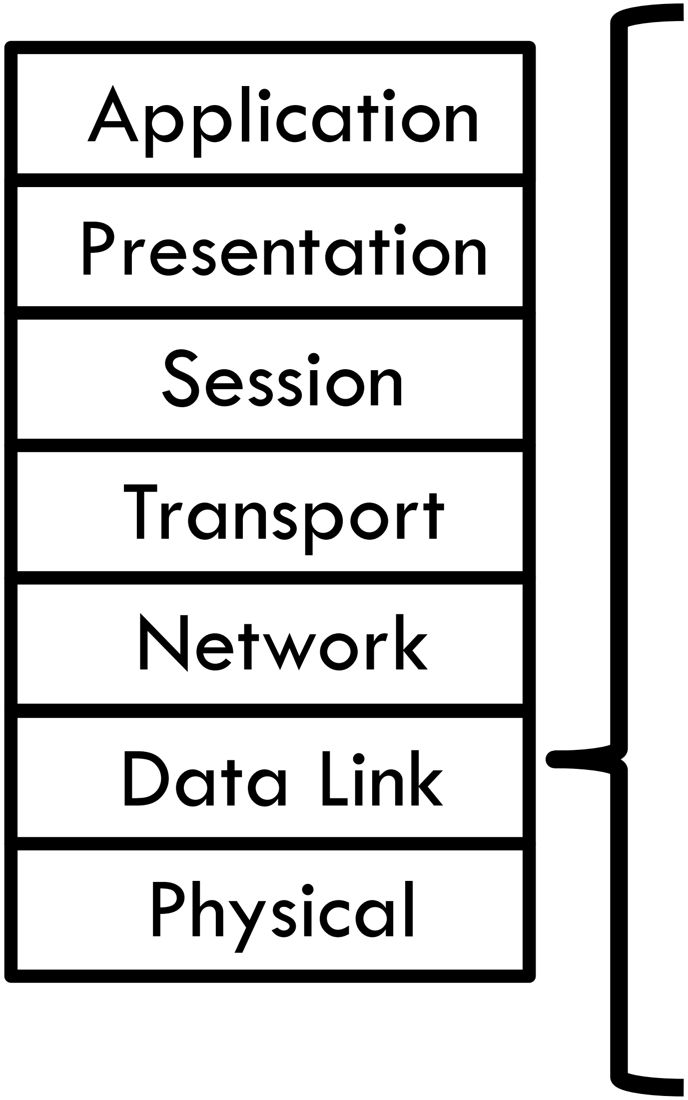
CSCI-351

Data communication and Networks

Lecture 7: Bridging
(From Hub to Switch by Way of Tree)

The slide is built with the help of Prof. Alan Mislove, Christo Wilson, and David Choffnes's class

