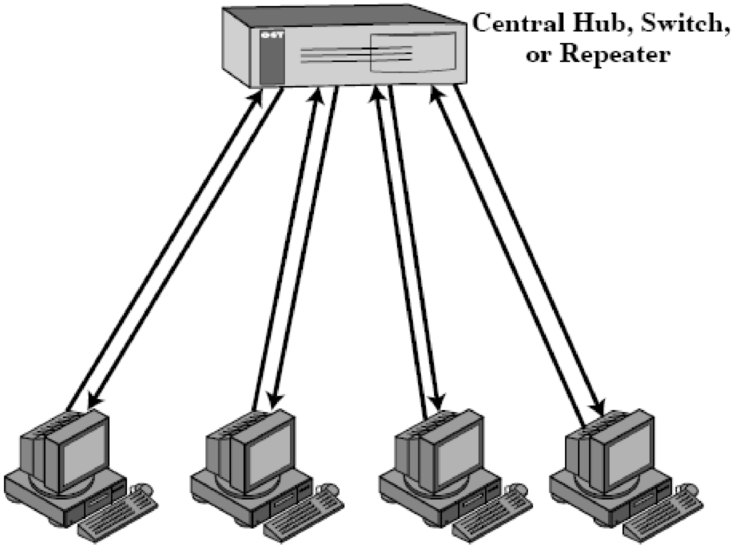


4. C absorbs returning frame



Topologies

- Star
  - Each station is directly connected to common central node
  - Usually two point-to-point links between station and central node (one for transmit, one for receive)
  - Two options:
    - Hub: Central node broadcasts a frame to all stations (logically equivalent to a bus)
    - Switch: Central node only sends frame to destination station (more efficient, but requires more complexity in central node)



