Connecting LANs, Backbone Networks, and Virtual LANs
Connecting Devices

Repeater

Hubs

Bridges

Two-Layer Switches
Connecting devices

Local Area Networks and Devices

- Operate within a limited geographic area
- Allow multiaccess to high-bandwidth media
- Control the network privately under local administration
- Provide full-time connectivity to local services
- Connect physically adjacent devices

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A repeater connects segments of a LAN.

A repeater is a regenerator, not an amplifier.

A repeater forwards every frame; it has no filtering capability.
Function of a repeater

a. Right-to-left transmission.

b. Left-to-right transmission.
Hubs

- Active central element of star layout
- Each station connected to hub by two lines
  - Transmit and receive
- Hub acts as a repeater
- When single station transmits, hub repeats signal on outgoing line to each station
- Line consists of two unshielded twisted pairs
- Limited to about 100 m
  - High data rate and poor transmission qualities of UTP
- Optical fiber may be used
  - Max about 500 m
- Physically star, logically bus
- Transmission from any station received by all other stations
- If two stations transmit at the same time, collision
Hubs
Bridges

- Ability to expand beyond single LAN
- Provide interconnection to other LANs/WANs
- Use Bridge or router
- Bridge is simpler
  - Connects similar LANs
  - Identical protocols for physical and link layers
  - Minimal processing
- Router more general purpose
  - Interconnect various LANs and WANs
Bridge and Switch

Switch: Layer 2 Device

Bridge: Layer 2 Device

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In this example, a data packet originates from Computer V and its destination is Computer Hh.

The data packet reaches its final destination.
Functions of a Bridge

- Read all frames transmitted on one LAN and accept those address to any station on the other LAN
- Using MAC protocol for second LAN, retransmit each frame
- Do the same the other way round
Bridge Design Aspects

- No modification to content or format of frame
- No encapsulation
- Exact bitwise copy of frame
- Minimal buffering to meet peak demand
- Contains routing and address intelligence
  - Must be able to tell which frames to pass
  - May be more than one bridge to cross
- May connect more than two LANs
- Bridging is transparent to stations
  - Appears to all stations on multiple LANs as if they are on one single LAN
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
- Can pass frame over external communications system
  - e.g. WAN link
  - Capture frame
  - Encapsulate it
  - Forward it across link
  - Remove encapsulation and forward over LAN link
Connection of Two LANs

(a) Architecture

- $t_1, t_8$: User Data
- $t_2, t_7$: LLC-H User Data
- $t_3, t_4, t_5, t_6$: MAC-H LLC-H User Data MAC-T

(b) Operation
A bridge has a table used in filtering decisions.

A bridge does not change the physical (MAC) addresses in a frame.
Learning bridge

<table>
<thead>
<tr>
<th>Address</th>
<th>Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
</tr>
</tbody>
</table>

- **a. Original**
- **b. After A sends a frame to D**
- **c. After E sends a frame to A**
- **d. After B sends a frame to C**
Loop problem

The tables are empty. Both update their table

The Copy sent out by bridge 1 is received by bridge 2, which does not have information about destination address D. The copy sent out by bridge 2 is resent by bridge 1.

c. Both bridges forward the frame and improve tables

The process continues on and on
Spanning Tree

- Bridge automatically develops routing table
- Automatically update in response to changes
- Frame forwarding
- Address learning
- Loop resolution
Spanning tree

- Spanning tree is a graph in which there is no loop.
- In bridged LAN this means creating a topology in which each LAN can be reached from any other LAN thought one path only (no loop).
- We cannot change the physical topology but we can create a logical topology that overlays the physical one.
Spanning Tree Algorithm

- Address learning works for tree layout
  - i.e. no closed loops
- For any connected graph there is a spanning tree that maintains connectivity but contains no closed loops
- Each bridge assigned unique identifier
- Exchange between bridges to establish spanning tree
The steps

- Every bridge has a build-in ID. The one with the smallest ID is selected as **root bridge**.
- Mark one port of each bridge (except for root bridge) as the **root port**. The interpretation of least-cost path is left up to the system admin (can be min number of hops)
- Choose the designated bridge for each LAN. A designed bridge has the least-cost path between LAN and the root bridge. Make the corresponding port the designed port. If two bridges have the same least-cost value, chose one with the smaller ID.
- Mark the root port and designed port as **forwarding ports**, the others as **blocking ports**.
Prior to spanning tree application
Applying spanning tree

- B1 has the least ID -> B1 root bridge
- The root ports are marked with *
- The designed bridges has an arrow pointed to them from corresponding LAN
- Designed ports are marked by **
• The root ports and the designed ports as forwarding ports.
• The others are blocking ports.
• The physical connection is there but the bridge never forwards any from from these ports.
Backbone Networks

- Bus Backbone
- Star Backbone
- Connecting Remote LANs
In a bus backbone, the topology of the backbone is a bus.
In a star backbone, the topology of the backbone is a star; the backbone is just one switch.
A point-to-point link acts as a LAN in a remote backbone connected by remote bridges.
Type of Switches

- There are:
  - Two-layer switch performs at the physical and data link layer
  - Three-layer switch is used at the network layer.

- A two layer switch is a bridge with many ports, able to allocate a unique port for each station on its own independent entity.

- For eliminate the confusion in general is used:
  - the term bridge for two layer switch and
  - the term switch for three layer switch
Benefits of Switching

- Number of collisions reduced
- Simultaneous, multiple communications
- High-speed uplinks
- Improved network response
- Increased user productivity
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
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
  - For example if switch can sustain throughput of 20 Mbps, each device appears to have dedicated capacity for either input or output of 10 Mbps
- Layer 2 switch scales easily
  - Additional devices attached to switch by increasing capacity of layer 2
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
  - Highest possible throughput
  - Risk of propagating bad frames
    - Switch unable to check CRC prior to retransmission
Layer 2 Switch v Bridge

- Layer 2 switch can be viewed as full-duplex hub
- 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 can have cut-through operation
  - Bridge suffered commercially
    - New installations typically include layer 2 switches with bridge functionality rather than bridges
Packet by Packet or Flow Based

- Operates in same way as traditional router
- Order of magnitude increase in performance compared to software-based router
- Flow-based switch tries to enhance performance by identifying flows of IP packets
  - Same source and destination
  - Done by observing ongoing traffic or using a special flow label in packet header (IPv6)
  - Once flow is identified, predefined route can be established
Typical Large LAN Organization

- Thousands to tens of thousands of devices
- Desktop systems links 10 Mbps to 1000 Mbps
  - Into layer 2 switch
- Wireless LAN connectivity available for mobile users
- Layer 3 switches at local network's core
  - Form local backbone
  - Interconnected at 1 Gbps (10 Gbps)
  - Connect to layer 2 switches at 100 Mbps to 1 Gbps
- Servers connect directly to layer 2 or layer 3 switches at 1 Gbps (or 10Gbps)
- Lower-cost software-based router provides WAN connection
- Circles in diagram identify separate LAN subnetworks
- MAC broadcast frame limited to own subnetwork
Typical Large LAN Organization Diagram
VLAN is defined as a virtual LAN configured by software, not by physical wiring.

Membership

IEEE Standard

Configuration

Advantages
A switch connecting three LANs

**VLANs create broadcast domains.**
A switch using VLAN software

Switch with VLAN software

VLAN 1

VLAN 2

VLAN 3
Two switches in a backbone using VLAN software