Ethernet LAN and Extended LAN

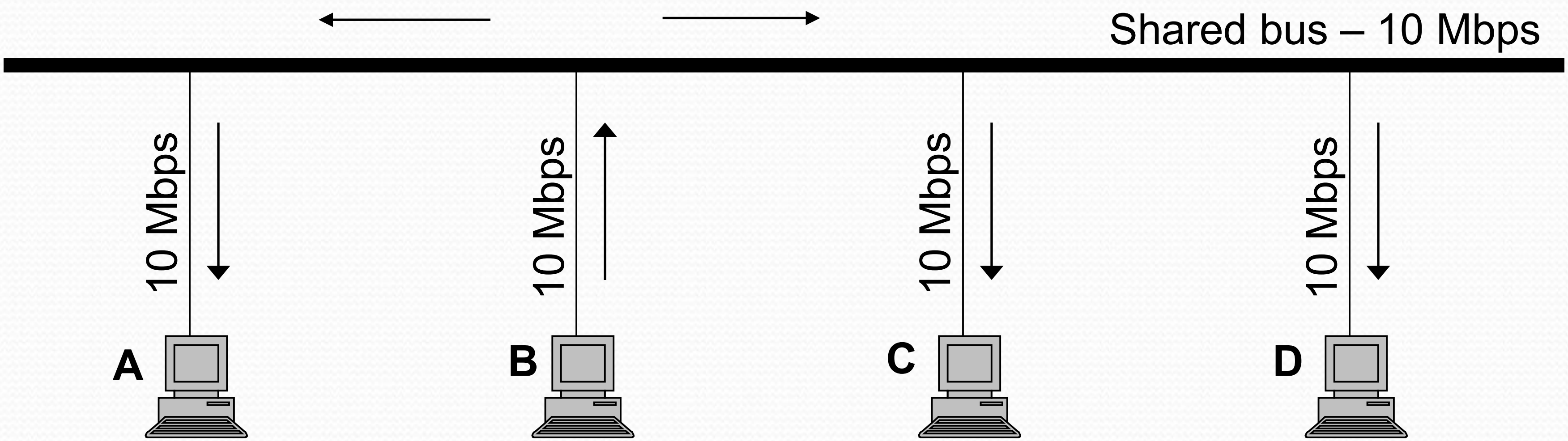
Key Reference:

Peterson and Davie, "Computer Networks: A Systems Approach", 4th Edition, Morgan Kaufmann, 2007

Medium Access Control (MAC)

- Broadcast LAN (See Figure in next slide)
- MAC is a sublayer of the data link layer (Layer 2)
- MAC is to control access to multi-access (multiple-access or random access) channels (links, lines)
- When more than one host share a channel we need MAC
- Usually used in LANs
- Ethernet (IEEE 802.3 standard) (popularly used)
- Token ring (802.5, FDDI) (not popular now)
- Wireless (802.11) (popularly used)

Ethernet Broadcast LAN



Ethernet Cabling

- In traditional Ethernet, hosts are connected to Ethernet cable (shared bus) through adapters
  - Coaxial cable, half-duplex, Up to 10 Mbps,
- Length: Max 2500m
  - There can be at most 5 segments (length up to 500 m)separated by 4 repeaters.
- Later hub and switch based Ethernet evolved
  - Eg: twisted-pair cable based star-connected hub
- See the table in the next slide which lists a few types of Ethernet and features

Different kinds of Ethernet LANs

Name (10Mbps)	cable	Max segment	Nodes/ segment
10Base5	Thick coax	500 m	100
10Base2	Thin coax	200 m	30
10Base-T	Twisted pair	100 m	1024
10Base-F	Fiber optics	2000 m	1024

Ethernet Frame Format

- Manchester encoding is used (Later 4B/5B & others as well)
  - Low-to-high transition to encode a 0 and high-to-low transition to encode a 1
  - 1: transmit high signal followed by low signal
  - 0: transmit low signal followed by high signal
- Preamble
  - 7 bytes (10101010) used for clock synchronization
  - 1 byte (10101011) used to mark the start of frame
- Type (or length)
  - Used as a demultiplexing key. Usually >1500
    - (eg: VLAN frame, ARP frame)
  - Can also be used as a length field (0 to 1500 bytes)
  - Frame format showing fields and their size (in bits)

64	48	48	16		32
Preamble	Dest addr	Src addr	Type or Len	Body	CRC

Ethernet Addresses

- Addresses
  - Unique world-wide, 48-bit unicast address assigned to each adapter
  - example: **08:c0:65:b1:2a:5d**
  - broadcast: all **1**s: **ff: ff: ff: ff: ff: ff**
  - multicast: first bit is **1 (the rightmost bit of the most significant byte)**
    - First byte is the most significant byte
- Ethernet adapter receives all frames and accepts
  - Frames addressed to it
  - Frames addressed to the broadcast address
  - Frames addressed to a multicast address if instructed
  - All frames if it operates in promiscuous mode (eg: Ethernet switch)