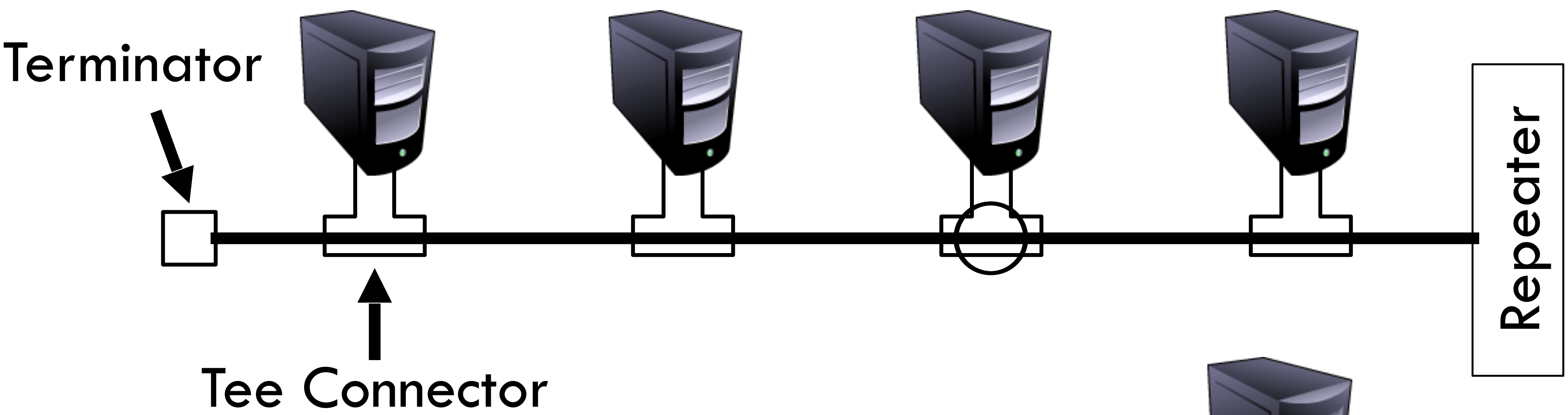
Just Above the Data Link Layer

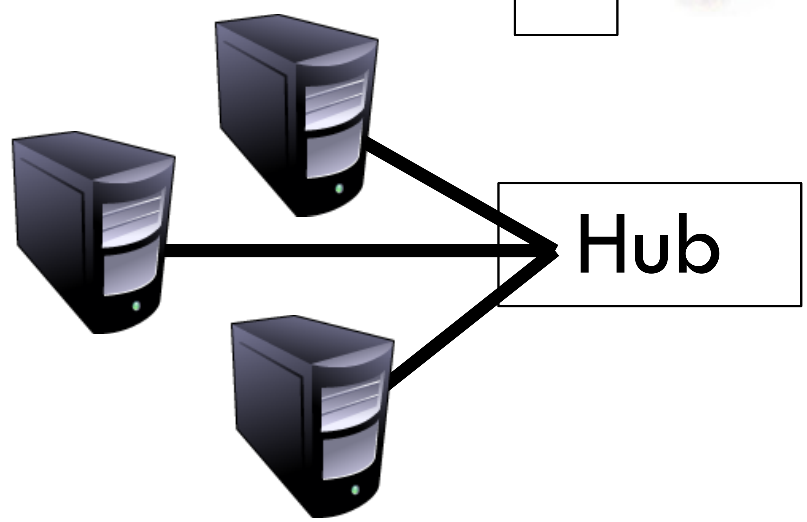


- Bridging
  - How do we connect LANs?
- Function:
  - Route packets between LANs
- Key challenges:
  - Plug-and-play, self configuration
  - How to resolve loops

