CSCI-1680 - Computer Networks

Link Layer III:
LAN & Switching

Chen Avin

Based partly on lecture notes by David Mazières, Phil Levis, John Jannotti, Peterson & Davie, Rodrigo Fonseca

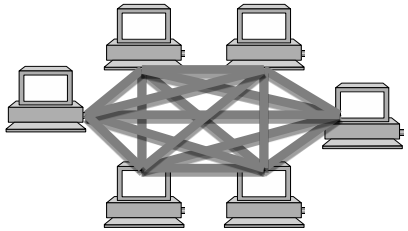
Today: Link Layer (cont.)

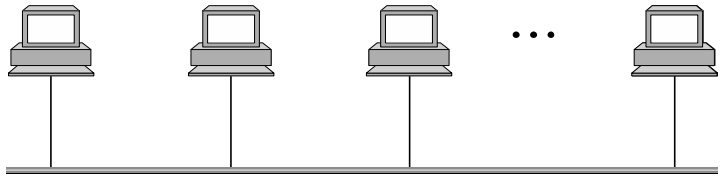
- Framing
- Reliability
  - Error correction
  - Sliding window
- Medium Access Control
- Case study: Ethernet
- **Link Layer Switching**

Switching

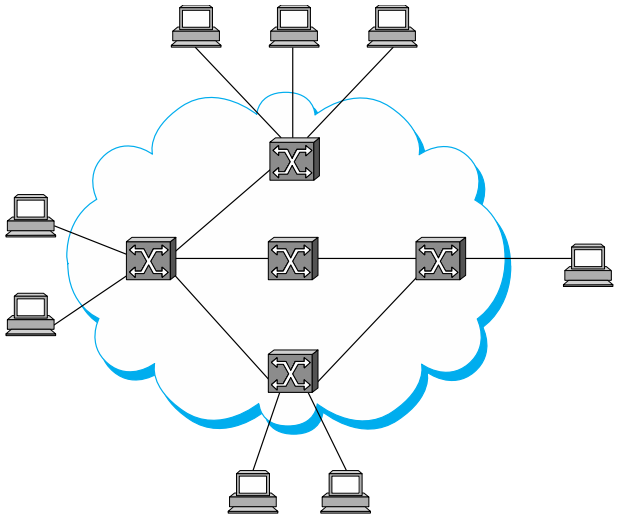
Basic Problem

- **Direct-link networks don't scale**

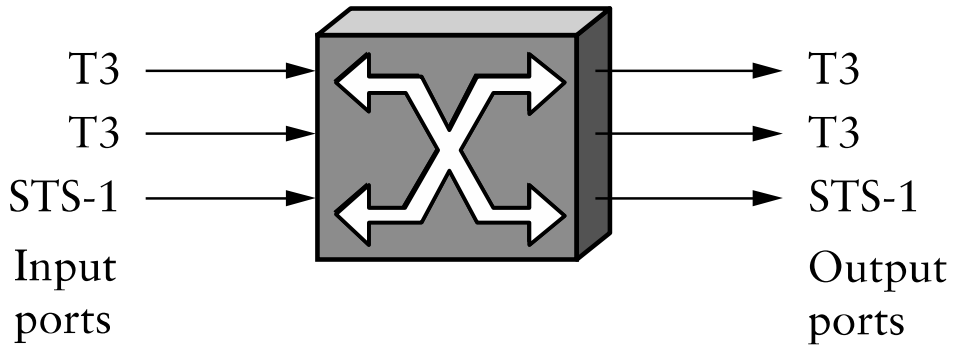




- **Solution: use *switches* to connect network segments**

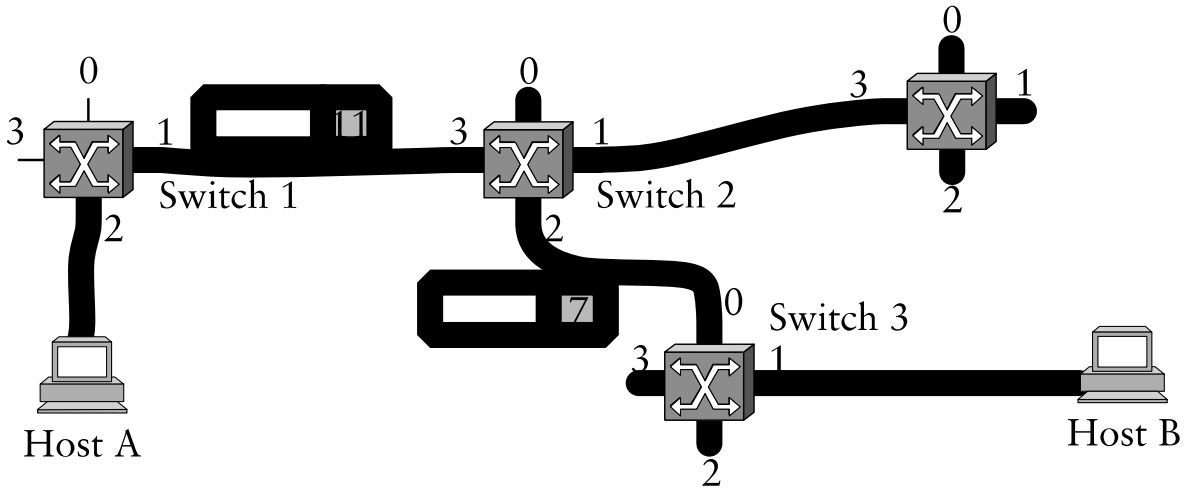


Switching



- **Switches must be able to, given a packet, determine the outgoing port**
- **Store and Forward**