CSMA - CD

- Ethernet uses CSMA-CD technique
- CSMA-CD: carrier sense multiple access – collision detection
- Carrier sense
  - A host senses the link and can distinguish if the link is idle or busy (if there is any signal transmission going on the link or not)
- Collision detect
  - A host listens what it is transmitting and therefore can detect if it collides with any other frame transmitted by some other host

1-Persistent CSMA

- p-persistent CSMA
  - If a host is ready to send a frame, it continuously senses the channel (link). If it is idle, then transmit frame with probability p
- 1-persistent CSMA
  - If a host is ready to send a frame, it continuously senses the channel (link). If it is idle, then transmit frame with probability 1
  - Ethernet uses 1-persistent protocol

Transmit Algorithm

- A node (host) can transmit independent of what other nodes (hosts) are doing.
- uses *exponential backoff algorithm* to dynamically adapt to the number of nodes (hosts) trying to send
  - To estimate the number of active hosts in the event of collisions
- If line (link) is idle…
  - send immediately
  - upper bound message size of 1500 bytes
- If line (link) is busy…
  - wait until idle and transmit immediately

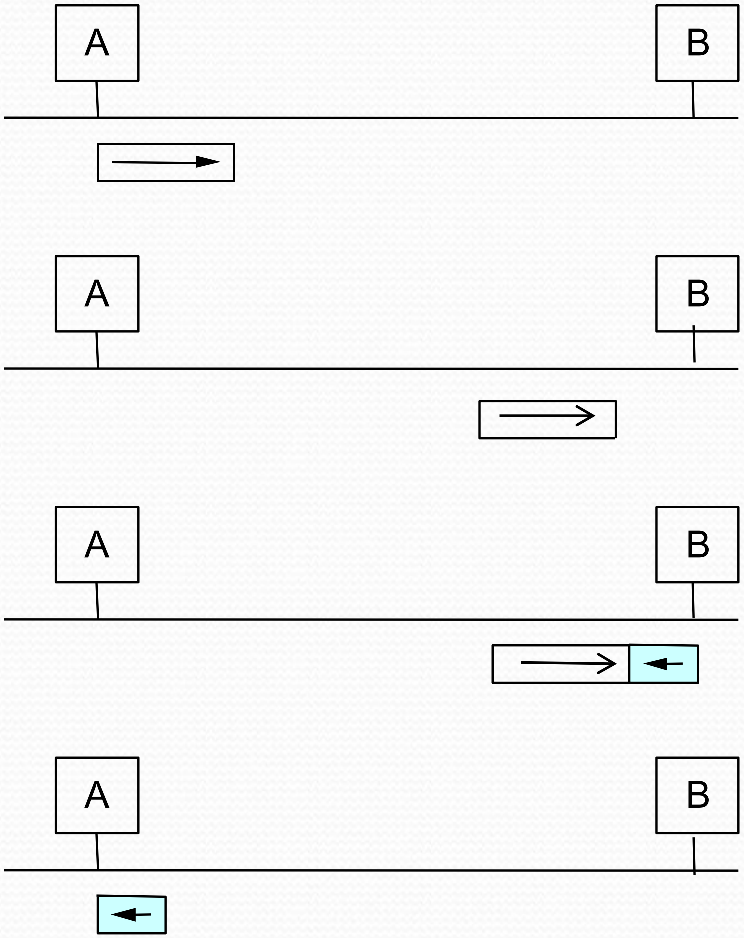
Transmit Algorithm (contd.)

- If collision…
  - Transmit a 32 bit jamming sequence (noise burst) along with 64 bit preamble, then stop transmitting frame (Why jam signal?)
  - delay and try again
  - 1st collision: waits for n slots where n is chosen randomly from the interval [0,1], 1 slot is usually 51.2μs
  - 2^{nd} consecutive collision: waits for n slots where n is chosen randomly from the interval [0,3]
  - i^{th} consecutive collision: waits for n slots where n is chosen randomly from the interval $[0,2^i -1]$
    - for $i > 10$, the interval used is $[0,2^{10} -1]$
    - give up after several tries (usually 16)

Minimum frame size

- Minimum size is 64 bytes: 14 bytes header 46 bytes data, and 4 bytes CRC (WHY?) A situation should not arise wherein, the sending host has transmitted the frame, without detecting any collision, but there is actually a collision
- From the Figure (shown in next slide, see reference book Peterson and Davie), it is observed that a host needs to send for "RTT" to detect all possible collisions (Tf >= RTT)
  - Host A finds the link is free and sends a frame
  - Just before the arrival of frame bits, host B finds that the link is free and starts transmitting a frame
  - Collision occurs near host B's link interface which is detected by Host B; jam signal is sent by host B
  - If host A does not transmit its frame for "RTT", it cannot detect collision
    - Because it has stopped frame transmission when the jam signal reaches
- Ethernet length is limited to 2500 m and four repeaters; for this case RTT is estimated to be bound by 51.2μs = 512 bits for 10 Mbps Ethernet Tf = size/B
- [Why jam signal?] If host B terminates its transmission after sending only a very few bits without jam sequence, host A may not receive sufficient energy to detect collision