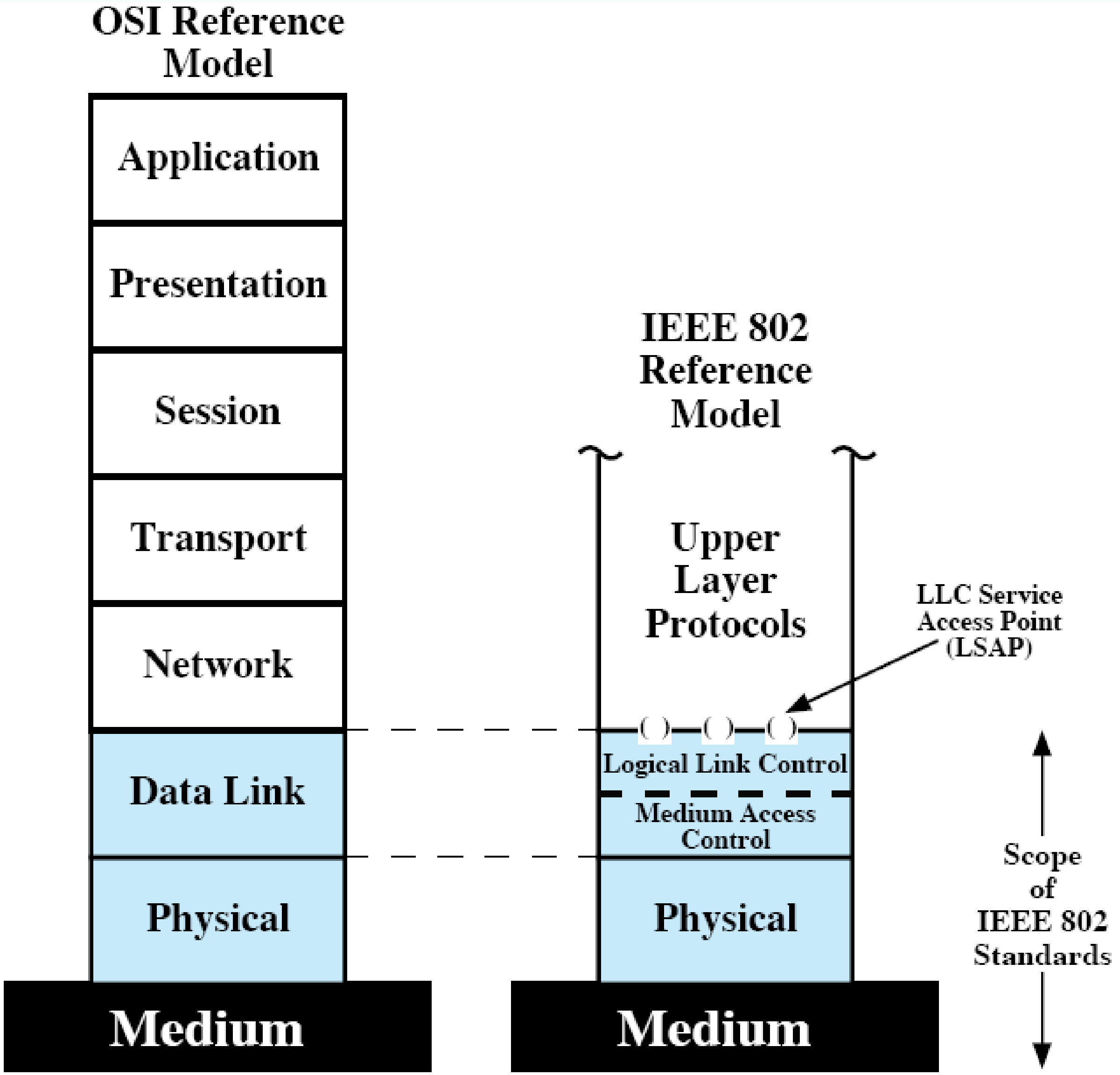
Choice of Topology and Medium

- Many factors: reliability, expandability, performance, building layout, medium available
- Some common cases (not always the case):
  - Coaxial cable often used for bus topology
  - Optical fibre for ring topology; usually the highest speed networks
  - Twisted pair for star topologies; often well-suited for LANs in buildings

IEEE 802 LAN Architecture

- IEEE 802 LAN/MAN standards committee has developed the majority of the LAN standards in use including:
  – Ethernet, Fast Ethernet, Gigabit Ethernet, Token Ring, …
- The 802 series of standards follow a common architecture
  – Standardised only at Physical layer and Data Link layer
    - Data Link layer is broken into two sub-layers: Medium Access Control (MAC) and Logical Link Control (LLC)
  – Assumes any upper layers (e.g. any Network layer, including IP)
  – Data Link layer must support multiple nodes accessing the link
  – 802 can support many MAC/Physical protocols, and uses one common LLC protocol
    - E.g. 802.2 defines the LLC; 802.3 defines MAC and Physical protocols for Ethernet; 802.11 defines the MAC and Physical protocols for wireless LAN

IEEE 802 LAN Architecture



Need for Multiple Access Techniques

- Currently, we have assumed data link layer connects two computers, that is, point-to-point topology
  - Examples:
    - one router has a optical fibre to another router
    - a PC has a twisted pair cable to a router
  - Two computer devices have dedicated link between them
- But in some cases have point to multipoint topology:
  - Examples:
    - An Ethernet with many computers connected to one cable
    - Wireless systems: Wireless LAN, Mobile Phone, Satellite, …
  - Many computer devices (more than two) must share the link
- Multiple access techniques define rules for “sharing” the link
  - That is, which devices can transmit so that they don’t interfere with other transmissions

Multiple Access: Where and How?

- Where is the control point?
  - Centralised: a single node in the network (usually a special node) controls who transmits and how.
    - Advantages are:
      - Greater control over providing priority and guarantees
      - Each node (except central node) is simple
      - Avoids problems of distributing information between nodes
    - Disadvantages are:
      - Single point of failure; if central node fails, MAC won't work
      - Central node may become a bottleneck, reduce performance
  - Distributed: all nodes collectively make decisions on who transmits and how
    - Advantages and disadvantages: opposite to centralised
- How to perform control?
  - Synchronous (fixed): a specific capacity is dedicated (reserved) for a connection; similar to TDM, FDM, circuit switching
  - Asynchronous (dynamic): capacity is allocated to nodes (connections) on demand
    - Dynamic is preferable for LANs because difficult to predict traffic requirements of users
    - Subdivided into: Round Robin; Reservation; Contention