- **3 ways to do this:**
  - Virtual Circuit Switching
  - Datagram Switching
  - Source Routing

Virtual Circuit Switching

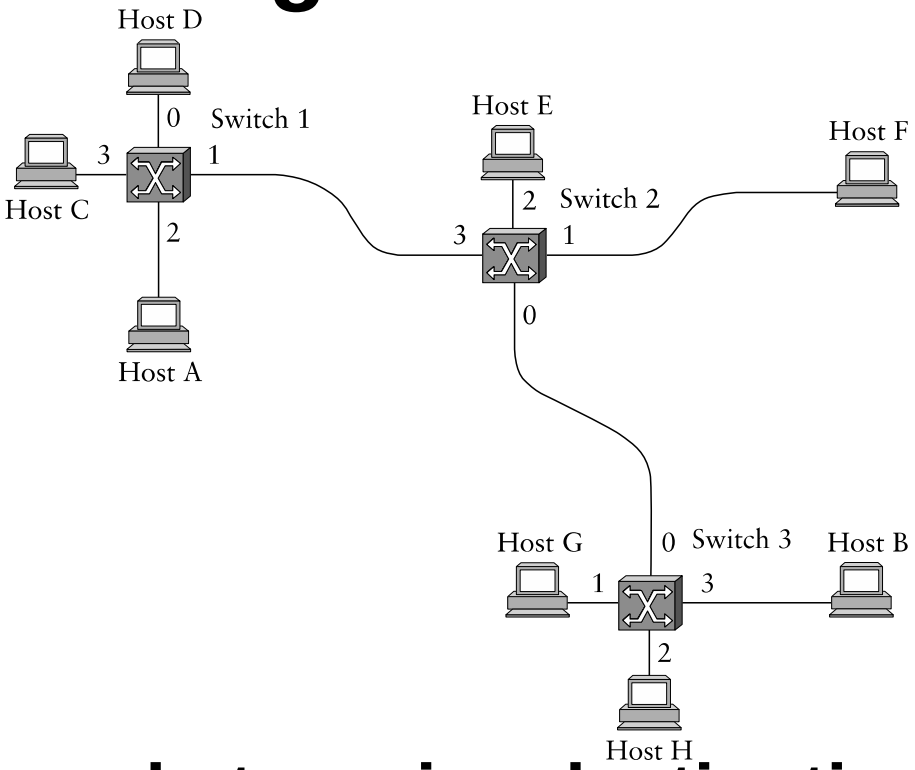


- **Explicit set-up and tear down phases**
  - Establishes Virtual Circuit Identifier on each link
  - Each switch stores VC table
- **Subsequent packets follow same path**
  - Switches map [in-port, in-VCI] : [out-port, out-VCI]
- **Also called *connection-oriented* model**

Virtual Circuit Model

- **Requires one RTT before sending first packet**
- **Connection request contain full destination address, subsequent packets only small VCI**
- **Setup phase allows reservation of resources, such as bandwidth or buffer-space**
  - Any problems here?
- **If a link or switch fails, must re-establish whole circuit**
- **Example: ATM**