Need for minimum frame size



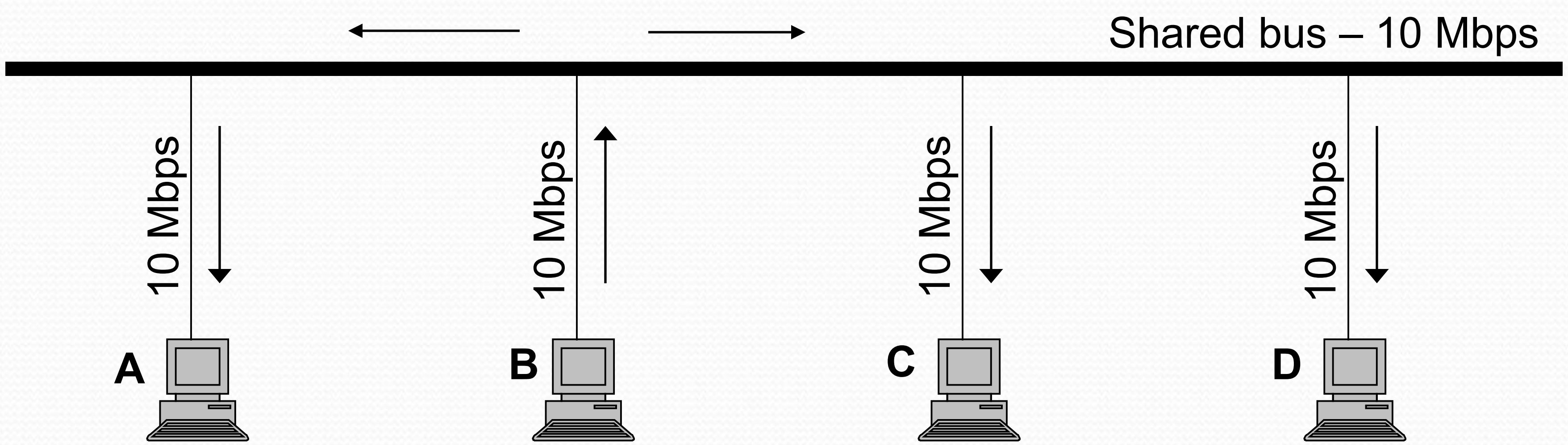
LAN Hubs and Switches

- Shared-Medium Bus (also referred to as a bus)
  - popular from late 1970s to early 1990s
- Shared-Medium Hub (also referred to as a hub)
  - popular from late 1990s
- Switching Hub (also referred to as a switch)
  - popular from early 2000s

Bus-based LAN

- Shared-Medium Bus (or simply a bus)
  - Bus configuration
  - Traditional Ethernet (e.g. 10BASE 5)
  - Single collision domain
    - Set of nodes (hosts) wherein a frame sent by a node can possibly collide with frames sent by any other node
  - 10 Mbps Bus LAN
    - 10Mbps shared by all hosts; total no of bits transmitted by all hosts in one second is at most 10 million
  - All stations (hosts) share the total capacity of the LAN or bus
  - One station transmits, others receive
  - Cable cut disconnects the network