Recap

- Originally, Ethernet was a broadcast technology

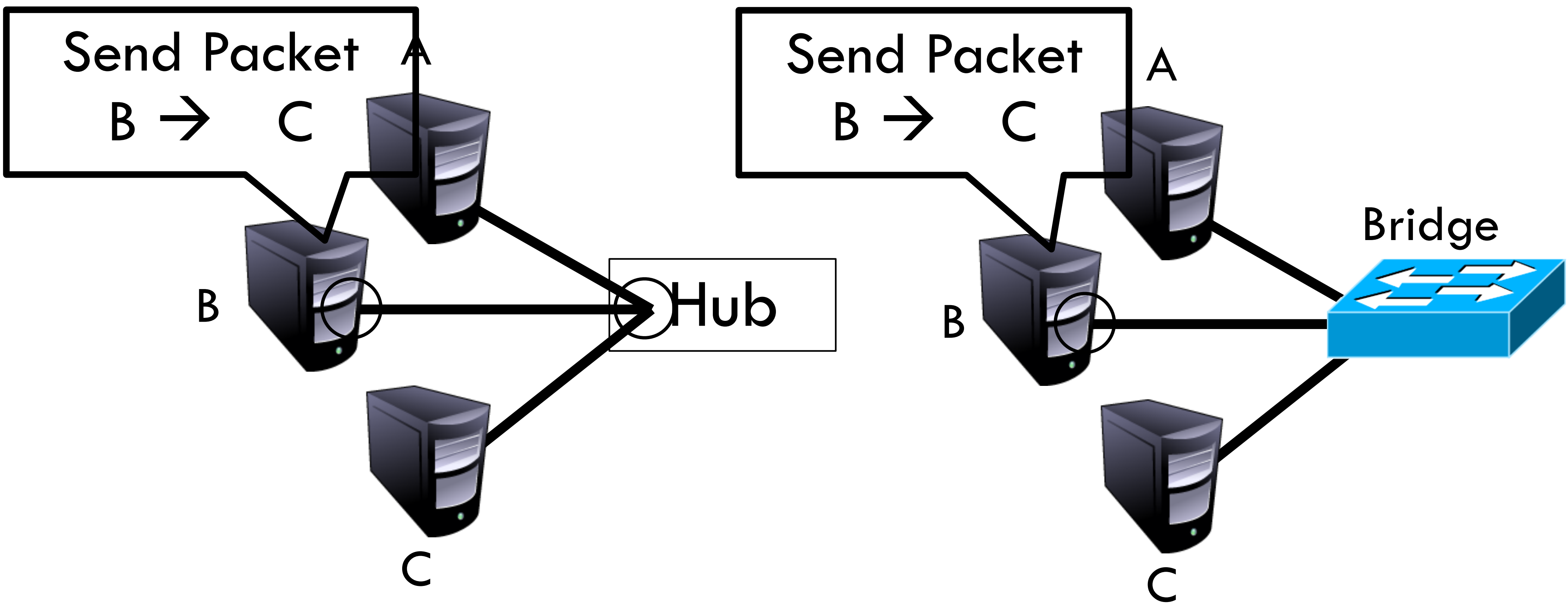




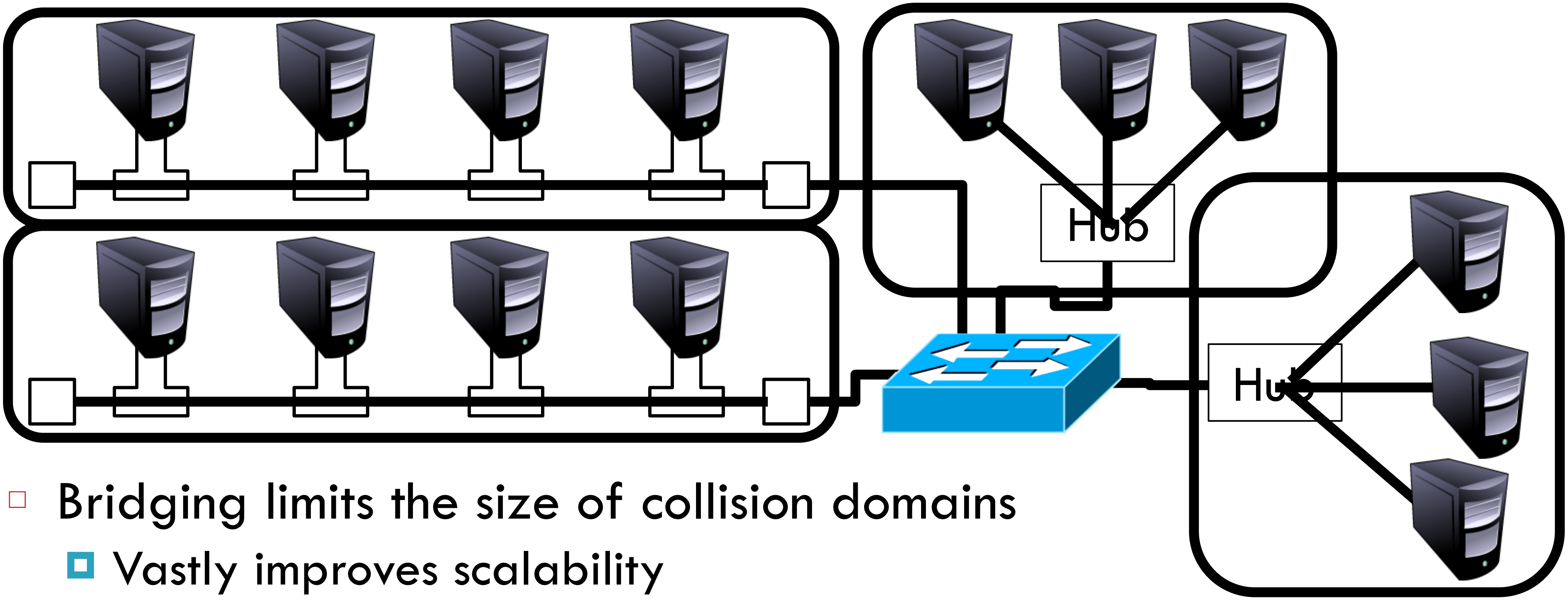
- Pros: Simplicity
  - Hardware is stupid and cheap
- Cons: No scalability
  - More hosts = more collisions = pandemonium

The Case for Bridging

- Need a device that can bridge different LANs
  - Only forward packets to intended recipients
  - No broadcast!

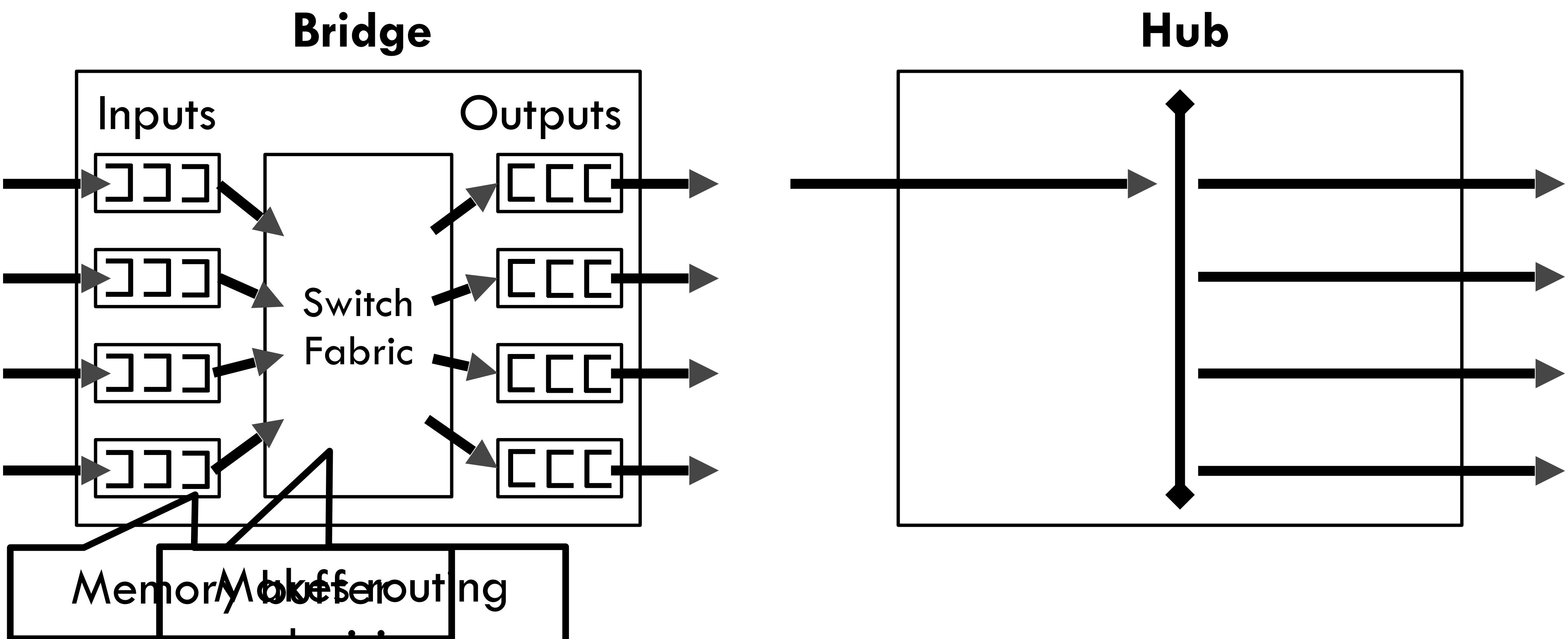


Bridging the LANs



- Bridging limits the size of collision domains
  - Vastly improves scalability
  - Question: could the whole Internet be one bridging domain?
- Tradeoff: bridges are more complex than hubs
  - Physical layer device vs. data link layer device
  - Need memory buffers, packet processing hardware, routing tables