Datagram Switching



Switch 2

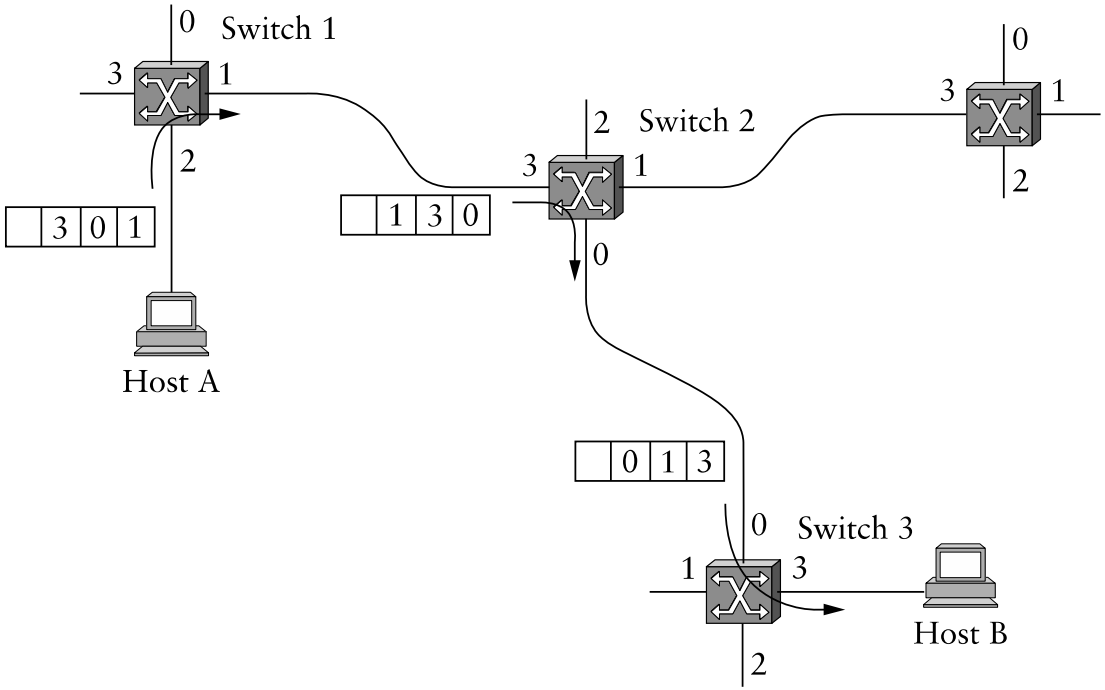
Addr	Port
A	3
B	0
C	3
D	3
E	2
F	1
G	0
H	0

- **Each packet carries destination address**
- **Switches maintain address-based tables**
  - Maps [destination address]:[out-port]
- **Also called *connectionless* model**

Datagram Switching

- No delay for connection setup
- Source can’t know if network can deliver a packet
- Possible to route around failures
- Higher overhead per-packet
- Potentially larger tables at switches

Source Routing

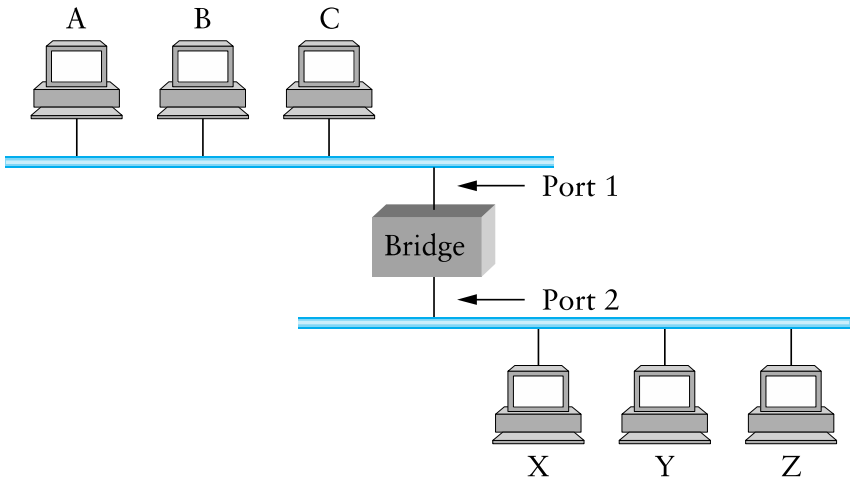


- **Packets carry entire route: ports**
- **Switches need no tables!**
  - But end hosts must obtain the path information
- **Variable packet header**