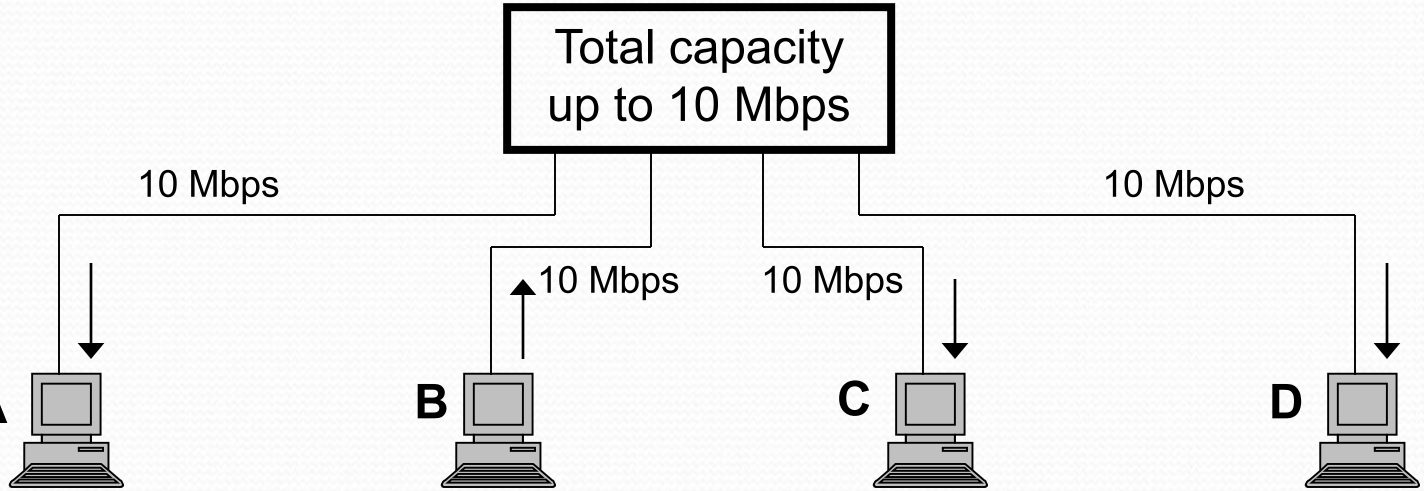
Bus LAN



Hub-based LAN

- Shared-Medium Hub (or simply a hub)
  - Star configuration, e.g. 10BASE-T Ethernet
  - E.g. 802.3u 100 Mbps Fast Ethernet (e.g. 100 BASE T)
  - When a frame is received on a port, the hub copies it to all the other ports
  - Single collision domain, hub transmits jam signal to all when collision occurs
  - All stations share the total capacity of the LAN or hub
    - 10 Mbps Hub LAN: 10Mbps shared by all hosts; total no of bits transmitted by all hosts in one second is at most 10 million
  - One station transmits, others receive
  - Can exploit building wiring practices for cable layout
  - Hub can recognize a malfunctioning station that jams the network and remove it from the network
  - Cable cut does not disconnect the network