Bridge Internals

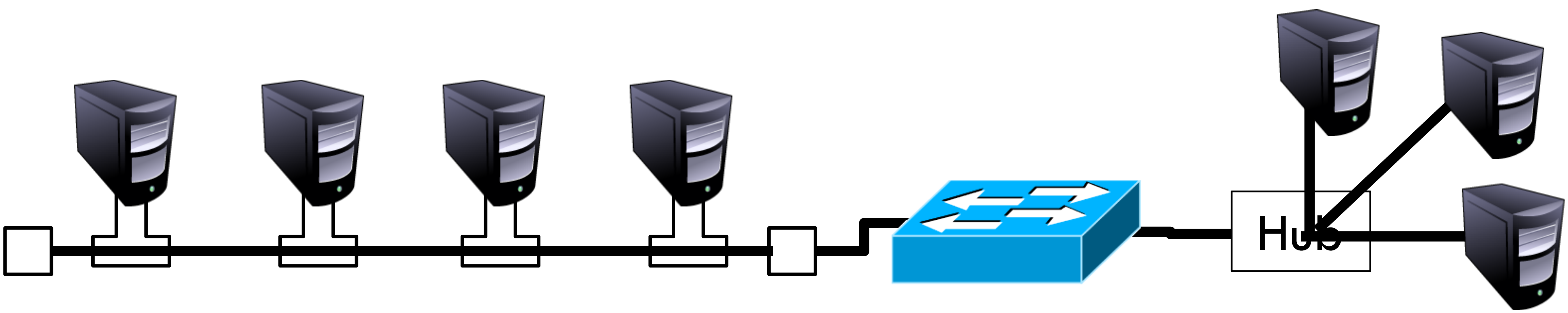


- Bridges have memory buffers to queue packets
- Bridge is intelligent, only forwards packets to the correct output
- Bridges are high performance, full N x line rate is possible

Bridges

- Original form of Ethernet switch
- Connect multiple IEEE 802 LANs at layer 2
- Goals
  - Reduce the collision domain
  - Complete transparency
    - "Plug-and-play," self-configuring
    - No hardware of software changes on hosts/hubs
    - Should not impact existing LAN operations

- Forwarding of frames
- Learning of (MAC) Addresses
- Spanning Tree Algorithm (to handle loops)

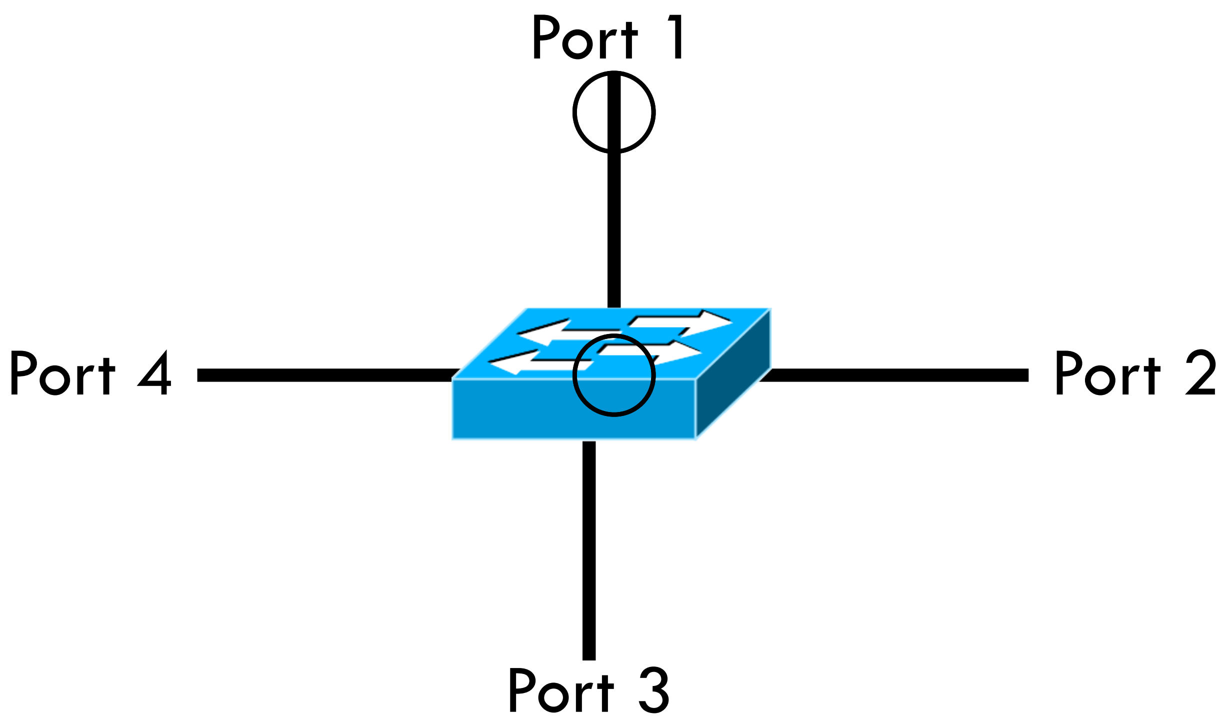


Frame Forwarding Tables

- Each bridge maintains a forwarding table

MAC Address	Port	Age
00:00:00:00:00:AA	1	1 minute
00:00:00:00:00:BB	2	7 minutes
00:00:00:00:00:CC	3	2 seconds
00:00:00:00:00:DD	1	3 minutes