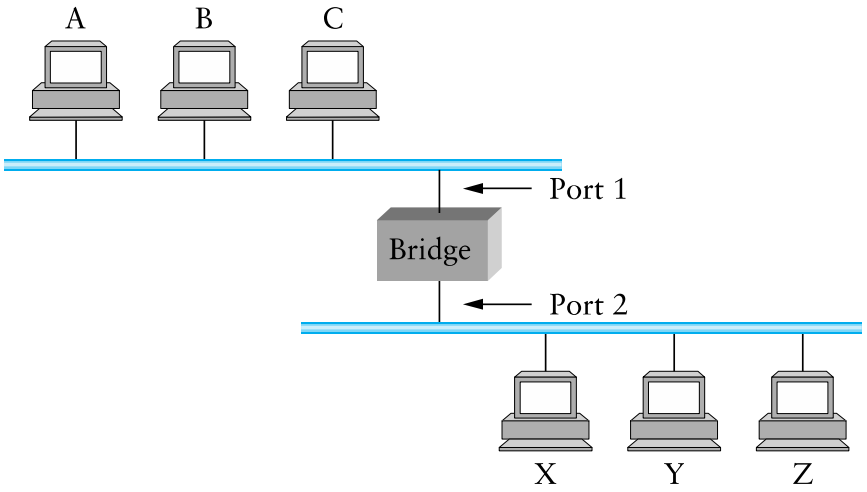
Bridging

Bridges and Extended LANs

- **LANs have limitations**
  - E.g. Ethernet < 1024 hosts, < 2500m
- **Connect two or more LANs with a *bridge***
  - Operates on Ethernet addresses
  - Forwards packets from one LAN to the other(s)
- **Ethernet *switch* is just a multi-way bridge**



Learning Bridges



- **Idea: don't forward a packet where it isn't needed**
  - If you know recipient is not on that port
- **Learn hosts' locations based on source addresses**
  - Build a table as you receive packets
  - Table is a *cache*: if full, evict old entries. Why is this fine?
- **Table says when *not* to forward a packet**
  - Doesn't need to be complete for *correctness*

Attack on a Learning Switch

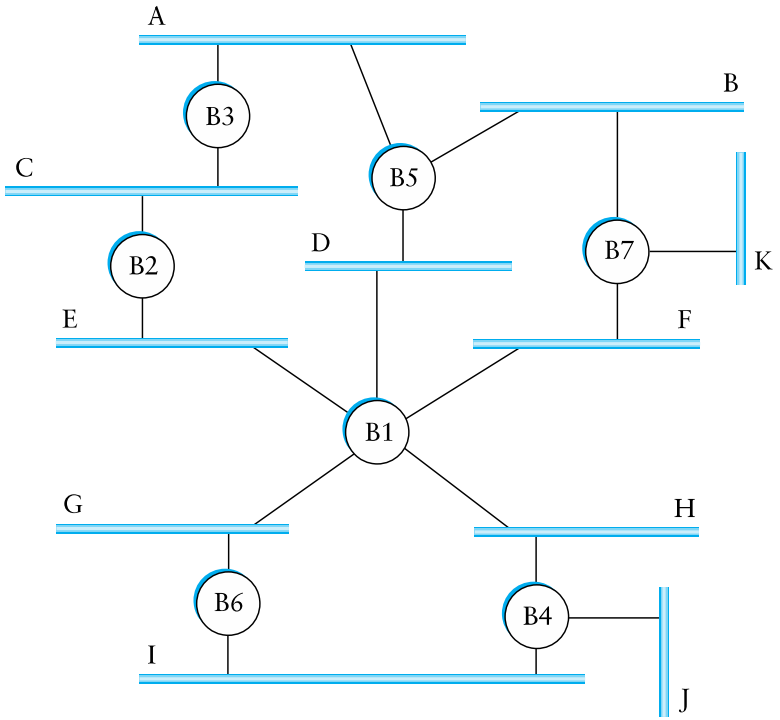
- **Eve: wants to sniff all packets sent to Bob**
- **Same segment: easy (shared medium)**
- **Different segment on a learning bridge: hard**
  - Once bridge learns Bob's port, stop broadcasting
- **How can Eve force the bridge to keep broadcasting?**
  - Flood the network with frames with spoofed src addr!

Bridges

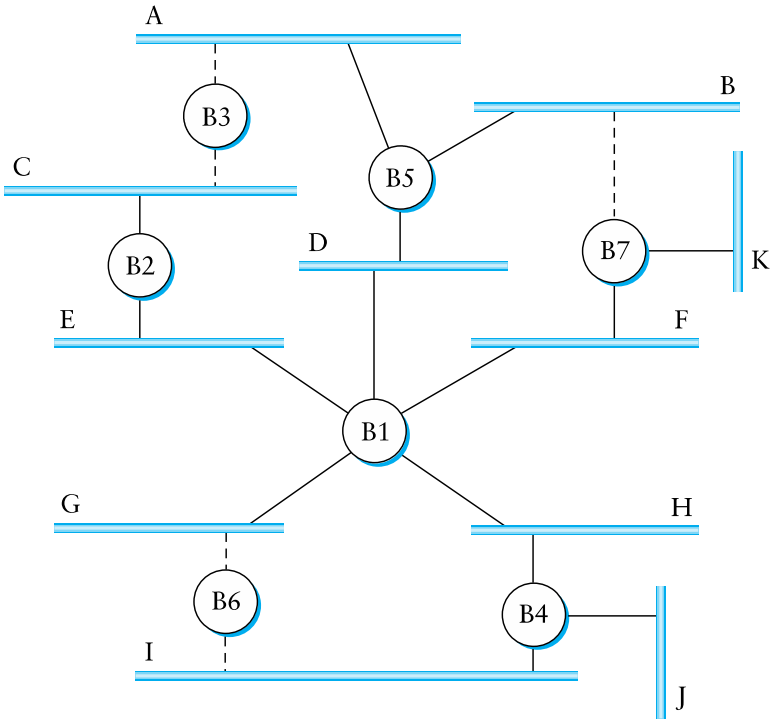
- **Unicast: forward with filtering**
- **Broadcast: always forward**
- **Multicast: always forward or learn groups**
- **Difference between bridges and repeaters?**
  - Bridges: same broadcast domain; copy *frames*
  - Repeaters: same broadcast and *collision domain*; copy *signals*

