Data Link Layer
- Hub, Bridges and Switches

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LAN Interconnecting

- Interconnecting LAN segments
  - Hubs
  - Bridges
  - Switches
- Remark: switches are essentially multi-port bridges.
- What we say about bridges also holds for switches!
Hubs

- Active central element of star layout
  - Physically star, logically bus
    - If two stations transmit at the same time, collision
  - Transmission from any station received by all other stations
- Each station connected to hub by two lines
  - Transmit and receive on two unshielded twisted pairs
- Hub acts as a repeater
  - When single station transmits, hub repeats signal on outgoing line to each station
Hubs

- Backbone hub interconnects LAN segments
- Extends max distance between nodes
- But individual segment collision domains become one large collision domain
  - if a node in CS and a node EE transmit at same time: collision
- Can’t interconnect 10BaseT & 100BaseT
Bridge

- A bridge is a layer-2 device that connects LANs that may or may not be based on the same technology.
- A simple configuration:
Bridges for Traffic Isolation

- Bridge installation breaks LAN into LAN segments
- Bridges filter packets:
  - same-LAN-segment frames not usually forwarded onto other LAN segments
  - segments become separate collision domains

Collision domain 1

Collision domain 2
Other Reasons for Bridges

- Overcomes the distance limitations of LANs
- Connects LANs that use different technologies
- Connects LANs built by different organizations

Nowadays we use Internet technologies to achieve these goals.
Bridge Routing

• A sophisticated bridge can perform routing
  ▫ decide whether or not to forward frame
  ▫ if attached to more than two networks, must also decide which LAN, if any, to forward it on

• Methods:
  ▫ fixed routing
  ▫ self learning
  ▫ source routing
• Who does the download?
  • Human
  • Too much work for maintenance

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<th>Port</th>
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<tr>
<td>B</td>
<td>1</td>
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<tr>
<td>C</td>
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<td>2</td>
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<td>Y</td>
<td>2</td>
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<td>Z</td>
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Self-Learning (Transparent) Bridges

- Bridges listen “promiscuously”
- For each packet received, the bridge
  - stores the source address in a cache along with the port the packet arrives at
  - If the destination address is broadcast (all 1’s), forward the packet via all interfaces except the one from which the frame was received.
• For a regular destination address, looks for the destination in its cache
  ▫ if not found, forward the packet via all interfaces except the one from which the frame was received
  ▫ if found, forward the packet via the port indicated by the cache entry (if the port is the one via which the frame arrived, the frame is dropped)
Example

- Starting with empty caches at all bridges, show the cache of Bridge A after Station 1 sends a frame to Station 4, Station 2 to Station 10, and Station 5 to Station 2.
Problems with Parallel Bridges

- In general, this problem arises with any topology containing loops.
- Solution?
  - 1. avoid loops
  - 2. construct a spanning tree
Spanning Trees

- **Transparent bridges** route through a spanning tree
- Spanning tree algorithm uses the following:
  - Each bridge has a unique ID
  - There is a MAC address that means “All bridges on this LAN.”
  - Each port of a bridge is uniquely identified within the bridge by a port identifier.
Spanning Tree Rules

- Data traffic is forwarded to and from ports selected for inclusion in the spanning tree.
- Data traffic is discarded upon receipt and never forwarded onto ports that are not selected for inclusion in the spanning tree.
Spanning Tree Operation

- Based on the spanning tree algorithm and info from the previous slide, bridges can:
  - Elect a single bridge.
  - Calculate the distance from themselves to the root.
  - For each LAN, elect the bridge closest to the root as the designated bridge.
Configuration Messages

- **Config.** messages are transmitted by a bridge onto a port.
  - Sent to “all ports address.”
- Each message contains:
  - **Root id:** ID of the bridge assumed to be root by the transmitting bridge
  - **Cost** of the least cost path to the root from the transmitting bridge, i.e., the distance, measured in hops
  - **Transmitting Bridge ID**
Pruning Messages

• Each bridge initially assumes that itself is the root
• Given two Messages M1 and M2:
  ▫ M1 is better if the root ID in M1 is lower than M2
  ▫ If IDs are equal, M1 is better if the cost listed in M1 is lower than the cost in M2.
  ▫ If root ID and cost are equal, then M1 is better if the transmitting bridge ID is lower than in M2.
Selecting Spanning Tree Ports