Round Robin MAC

- Each station in turn is given the opportunity to transmit
  - E.g. Station 1 has an opportunity to transmit, then station 2 has an opportunity and then station 3 and so on
  - If a station accepts to opportunity, it can transmit up to a maximum amount of time (or maximum amount of data)
  - The station may reject the opportunity (e.g. if it has no data to transmit); then the next station is given the opportunity
- Efficient when:
  - Many stations have data to transmit over a long period of time
    - Inefficient of only some stations have data to transmit, because waste time switching between stations

Reservation-based MAC

- Time is divided into slots, and stations reserve future slots for an extended or even indefinite period
  - Similar to Time Division Multiplexing (TDM)
  - E.g. If we have ten slots per second, then a station may reserve the second slot for the next 5 seconds
  - Reservations may be centralised or distributed
  - Suitable for stream traffic since data needs to be transmitted at regular, known intervals
    - Voice/video calls, audio/video streaming

Contention-based MAC

- No control over stations; each station contends (or "fights") for its chance to transmit
  - E.g. random access: if a station has data to send, and no-one else is transmitting, then the station transmits; if someone else is transmitting, then wait a random period and try again
  - Works well for bursty traffic (data arrives at unknown intervals, and sometimes in bursts)
    - Simple to implement
    - Distributed – each station follows its own rules
    - Efficient for light/moderate loads (sometimes inefficient if heavy load)
      - What is load? Amount of traffic.

- Although MAC protocols have been implemented using Round Robin, Reservation and Contention, the most common products today are round-robin and contention