Dealing with Loops

- **Problem: people may create loops in LAN!**
  - Accidentally, or to provide redundancy
  - Don't want to forward packets indefinitely



Spanning Tree



- **Need to disable ports, so that no loops in network**
- **Like creating a spanning tree in a graph**
  - View switches and networks as nodes, ports as edges

Distributed Spanning Tree Algorithm

- **Every bridge has a unique ID (Ethernet address)**
- **Goal:**
  - Bridge with the smallest ID is the root
  - Each segment has one designated bridge, responsible for forwarding its packets towards the root
    - Bridge closest to root is designated bridge
    - If there is a tie, bridge with lowest ID wins

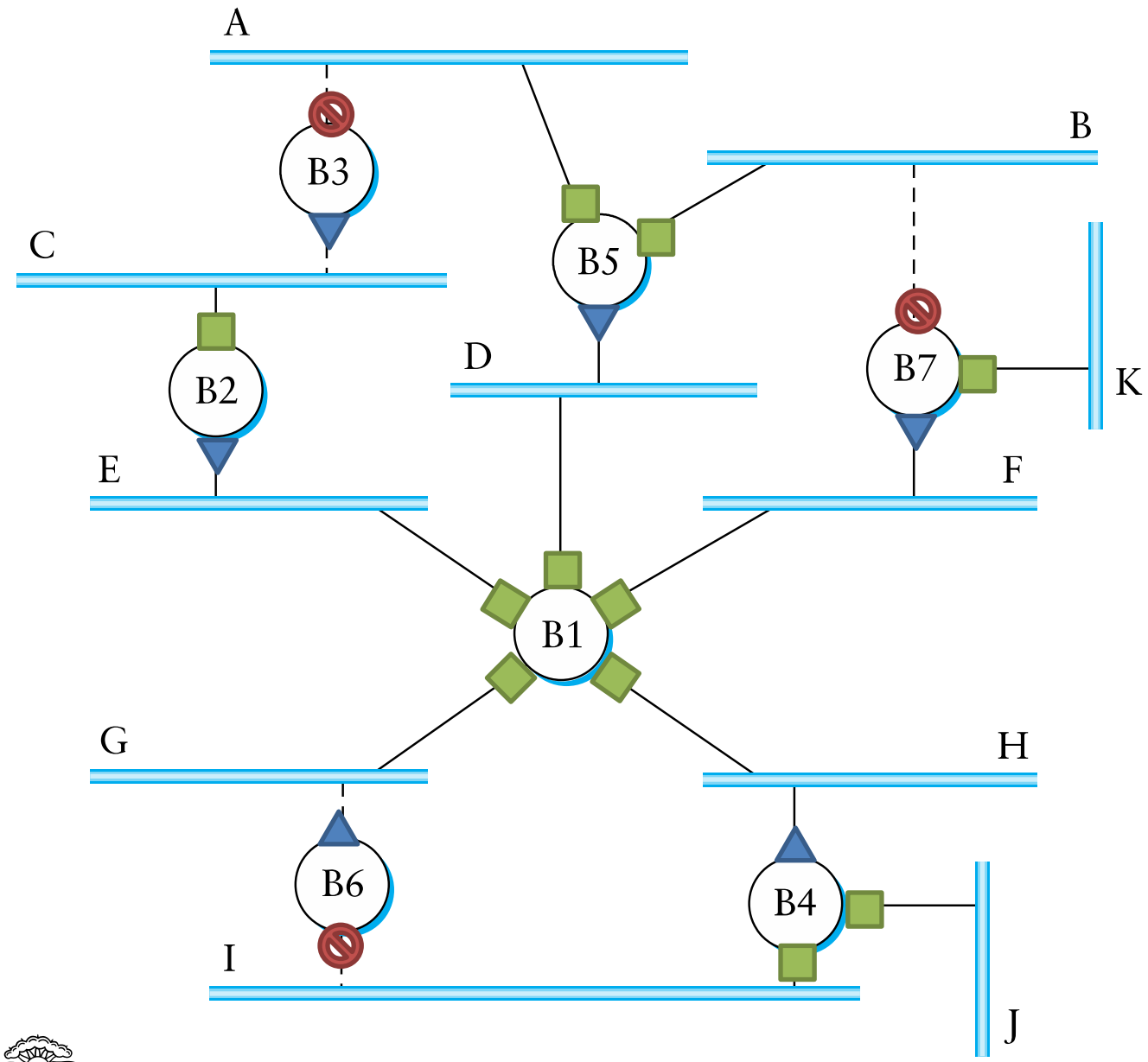
Spanning Tree Protocol

- **Spanning Tree messages contain:**
  - ID of bridge sending the message
  - ID sender believes to be the root
  - Distance (in hops) from sender to root
- **Bridges remember best config msg on each port**
- **Send message when you think you are the root**
- **Otherwise, forward messages from best known root**
  - Add one to distance before forwarding
  - Don’t forward if you know you aren’t dedicated bridge
- **In the end, only root is generating messages**

Spanning Tree Protocol (cont.)

- **Forwarding and Broadcasting**