Hub LAN

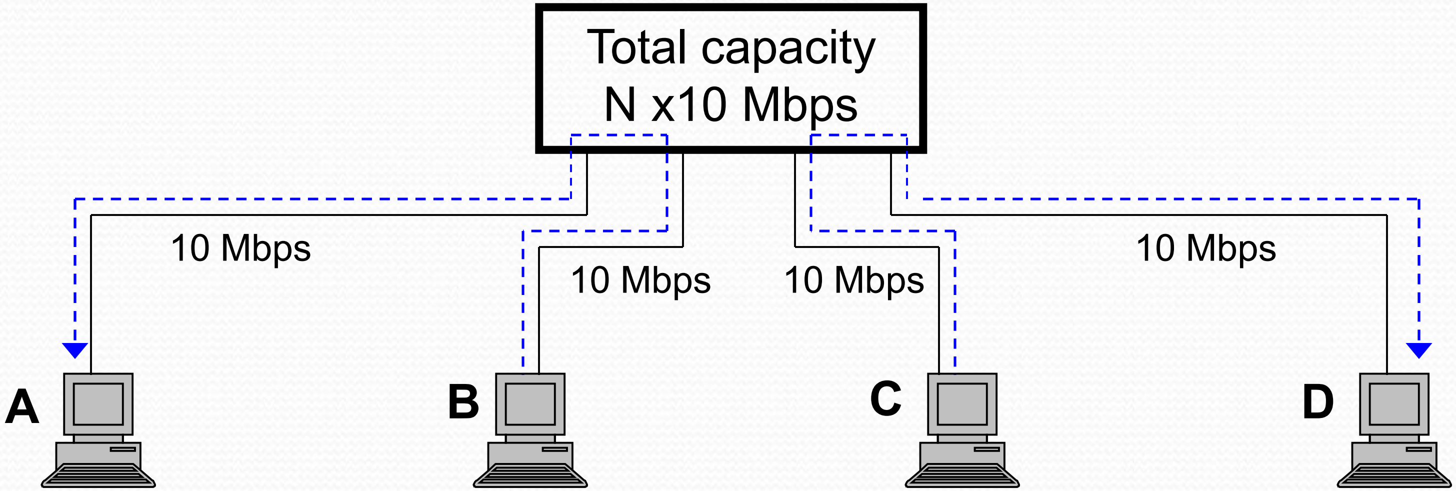


Total capacity
up to 10 Mbps
10 Mbps
10 Mbps
10 Mbps
10 Mbps
A
B
C
D

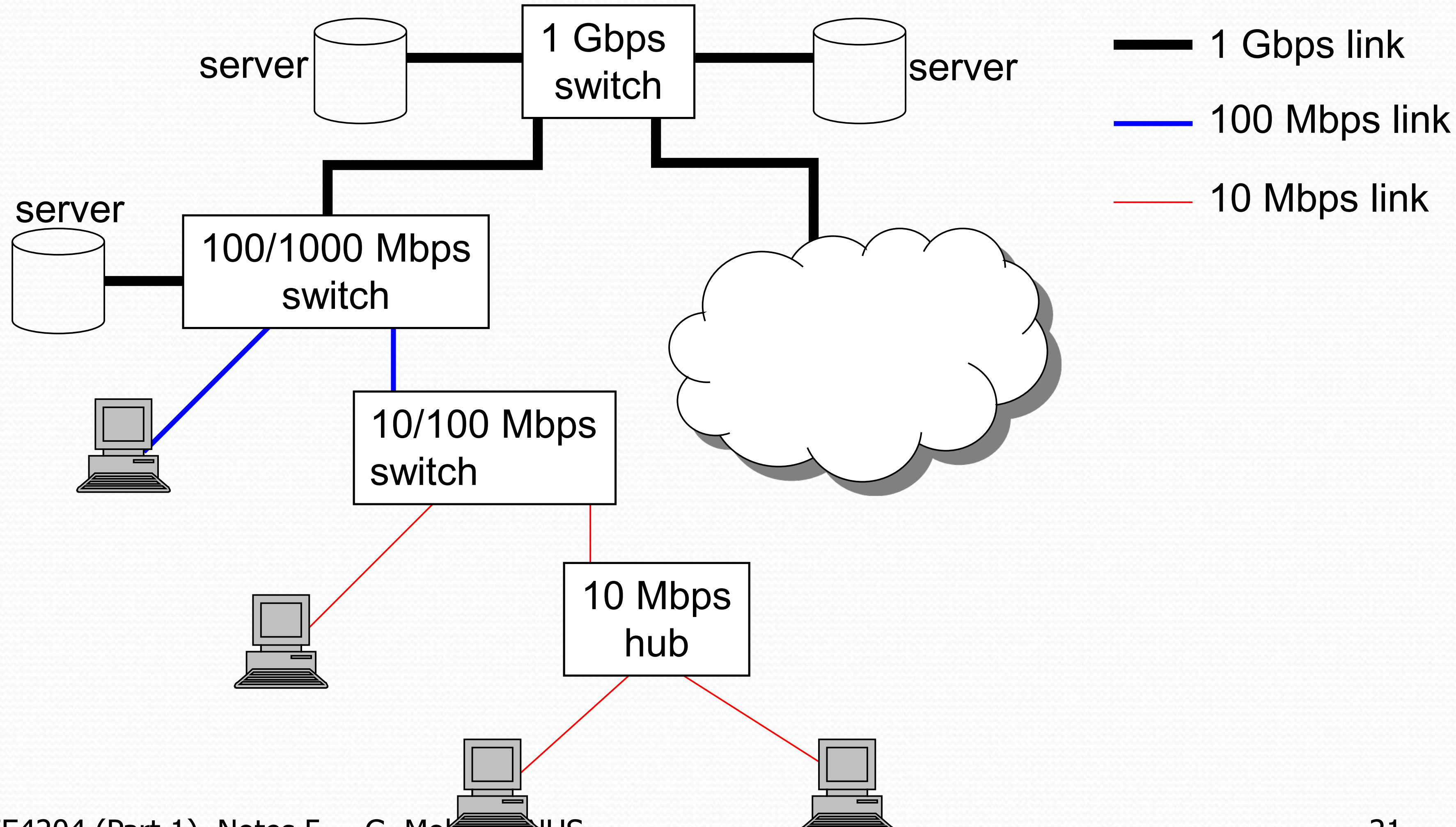
Switch-based LAN

- Switching Hub (or simply a switch)
  - Star configuration
  - E.g. 802.3u 100 Mbps Fast Ethernet (e.g. 100 BASE T)
  - E.g. 802.3z Gigabit Ethernet (e.g. 1000 BASE SX, 1000 BASE LX)
    - SX: short wavelength 0.85 micron, multimode fiber
    - LX: long wavelength 1.3 micron, single mode fiber
  - Store and Forward Packet Switch, use buffer to keep the excess frames
  - No collision between ports, Port is the collision domain, when only one station is connected to a port, there is no collision
  - More than one pair can communicate simultaneously.
    - Switch with N 10-Mbps ports: Total no of bits transmitted by all hosts in one second is at most $N \times 10$ million
  - Cable cut does not disconnect the network
  - Without any change in hardware or software of the attached stations, a bus LAN can be converted into a hub LAN or to a switch LAN.