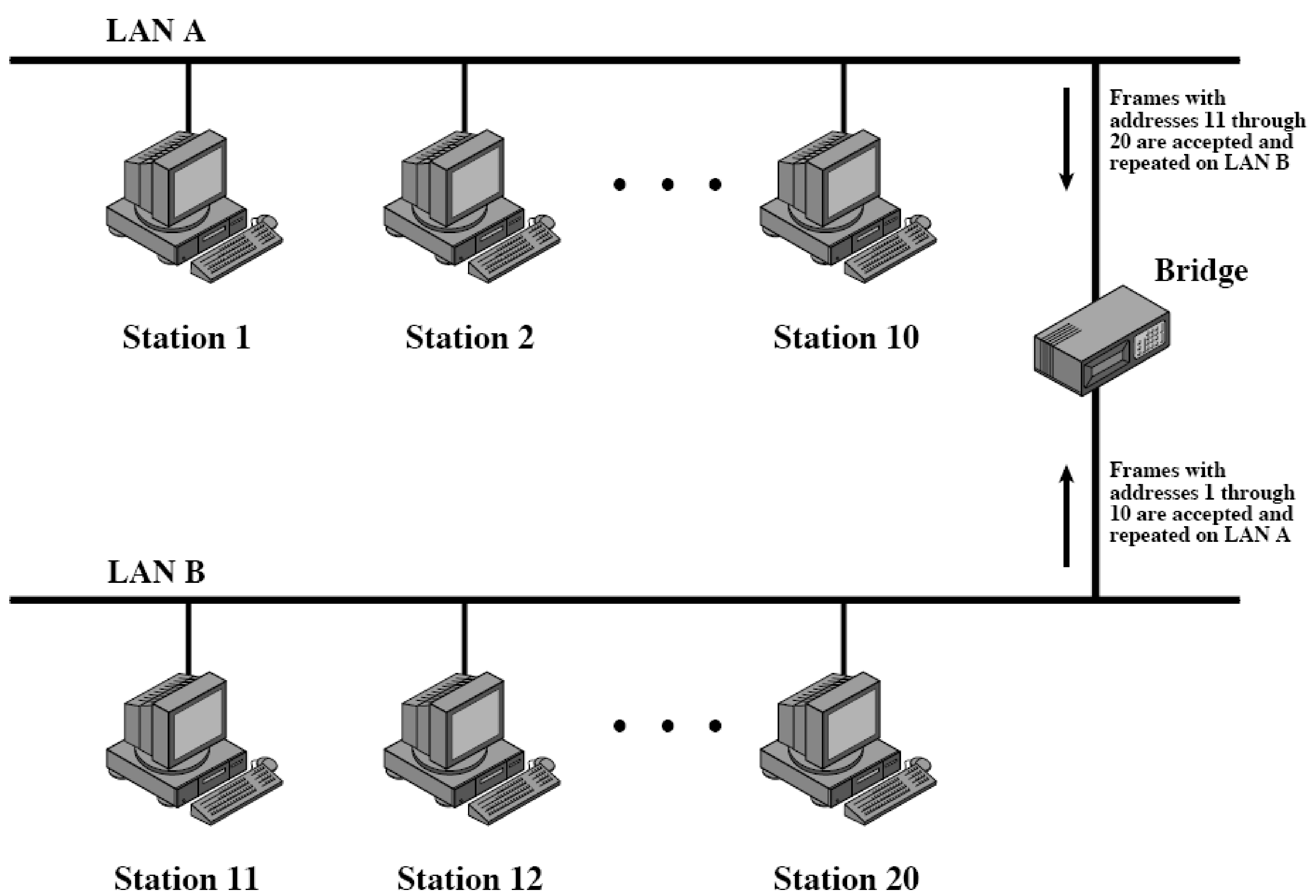
LAN Elements

Bridges, Hubs, Switches

LAN Elements: Bridges

- Almost every LAN needs to interconnect to other LANs and WANs. Two approaches:
  - Bridges: for interconnecting LANs (most often using the same LAN protocol)
  - Routers: for interconnecting LANs and WANs (often different protocols) – covered in later lectures
- A basic bridge interconnects two (or more) LANs using the same protocol
  - Why not just make one large LAN (instead of connect two small LANs)?
    - Reliability: a bridge can partition networks; a failure on one LAN will not affect the other LANs
    - Performance: Generally LAN performance declines with length of wire and number of stations; partitioning can be used to increase performance
    - Security: Traffic from one LAN (e.g. for finance department) can be kept separate from the other (e.g. student) LAN, although some monitored traffic can pass through the bridge
    - Geography: it may be easier to connect a LAN in one building with a LAN in another building via microwave bridge (rather than coaxial cable to make one large LAN)