Frame Forwarding in Action



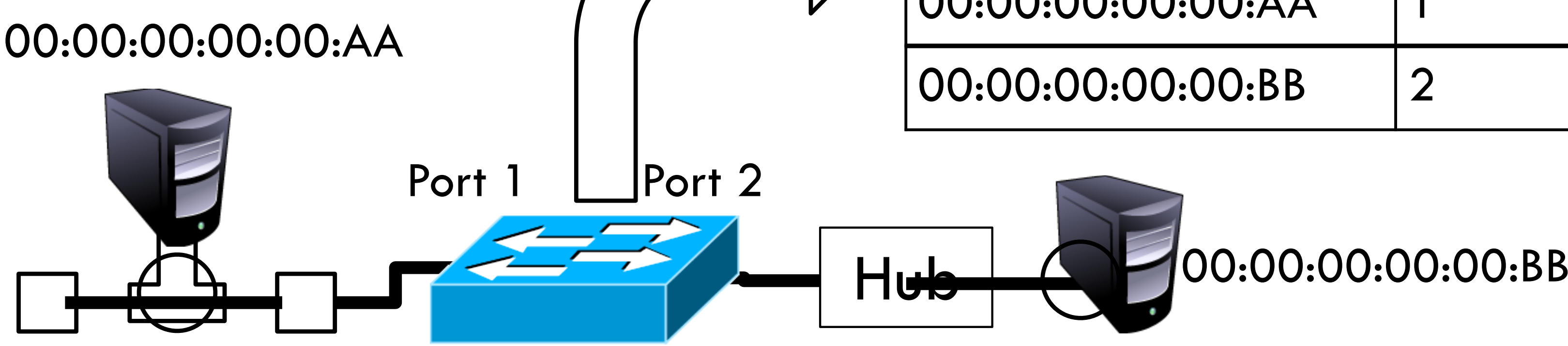
- Assume a frame arrives on port 1
- If the destination MAC address is in the forwarding table, send the frame on the correct output port
- If the destination MAC isn't in the forwarding table, broadcast the frame on all ports except 1

Learning Addresses

- Manual configuration is possible, but…
  - Time consuming
  - Error Prone
  - Not adaptable (hosts may get added or removed)
- Instead, learn addresses using a simple heuristic
  - Look at the source of frames that arrive on each port