- **Port states*:**
  - **Root port**: a port the bridge uses to reach the root
  - **Designated port**: the lowest-cost port attached to a single LAN
  - If a port is not a root port or a designated port, it is a **discarding port**.

* In a later protocol RSTP, there can be ports configured as backups and alternates.



Root Port

Designated Port

Discarding Port

Algorhyme

I think that I shall never see
a graph more lovely that a tree.
A tree whose crucial property
is loop-free connectivity.
A tree that must be sure to span
so packet can reach every LAN.
First the root must be selected.
By ID, it is elected.
Least cost paths from root are traced.
In the tree, these paths are placed.
A mesh is made by folks like me,
then bridges find a spanning tree.

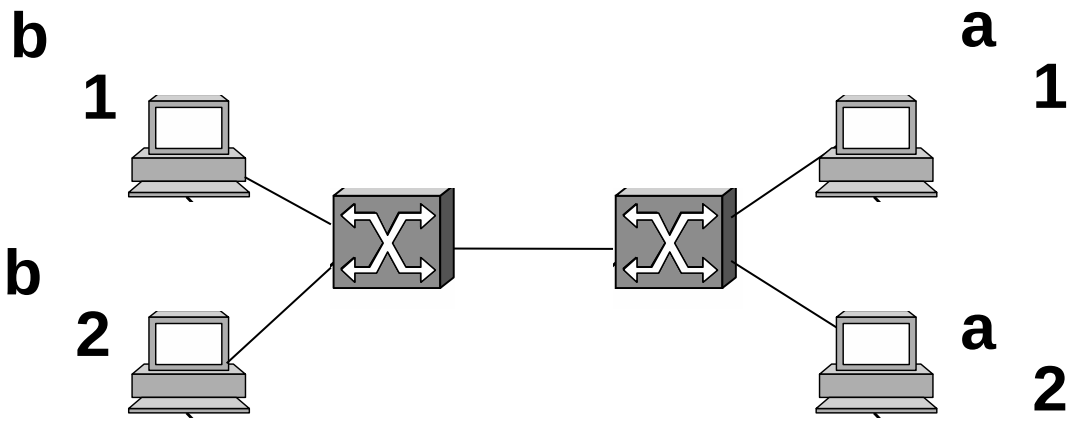
Radia Perlman

http://youtu.be/iE_AbM8ZykI

Limitations of Bridges

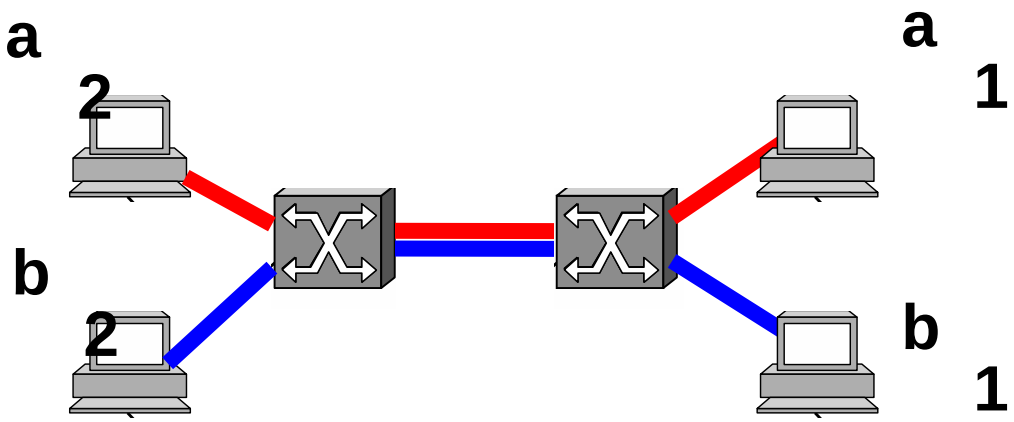
- **Scaling**
  - Spanning tree algorithm doesn't scale
  - Broadcast does not scale
  - No way to route around congested links, *even if path exists*
- **May violate assumptions**
  - Could confuse some applications that assume single segment
    - Much more likely to drop packets
    - Makes latency between nodes non-uniform
  - Beware of transparency