Bridge Operation

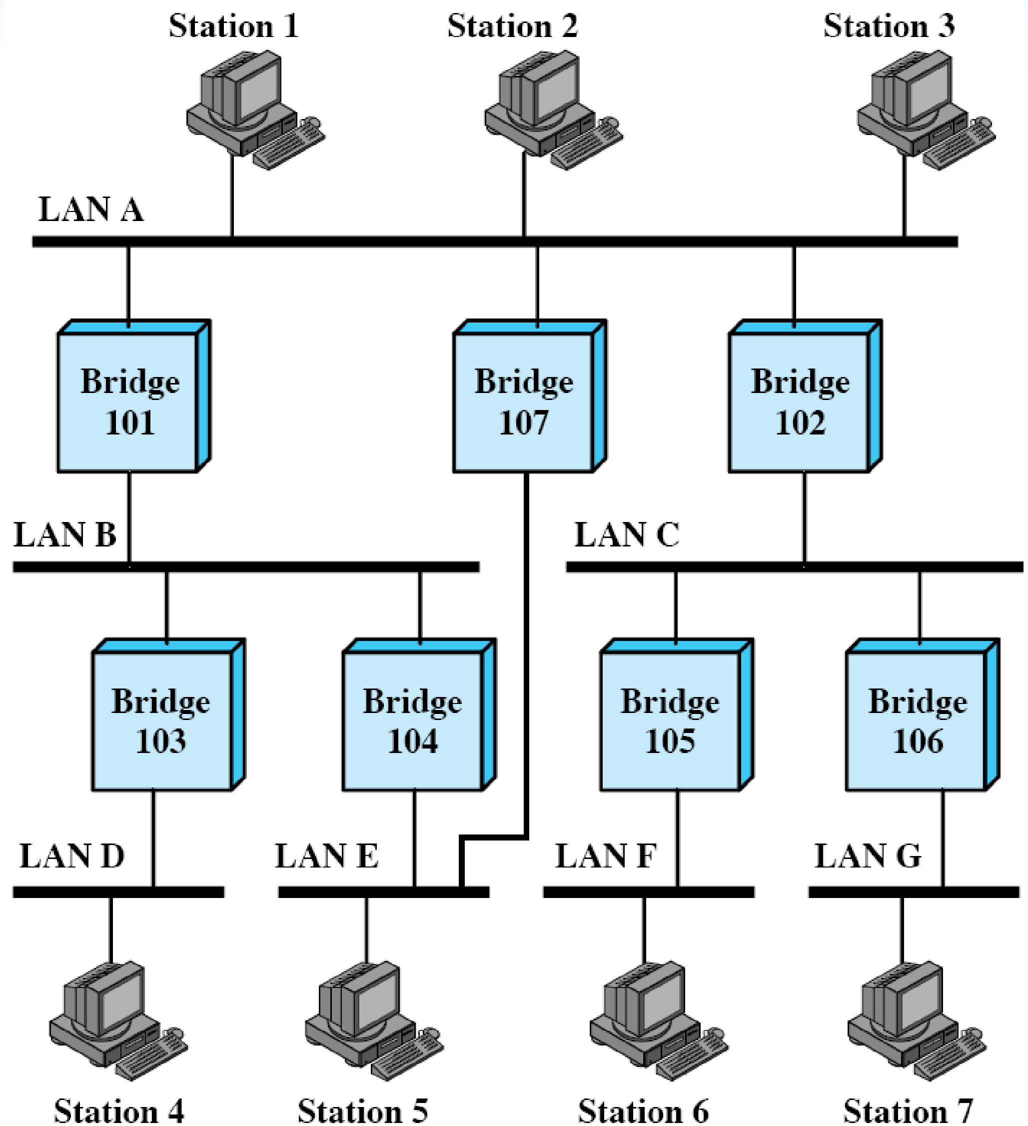


Bridge Operation

- A bridge connecting two LANs, A and B, performs the functions:
  - Read all frames transmitted on A, and accept those addressed to any station on B
  - Using the MAC, retransmit each frame on B
  - Do the same for B-to-A traffic
- Some design aspects of a bridge:
  - Bridge does not modify the content or format of frames; nor does it add any more headers; it simply copies the received frame and retransmits (it can do this easily because same LAN protocol is used)
  - Bridge contains buffer space to meet peak demand; sometimes frames may arrive much faster than the bridge can retransmit (hence the frames have to be buffered)
  - Bridge must know something about addressing and routing – at minimum, it must know which addresses are on LAN A and which addresses on LAN B
  - Bridge can interconnect more than two LANs (in which case each bridge must know more addressing/routing information)

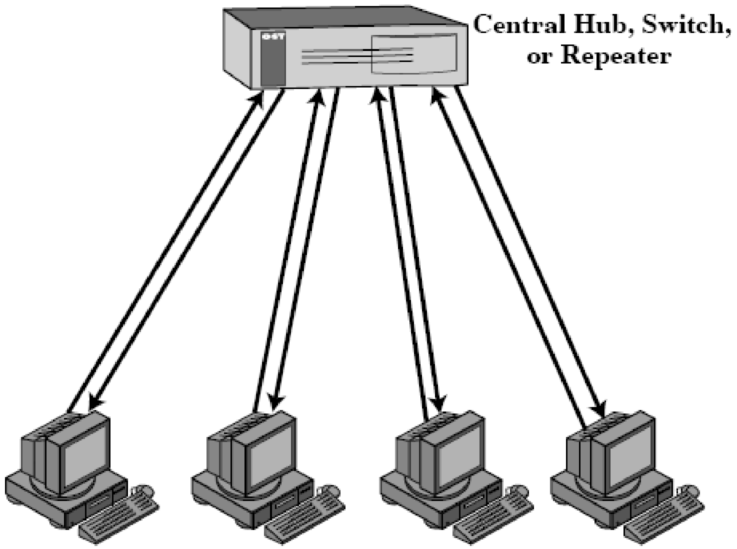
Connecting Multiple LANs

- Station 1 transmits a frame destined to station 6
- Bridges 101, 107 and 102 will receive on LAN A
- Only bridge 102 should retransmit
- Then bridge 105 and 106 will receive on LAN C
- Only bridge 105 should retransmit
- Then Station 6 will receive on LAN F
- Bridges require complex routing information
  - Need to know when to retransmit (forward) and when not to
  - Sometimes multiple paths (for reliability) – should chose the best
  - Fixed routing is often not good
  - Use the Spanning Tree Protocol