Switch LAN



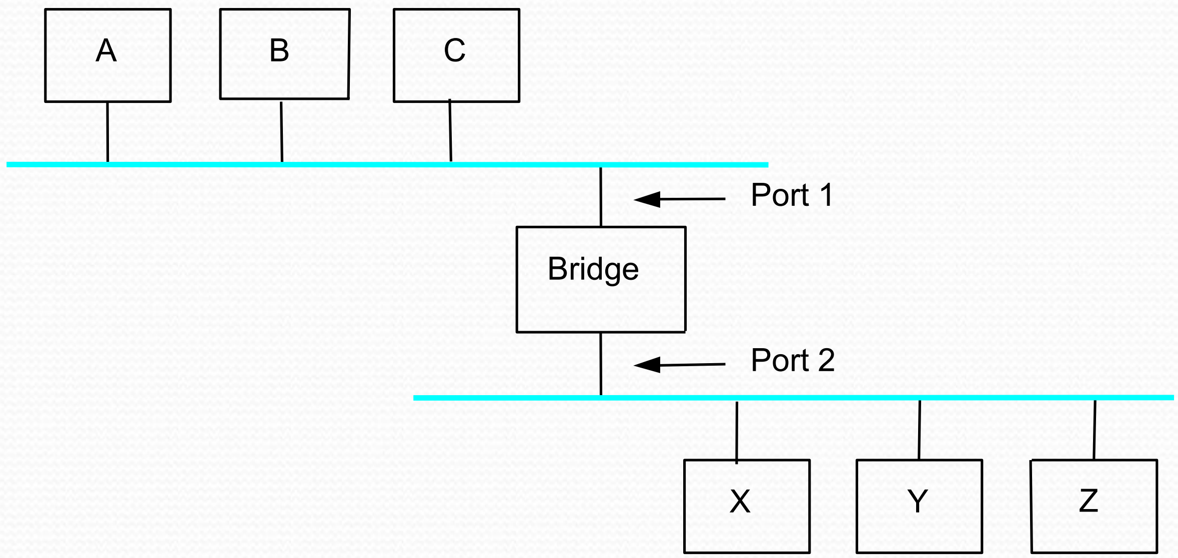
Ethernet Configuration in a Campus Network



Bridges and Extended LANs

- LANs have physical limitations (e.g., 2500m)
- Extended LAN: Interconnection of two or more LANs by one or more bridges
- Note: LAN bridges and switches are similar. In this lecture notes, they can be used interchangeably.
  - Switches (e.g. Ethernet switches) operate at layer 2. Routers (e.g. IP routers) also perform switching function but operate at layer 3 with more intelligent routing techniques
- Source routing bridge
  - Source host attaches complete address to the destination to the frame header ; token ring 802.5 group
- Transparent bridge or Spanning Tree bridge
  - Hosts need (do) not have the knowledge of the presence of bridges; CSMA/CD 802.3 group; WE STUDY TRANSPARENT BRIDGES
- A *bridge (switch)*
  - Operates in promiscuous mode; Multi-input and multi-output switch
  - An Ethernet bridge connecting n number of 10 Mbps Ethernet segments can carry up to 10n Mbps traffic
  - Operates in the data link layer. Uses accept and forward strategy; does not add packet header

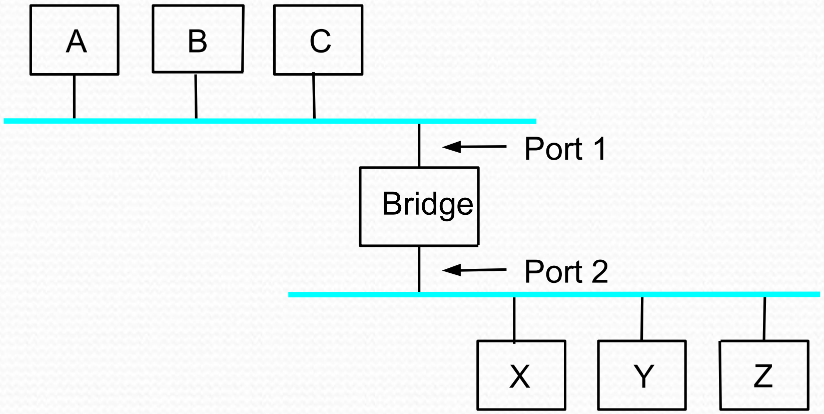
An extended LAN with a bridge



Learning Bridges

- Learn the ports through which a given host can be reached
- Maintain forwarding table