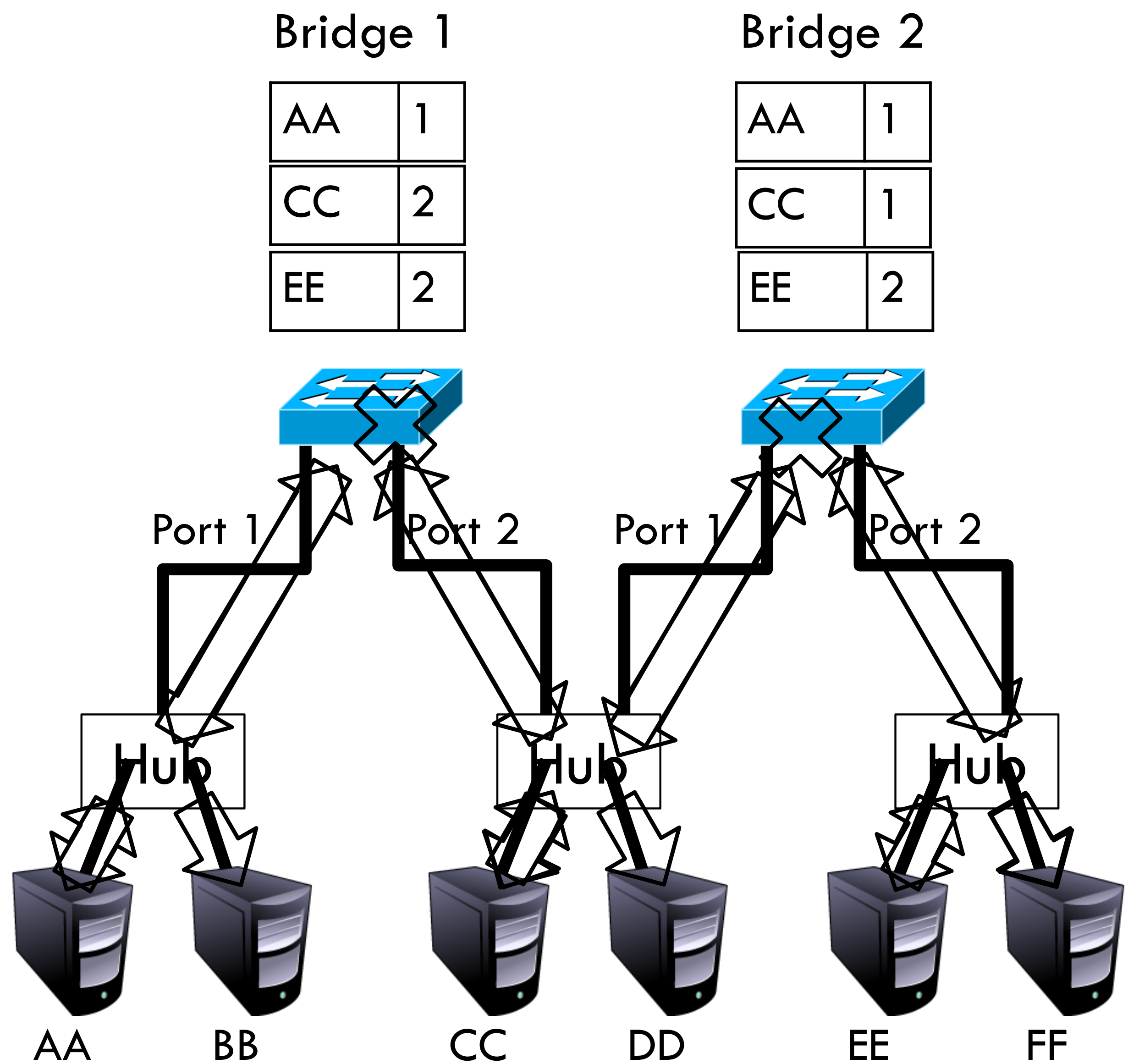
Delete old entries after a timeout

MAC Address	Port	Age
00:00:00:00:00:AA	1	0 minutes
00:00:00:00:00:BB	2	0 minutes



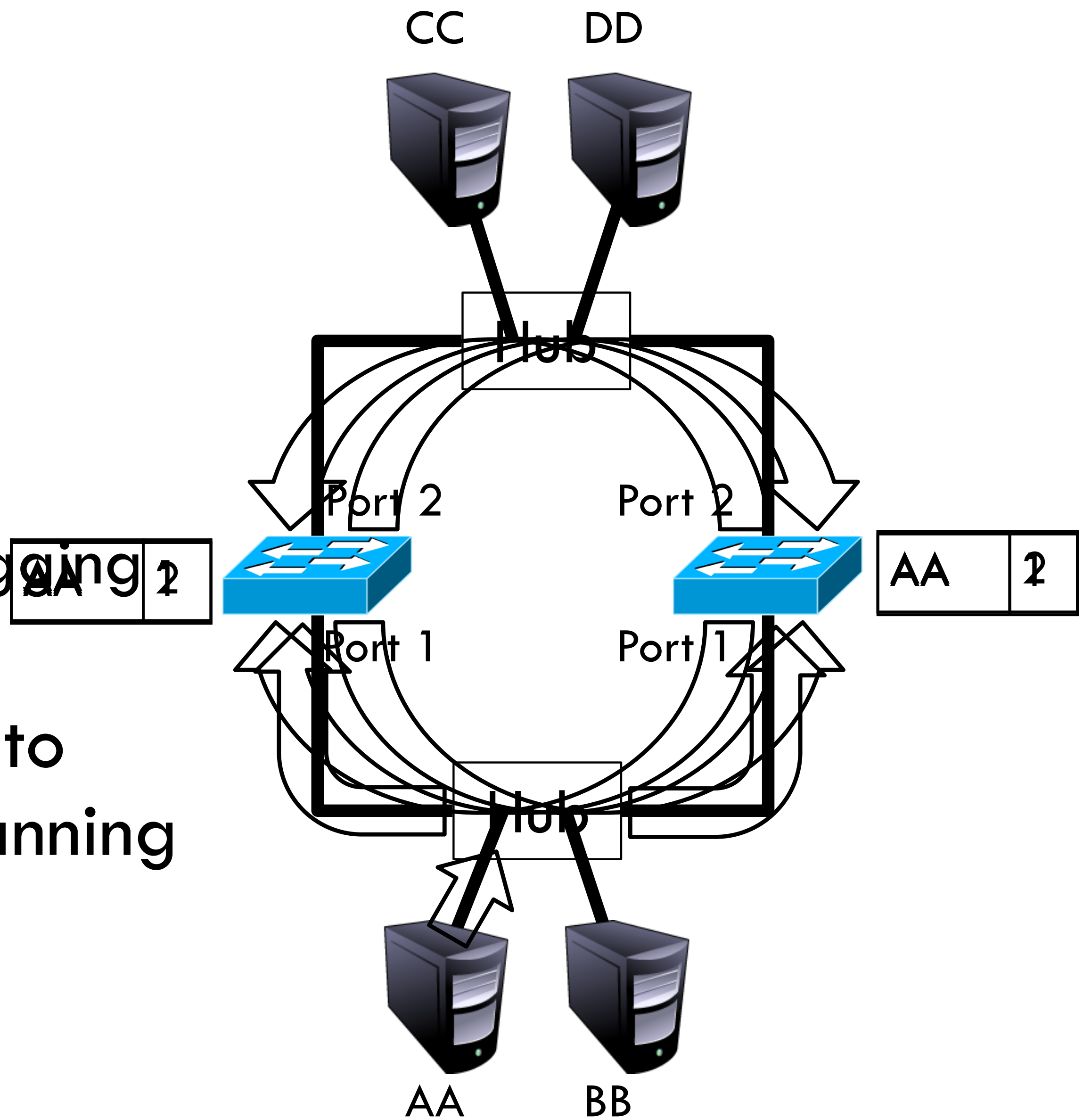
Complicated Learning Example

- <Src=AA, Dest=FF>
- <Src=CC, Dest=AA>
- <Src=EE, Dest=CC>



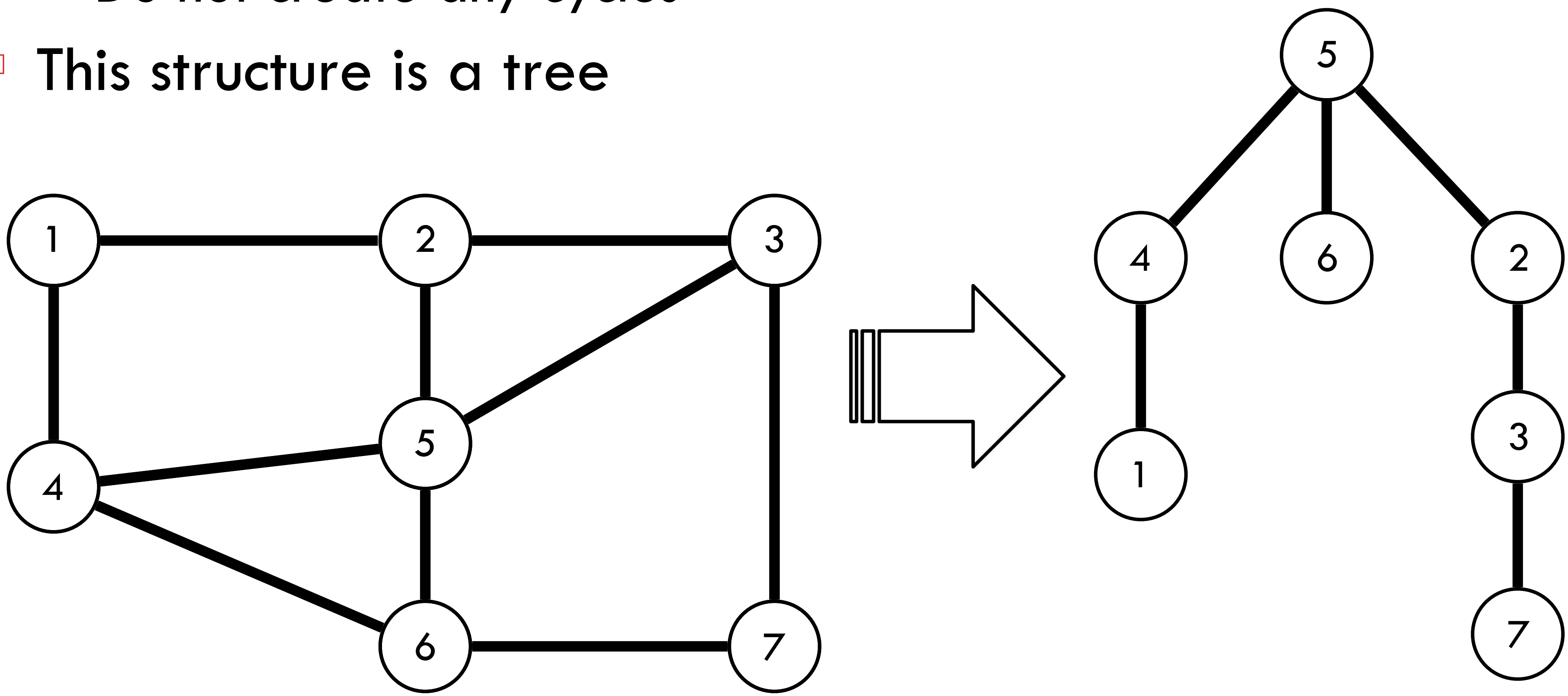
The Danger of Loops

- <Src=AA, Dest=DD>
- This continues to infinity
  - How do we stop this?
- Remove loops from the topology
  - Without physically unplugging cables
- 802.1 uses an algorithm to build and maintain a spanning tree for routing



Spanning Tree Definition

- A subset of edges in a graph that:
  - Span all nodes
  - Do not create any cycles
- This structure is a tree



802.1 Spanning Tree Approach

1. Elect a bridge to be the root of the tree
2. Every bridge finds shortest path to the root
3. Union of these paths becomes the spanning tree

- Bridges exchange Configuration Bridge Protocol Data Units (BPDUs) to build the tree
  - Used to elect the root bridge
  - Calculate shortest paths
  - Locate the next hop closest to the root, and its port
  - Select ports to be included in the spanning trees

Definitions

- Bridge ID (BID) = <Random Number>
- Root Bridge: bridge with the lowest BID in the tree
- Path Cost: cost (in hops) from a transmitting bridge to the root
- Each port on a bridge has a unique Port ID
- Root Port: port that forwards to the root on each bridge
- Designated Bridge: the bridge on a LAN that provides the minimal cost path to the root
  - The designated bridge on each LAN is unique

Determining the Root

- Initially, all hosts assume they are the root
- Bridges broadcast BPDUs:

Root ID	Path Cost to Root	Bridge ID

- Based on received BPDUs, each switch chooses:
  - A new root (smallest known Root ID)
  - A new root port (what interface goes towards the root)
  - A new designated bridge (who is the next hop to root)

Comparing BPDUs

BPDU1

R1	Cost1	B1

BPDU2

R2	Cost2	B2

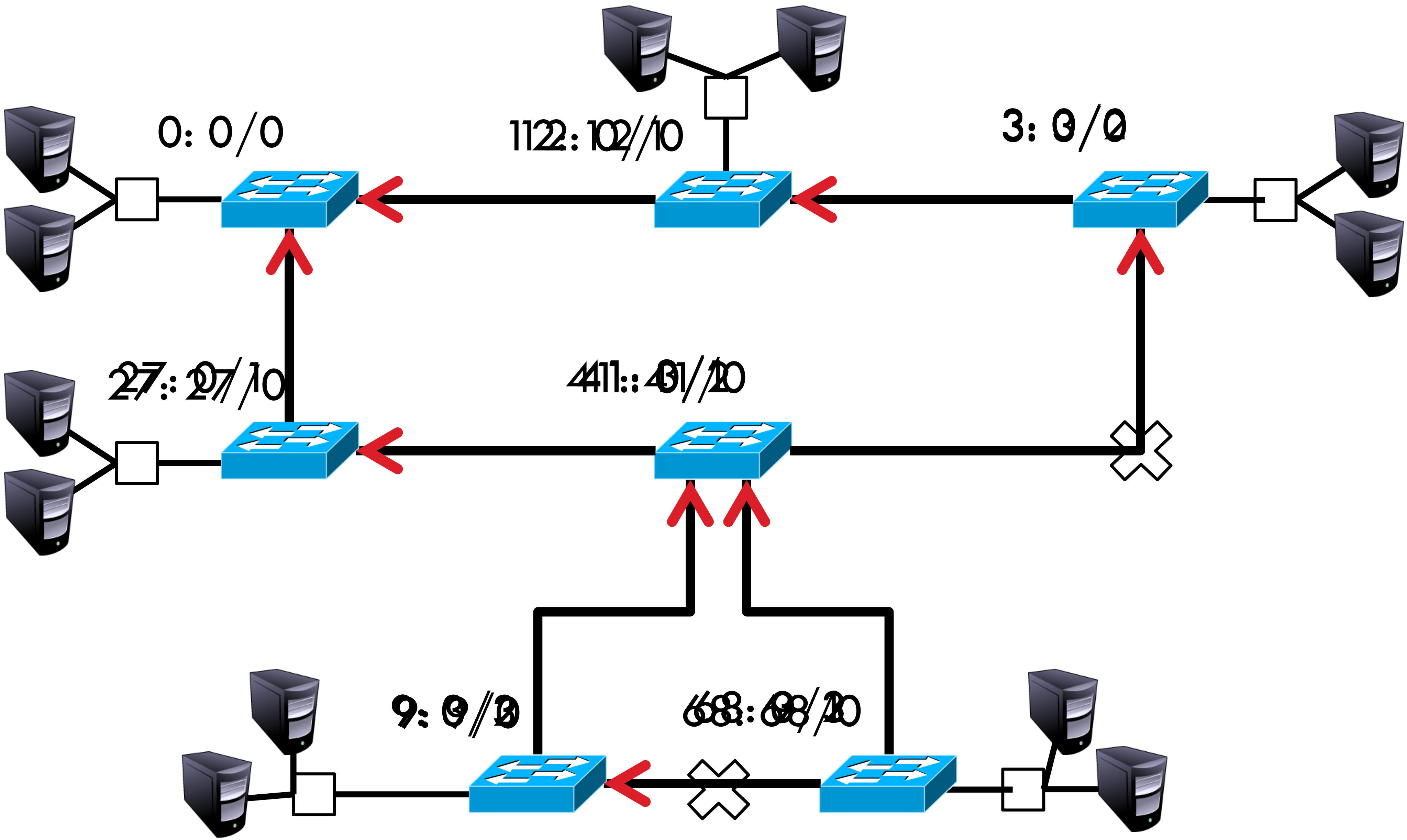
if R1 < R2: use BPDU1

else if R1 == R2 and Cost1 < Cost2: use BPDU1

else if R1 == R2 and Cost1 == Cost 2 and B1 < B2: use BPDU1

else: use BPDU2

Spanning Tree Construction



Bridges vs. Switches

- Bridges make it possible to increase LAN capacity
  - Reduces the amount of broadcast packets
  - No loops
- Switch is a special case of a bridge
  - Each port is connected to a single host
    - Either a client machine
    - Or another switch
  - Links are full duplex
  - Simplified hardware: no need for CSMA/CD!
  - Can have different speeds on each port

Switching the Internet

- Capabilities of switches:
  - Network-wide routing based on MAC addresses
  - Learn routes to new hosts automatically
  - Resolve loops
- Could the whole Internet be one switching domain?

NO

Limitations of MAC Routing

- Inefficient
  - Flooding packets to locate unknown hosts
- Poor Performance
  - Spanning tree does not balance load
  - Hot spots
- Extremely Poor Scalability
  - Every switch needs every MAC address on the Internet in its routing table!
- IP addresses solve these problems (next class…)