LAN Elements: Hubs

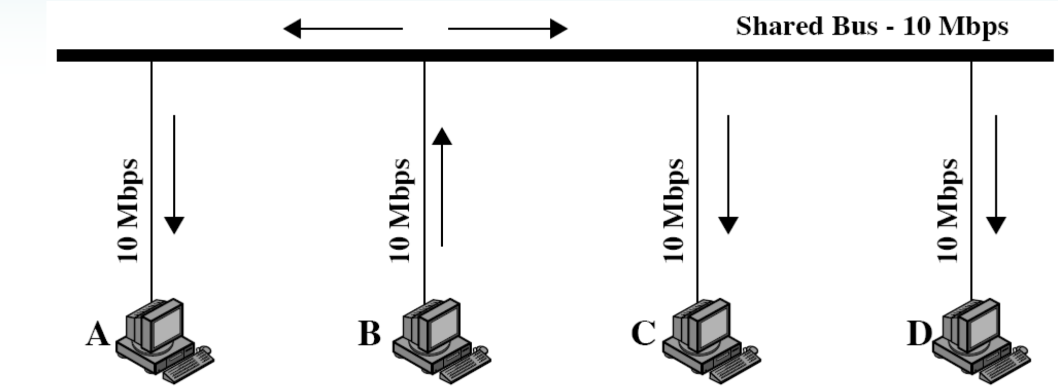
- In the star topology, a hub retransmits a received frame to all other stations
- This is effectively a bus: if two stations transmit at a time, then there will be a collision
- Often hubs are used in wiring closets in buildings to connect all computers on one floor; this suits the typical wiring of buildings today (wires from each office go to a central wiring closet)



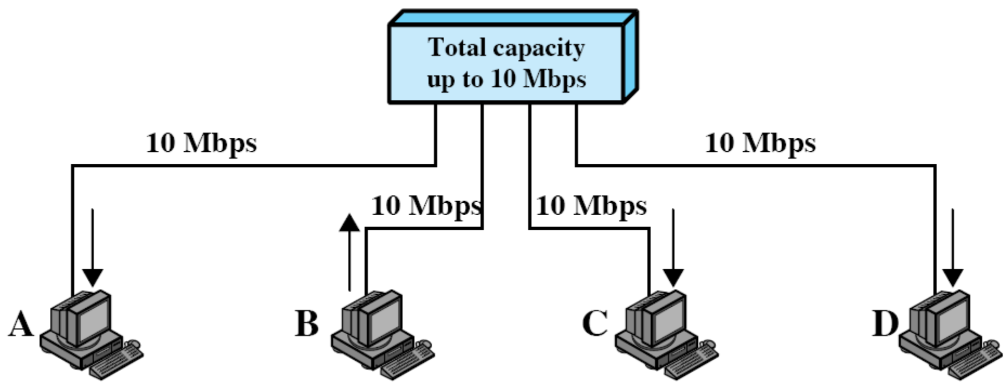
LAN Elements: Switches

- Switch used in same configuration as hub but only retransmits on a single line (not all)
  - Also called “layer 2 switch” or “switching hub”
- More complex than hub
  - Hub simply transmits the frame to everyone
  - Switch needs to look at destination of frame, and transmit only to that station
- But switch is more common today because:
  - Increase in performance in switched LAN (see next slide)
  - Easy to upgrade from bus or hub to switch: all the stations use the same protocol/hardware, just connect the cables to switch
  - Easy to scale network by adding more ports to switch
- Switches can perform functions of bridges as well
  - Today, most devices sold are switches that include bridge functionality