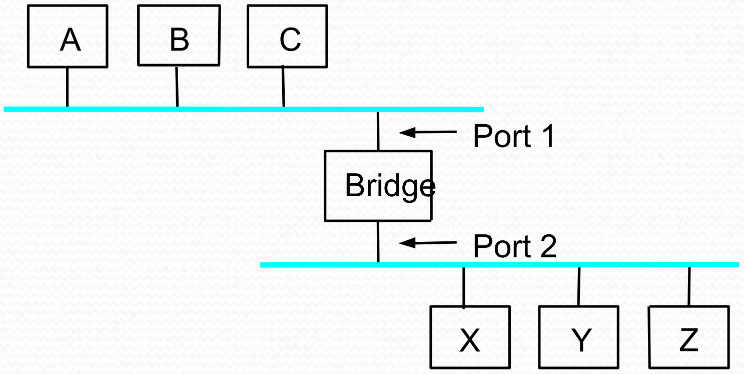
Host	Port
A	1
B	1
C	1
X	2
Y	2
Z	2



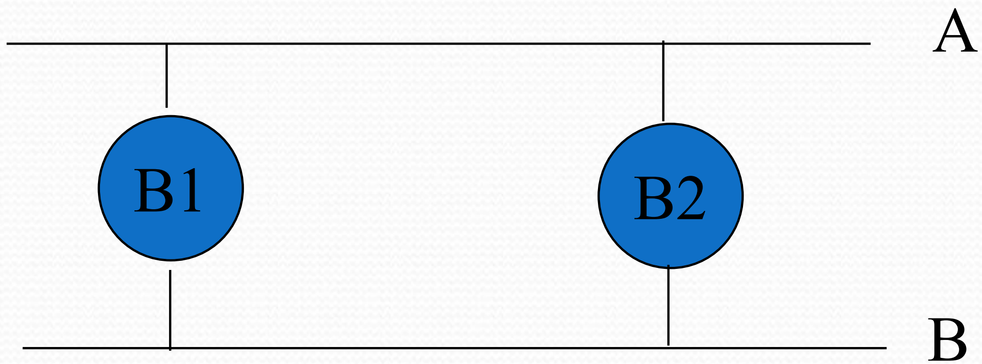
- Learn table entries based on source address
- Table need not be complete; can dynamically change (Why?)
- Always forward broadcast frames

Backward Learning Method

- Initially the forwarding table is empty
- When the bridge sees a frame <A,B> with source A and destination B, it learns where A is; i.e. through which port/interface A can be reached. Since the location of B is not known, the frame is forwarded through all the ports; here port 2; as the frame was received from port 1. An entry for A is made in the table.
- When <Y,A> is received, it is forwarded to port 1 as the bridge has already learnt A's location. Now the bridge learns Y's location and makes an entry in the forwarding table.
- When <B,Z> is received, the port associated with B is learnt. Frame is forwarded to all the ports; in this case, through port 2
- When <C,B> is received, the port associated with C is learnt the bridge does not forward it to port 2 as it already knows that B is on port 1.



Loops - Problem

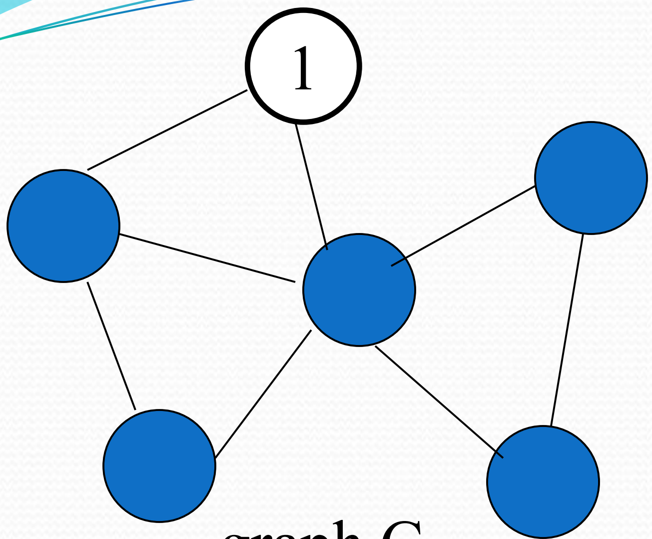


- Loops can exist to increase reliability but it may result in a situation where frames loop forever
- When frame F with unknown destination arrives at LAN B, B1 forwards it to LAN A generating frame F1, B2 forwards to LAN B generating frame F2. B1 on seeing F2 will forward it to LAN A generating F3. Similarly B2 on seeing F1 will forward it to LAN B generating F4. This continues forever.

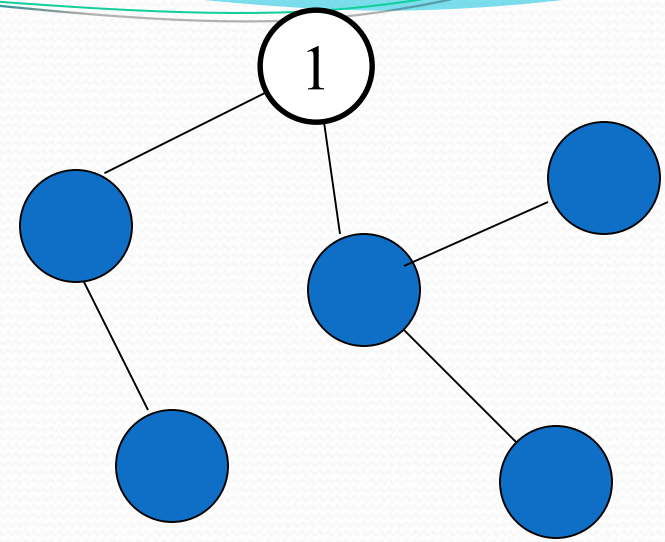
Spanning tree Bridges

- To avoid loops, generate a spanning tree topology over the actual topology
  - Graph: A set of nodes and edges
  - Spanning tree of a graph: subgraph with all nodes and a subset of edges; no loops; unique path from the root to any node; unique path between any two nodes (eg: trees T1 and T2 in the next slide, root: node 1)
  - Shortest path spanning tree: formed by shortest paths from the root to every other node (eg.: tree T1 in the next slide; root: node 1)
- The spanning tree spans all the LANs; but some bridges (or ports) may be (logically) removed to avoid loops
- There is a unique path between any two LANs
- Using a distributed spanning tree algorithm all bridges agree on the spanning tree
  - select which bridges on which ports actively forward
  - developed by Radia Perlman
  - now IEEE 802.1 D specification