VLANs



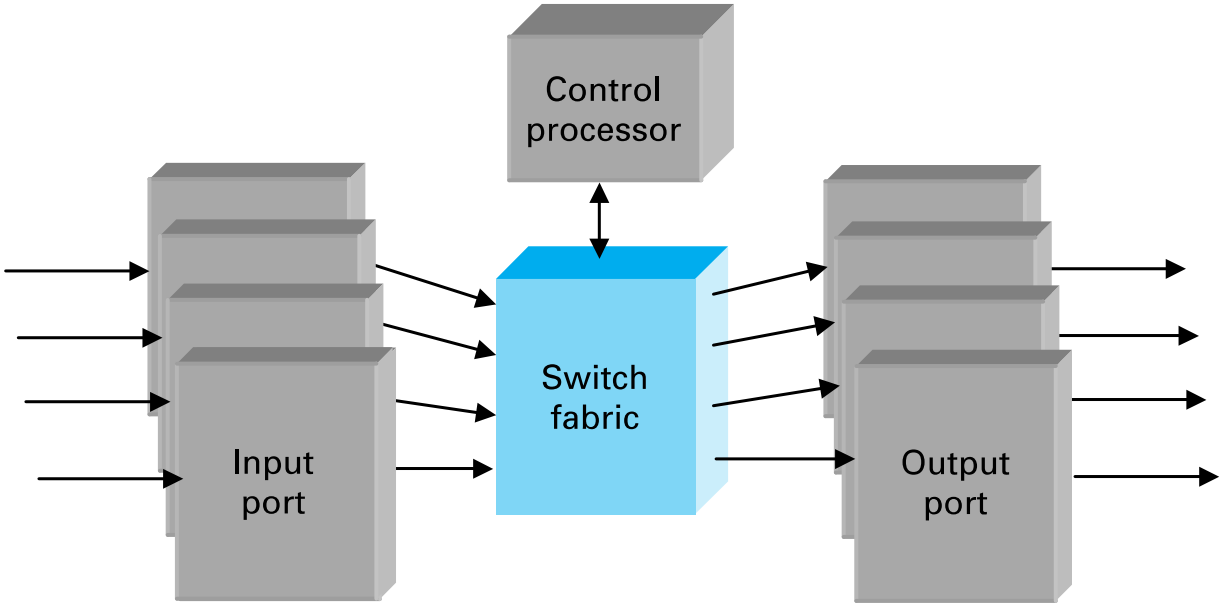
- **Company network, A and B departments**
  - Broadcast traffic does not scale
  - May not *want* traffic between the two departments
  - Topology has to mirror physical locations
  - What if employees move between offices?

VLANs



- **Solution: Virtual LANs**
  - Assign switch ports to a VLAN ID (color)
  - Isolate traffic: only same color
  - Trunk links may belong to multiple VLANs
  - Encapsulate packets: add 12-bit VLAN ID
- **Easy to change, no need to rewire**

Generic Switch Architecture



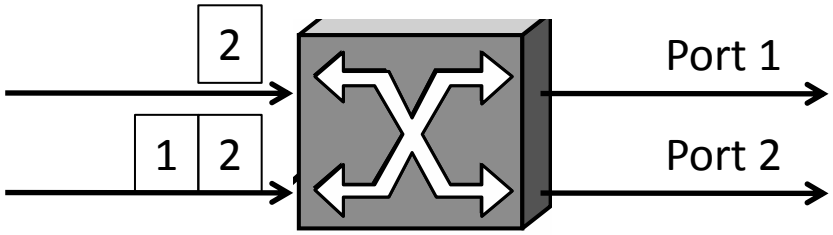
- **Goal: deliver packets from input to output ports**
- **Three potential performance concerns:**
  - Throughput in bytes/second
  - Throughput in packets/second
  - Latency