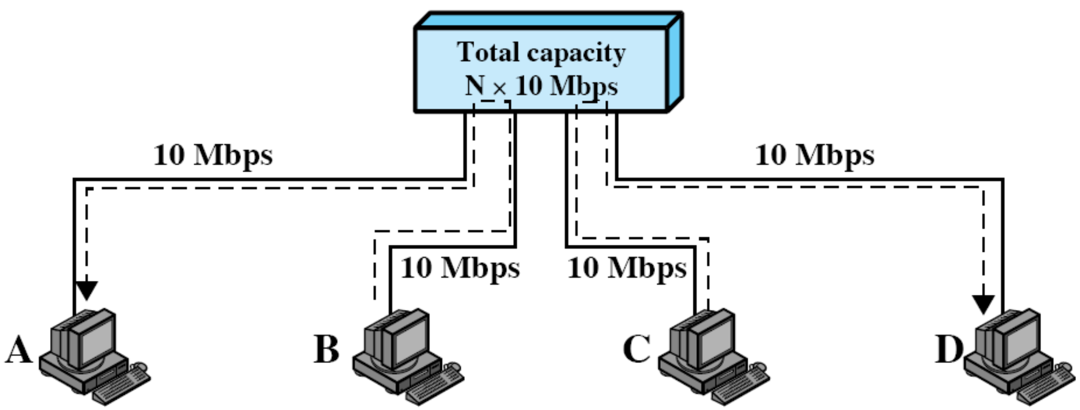
Switch Performance



Bus topology: only one station can transmit at a time; share LAN capacity between stations
e.g. 10/4 = 2.5Mb/s per station



Hub: only one station can transmit at a time; share LAN capacity between stations
e.g. 10/4 = 2.5Mb/s per station



Switch: each station can transmit at same time; dedicated LAN capacity for each station
e.g. 10Mb/s per station

High Speed LAN Technologies

- Some of the early standards for LANs were:
  - IEEE 802.3 bus- or star-based Ethernet
  - IEEE 802.5 ring-based Token Ring
- Ethernet, and its many enhancements, has become the most dominant LAN technology today
  - Ethernet (10Mb/s), Fast Ethernet (100Mb/s), Gigabit Ethernet (1Gb/s), 10GBe (10Gb/s), …
  - Alternatives today include Fibre Channel (up to 4Gb/s) and IEEE 802.11 Wireless LAN (54Mb/s and up)

	Fast Ethernet	Gigabit Ethernet	Fibre Channel	Wireless LAN
Data Rate	100 Mbps	1 Gbps, 10 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

Ethernet MAC

- IEEE 802.3 Ethernet uses a contention-based MAC protocol called:
  - Carrier Sense Multiple Access (CSMA) with Collision Detection (CD)
  - Aimed to ensure only one station transmits at a time, so to avoid collisions
    - A collision is when two (or more) frames are sent on the medium at the same time – they interfere with each other, and neither are received, meaning costly (in terms of performance) retransmissions are needed
  - With CSMA/CD the utilisation is less than 80% for more than 5 nodes; hence throughput of 10Mb/s Ethernet is typically between 5 and 8Mb/s
    - This is shared between stations: with 10 stations, each station gets 800kb/s
- However, Fast Ethernet uses a switched topology: each station has a dedicated link to the switch – there is no chance of collisions
  - But the same IEEE 802.3 MAC frame format and protocol are used on Fast Ethernet so it is compatible with older 10Mb/s Ethernet
    - LANs with mixture of 10Mb/s Ethernet and 100Mb/s Fast Ethernet devices can be deployed
  - Throughput can approach 90% with no collisions, hence each station gets 90Mb/s with Fast Ethernet!