• Once a bridge calculates the root, its own cost to the root, and the designated bridge for each LAN it is connected to, it decides which ports are in the spanning tree
  ▫ Add the port chosen by the bridge as its preferred path to the root.
  ▫ Add all the ports for which is the designated bridge
Spanning Tree

- Focus on B3
- Receives from B2 (B2,0,B2)
  - B3 accepts B2 as root
- B3 sends (B2,1,B3) to B5
- B2 accepts B1 as root and now sends (B1,1,B2) to B3
- B5 accepts B1 as root and sends (B1,1,B5) to B3
- B3 accepts B1 and root.
  - B2 and B5 are closer to the root
  - Stops forwarding on both interfaces
Spanning Tree
Bridge Characteristics

- Stores and forwards Ethernet frames
  - examines frame header and selectively forwards frame based on MAC destination address
  - when frame is to be forwarded on segment, uses CSMA/CD to access segment
- Transparent
  - hosts are unaware of presence of bridges
- Plug-and-play, self-learning
  - bridges do not need to be configured
Bridge Protocol Architecture

- **IEEE 802.1D**
- **MAC level**
  - Station address is at this level
- Bridge does not need LLC layer
  - It is relaying MAC frames
Layer 2 Switches

- Now many types of devices for interconnecting LANs
- Layer 2 switches is beyond bridges
Shared Medium Hub vs. Layer 2 Switch

(b) Shared medium hub

(c) Layer 2 switch
Layer 2 Switches

- Central hub acts as switch
- Incoming frame from particular station switched to appropriate output line
- Unused lines can switch other traffic
- More than one station transmitting at a time
- Multiplying capacity of LAN
- Can perform error detection by CRC
Layer 2 Switch Benefits

- No change to attached devices to convert bus LAN or hub LAN to switched LAN
- For Ethernet LAN, each device uses Ethernet MAC protocol
- Device has dedicated capacity equal to original LAN
  - Assuming switch has sufficient capacity to keep up with all devices
- Layer 2 switch scales easily
Types of Layer 2 Switch

- **Store-and-forward switch**
  - Accepts frame on input line
  - Buffers it briefly
  - Then routes it to appropriate output line
  - Delay between sender and receiver
  - Boosts integrity of network

- **Cut-through switch**
  - Takes advantage of destination address appearing at beginning of frame
  - Switch begins repeating frame onto output line as soon as it recognizes destination address (may start forwarding before receiving entire frame)
  - Highest possible throughput
  - Risk of propagating bad frames
    - Switch unable to check CRC prior to retransmission
Layer 2 Switch vs. Bridge

Layer 2 switch can be viewed as full-duplex hub + L2 functions
Can incorporate logic to function as multiport bridge

- Bridge frame handling done in software
- Switch performs address recognition and frame forwarding in hardware
- Bridge only analyzes and forwards one frame at a time
- Switch has multiple parallel data paths
  - Can handle multiple frames at a time
- Bridge uses store-and-forward operation
- Switch support both store-and-forward and cut-through operation
- Bridge suffered commercially
  - New installations typically include layer 2 switches with bridge functionality rather than bridges
Problems with Layer 2 Switches (1)

- As number of devices in building grows, layer 2 switches reveal some inadequacies
- Broadcast overload
- Lack of multiple links
- Set of devices and LANs connected by layer 2 switches have flat address space
  - All users share common MAC broadcast address
  - If any device issues broadcast frame, that frame is delivered to all devices attached to network connected by layer 2 switches and/or bridges
  - In large network, broadcast frames can create big overhead
  - Malfunctioning device can create broadcast storm
    - Numerous broadcast frames clog network
Problems with Layer 2 Switches (2)

- Current standards for bridge protocols dictate no closed loops
  - Only one path between any two devices
  - Impossible in standards-based implementation to provide multiple paths through multiple switches between devices
    - Limits both performance and reliability
- Solution: break up network into subnetworks connected by routers
- MAC broadcast frame limited to devices and switches contained in single subnetwork
- IP-based routers employ sophisticated routing algorithms
  - Allow use of multiple paths between subnetworks going through different routers
Discussion

• Each switch-to-station segment forms an independent collision domain.

• Moreover, one line is used in each direction.
  ▫ As such, there will be no collisions at all.

• Is this still Ethernet?
  ▫ Yes, in the sense that legacy Ethernet software and interface cards can still be used.
  ▫ No, because the resultant network is based on switching, as opposed to broadcast and CSMA/CD.
Hubs, Bridges, and Switches

(a) A hub. (b) A bridge. (c) A switch.
Reading

• Section 3.1 of textbook