SPANNING TREE : EXAMPLE

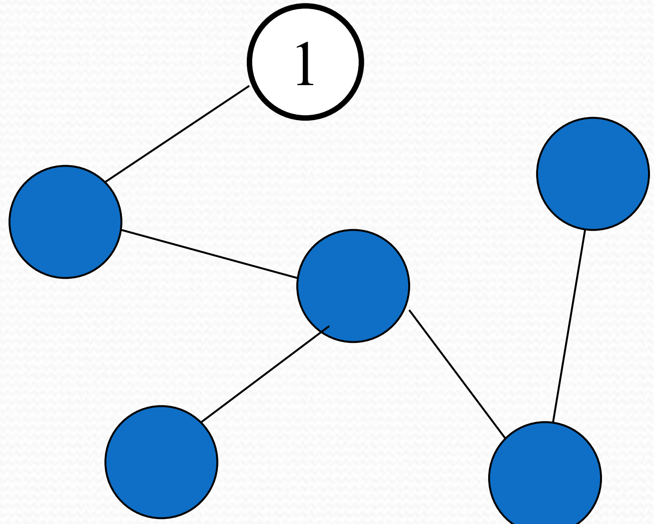


graph G



s.tree T1 of G. Shortest path spanning tree.

Node 1 is the root.



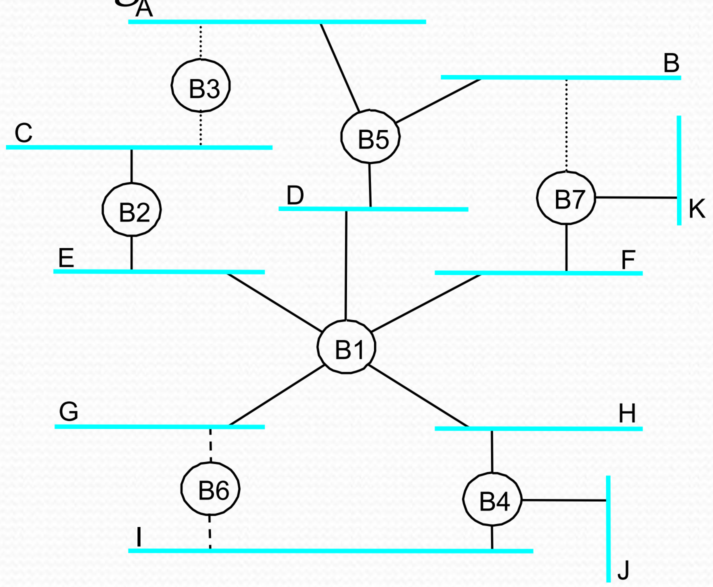
s.tree T2 of G

Node 1 is the root.

Spanning Tree Algorithm Overview

- Each bridge has unique id (e.g., B1, B2, B3) (*See figure - Ref book by Peterson and Davie)*
- Select bridge with smallest id as root
- Create a tree of shortest paths from every bridge to the root
- Select bridge on each LAN closest to root as designated bridge (use id to break ties)
- Forward frames following the spanning tree.

- Each bridge forwards frames over each LAN for which it is the designated bridge



Algorithm Details

- Bridges exchange configuration messages:(Y,d,X)
  - Id (X) for bridge sending the message
  - id (Y) for what bridge X believes to be root bridge
  - distance (hops) (d) from sending bridge to root bridge
- Each bridge records current best configuration message for each port
- Initially, each bridge believes it is the root
  - Send (X,o,X)

Algorithm Detail (contd.)

- When learn not root, stop generating config messages
  - in steady state, only root generates configuration messages
- When learn not designated bridge, stop forwarding config messages
  - in steady state, only designated bridges forward config messages
- Root continues to periodically send config messages
- If any bridge does not receive config message after a period of time, it starts generating config messages claiming to be the root

Spanning Tree Algorithm: An illustration

- B3 receives (B2, 0, B2) on LAN C
  - B3: accepts B2 as root since 2<3; sends (B2, 1, B3) to B5 on LAN A
- B2 receives (B1, 0, B1) on LAN E
  - B2 accepts B1 as root; sends (B1,1,B2) to B3 on LAN C
- B5 receives (B1, 0, B1) on LAN D
  - B5 accepts B1 as root; sends (B1,1,B5) to B3 on LAN A
- B3 receives (B1, 1, B2) from B2 on LAN C
  - B3 accepts B1 as root;
  - stops forwarding to LAN C as B2 is closer to B1 than itself
- B3 receives (B1, 1, B5) from B5 on LAN A.
  - B3 accepts B1 as root; stops forwarding to LAN A as B5 is closer to B1 than itself