IEEE 802.3 Specifications

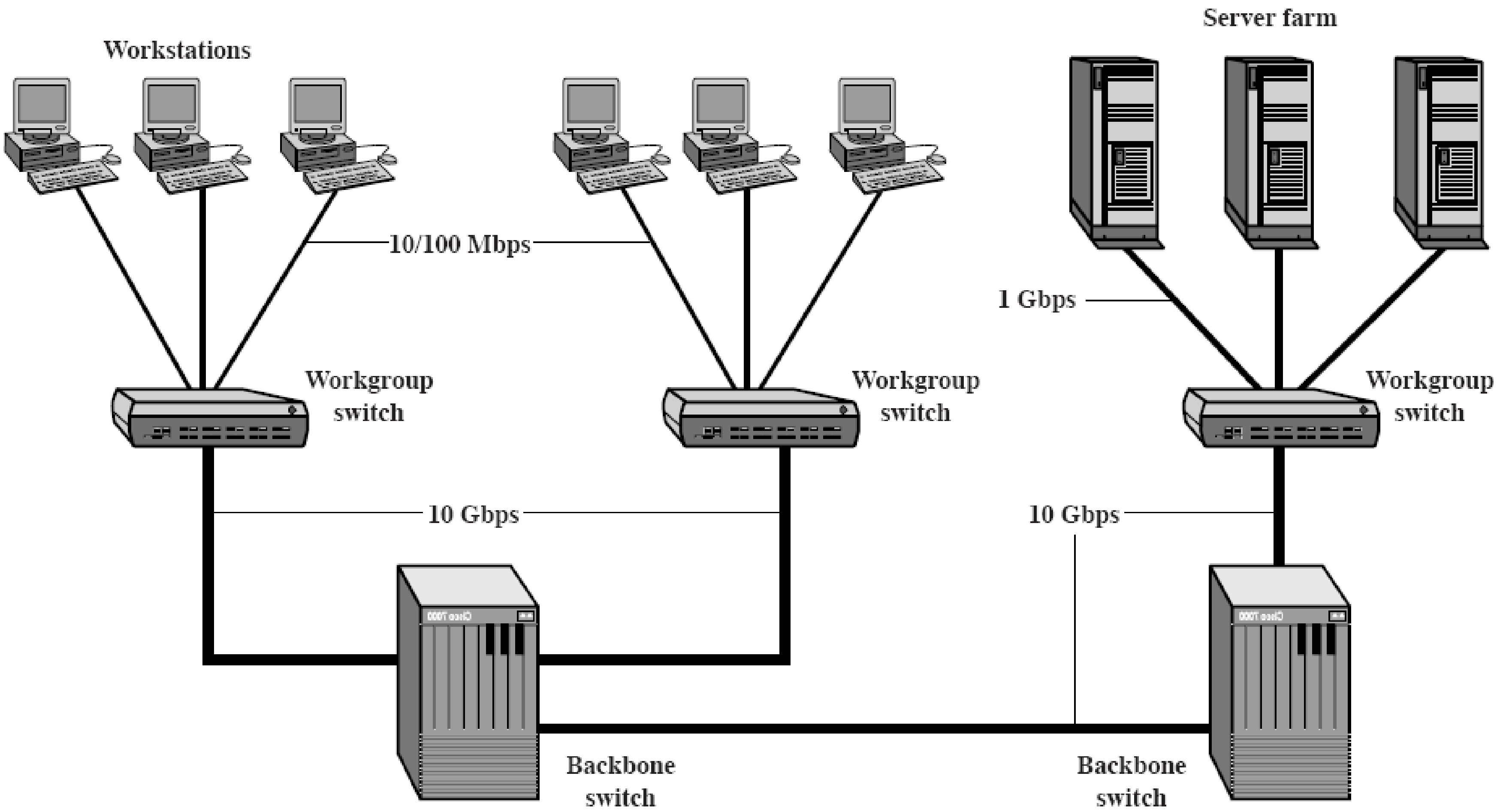
10Mb/s Ethernet

	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

100Mb/s 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

Example Ethernet Configuration



Ethernet Addressing

- Ethernet (IEEE 802.3) uses an IEEE standardised 48 bit address
  - Known as EUI-48 or MAC-48, but often referred to in general terms as “MAC address”, “Hardware address”, “Network Interface Card (NIC) address”, “Ethernet address”, and others
  - These addresses are also used by other Data Link layer protocols: Bluetooth, Wireless LAN (IEEE 802.11), ATM, Token Ring (IEEE 802.5), FDDI, Fibre Channel, …
- IEEE 48-bit addresses
  - Globally unique
    - IEEE typically assign a unique first 24 bits to companies that manufacturer cards (e.g. Dell, 3Com, Intel). Each company then assigns a unique last 24 bits to each device they manufacture
    - Individual users can “override” the assigned address (hence possibly that addresses are not globally unique) – used in security attacks
  - Usually represented as hexadecimal, e.g. 00:17:31:5A:E5:89
- IEE 64-bit addresses
  - Newer addresses used in Firewire, ZigBee/IEEE 802.15.4 and IPv6