Cut through vs. Store and Forward

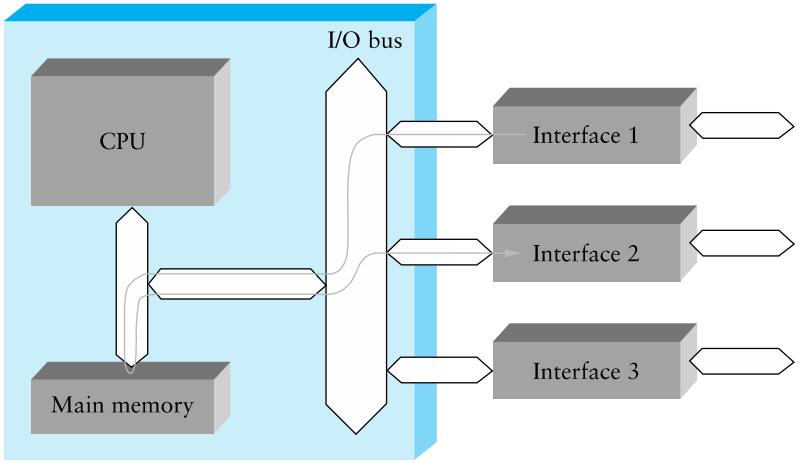
- **Two approaches to forwarding a packet**
  - Receive a full packet, then send to output port
  - Start retransmitting as soon as you know output port, before full packet
- **Cut-through routing can greatly decrease latency**
- **Disadvantage**
  - Can waste transmission (classic *optimistic* approach)
  - CRC may be bad
  - If Ethernet collision, may have to send runt packet on output link

Buffering

- **Buffering of packets can happen at input ports, fabric, and/or output ports**
- **Queuing discipline is very important**
- **Consider FIFO + input port buffering**
  - Only one packet per output port at any time
  - If multiple packets arrive for port 2, they may block packets to other ports that are free
  - *Head-of-line blocking*

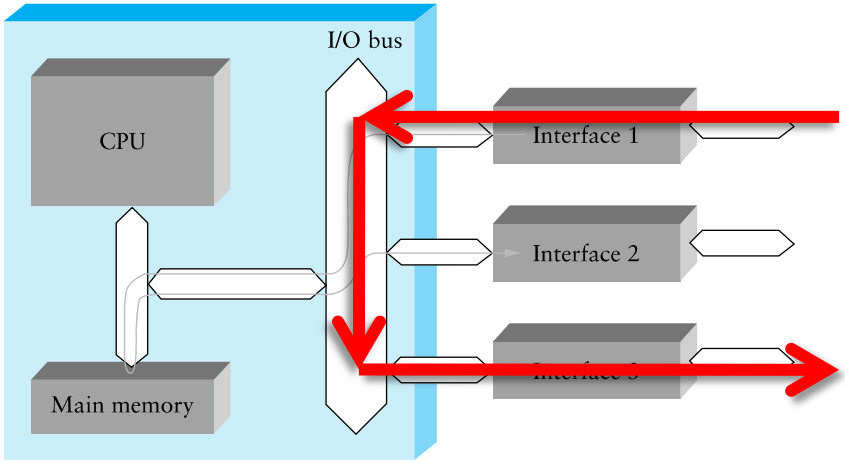


Shared Memory Switch



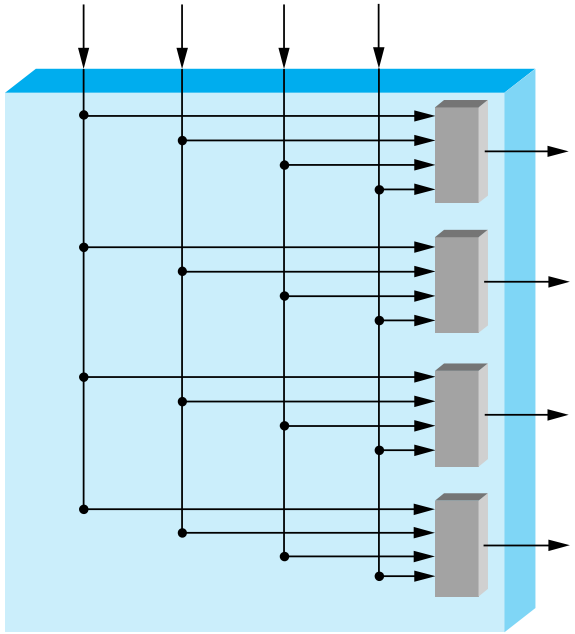
- **1st Generation – like a regular PC**
  - NIC DMAs packet to memory over I/O bus
  - CPU examines header, sends to destination NIC
  - I/O bus is serious bottleneck
  - For small packets, CPU may be limited too
  - Typically < 0.5 Gbps

Shared Bus Switch



- **2st Generation**
  - NIC has own processor, cache of forwarding table
  - Shared bus, doesn't have to go to main memory
  - Typically limited to bus bandwidth
    - (Cisco 5600 has a 32Gbps bus)

Point to Point Switch



- **3rd Generation: overcomes single-bus bottleneck**
- **Example: Cross-bar switch**
  - Any input-output permutation
  - Multiple inputs to same output requires trickery
  - Cisco 12000 series: 60Gbps

Coming Up

- **Connecting multiple networks: IP and the Network Layer**