Interconnecting Networks

COMP476
Networked Computer Systems

Bits on the Wire
• A 100 Mbit/sec Ethernet sends a bit every 10 nsec.
• Traveling at 2.0x10^8 m/s, a bit occupies 2.0m of the wire.
• If two computers were located 16m apart, there would be 8 bits traveling between them.
• The first bit would arrive at the receiver just as the sender sent the 8th bit.

LAN – Local Area Networks
• There is a Limit to the Maximum Length of a LAN
  - Ethernet cables (segments) can be up to 500m.
  - The restrictions are due to power and propagation delay.
  - The speed of light or electricity is not infinite.

Example: Ethernet and Token Ring

CSMA/CD restriction
• The time to transmit a frame must be greater than twice the time for the frame to travel to the end of the cable.
• If the cable is too long, collisions might go undetected.

\[
\frac{\min \text{PacketSize}}{\text{transRate}} > \frac{2 * \text{length}}{2.0 * 10^8}
\]
Max Ethernet Cable Length

- Consider a 100 Mbps Ethernet with 72 byte frame.

\[
\text{min length} = \frac{\text{min} \text{ PacketSize} \times 10^8}{\text{transRate}}
\]

\[
\text{length} = \frac{72 \text{bytes} \times 8 \text{bits/byte} \times 10^8 \text{m/sec}}{10^8 \text{bits/sec}} = 576m
\]

Repeaters

- Repeaters operate at the Physical Layer.
- Copies individual bits between cable segments.
- Every bit is copied to all segments, including collisions.
- Functions as an amplifier.
- Invisible to computers.
- Ethernet can be extended to 1500m with no more than 4 repeaters between hosts.

Methods of Interconnecting Networks

<table>
<thead>
<tr>
<th>Application</th>
<th>Router</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation</td>
<td></td>
</tr>
<tr>
<td>Session</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td></td>
</tr>
<tr>
<td>Network</td>
<td>Router</td>
</tr>
<tr>
<td>Data Link</td>
<td>Bridge</td>
</tr>
<tr>
<td>Physical</td>
<td>Repeater</td>
</tr>
</tbody>
</table>

Hubs

- Logically, a hub is a very short cable with long connecting wires.
- Bits flow in one wire and out all others.
- Hubs are usually less expensive than switches.
Interconnecting LANs

On what OSI layer does a hub operate?

1. Physical
2. MAC Data Link
3. Network
4. Transport
5. Application

Bridges

- Bridges operate at the Data Link Layer.
- Store and forward frames between LANs. Bridges receive a packet and then transmit it on the other side.
- Retransmitting the packet introduces a delay.
- Invisible to computers on the network.
- Each segment is shielded from local traffic on the other segments (reduces collisions).

More on Bridges

- Bridges only forward frames that need to go to the other side (Frame Filtering)
- Broadcasts always go through a bridge
- Bridges learn the location of hosts

Long Distance Bridging

- Bridges (designed for this purpose) can be connected by a point to point connection (fiber optic line, leased phone line or satellite).
**Learning Bridges**

- Bridges do not need to be configured. They can be used straight from the box.
- Bridges automatically learn which side of the bridge a computer is located.
- Bridges look at all source addresses to determine where a computer is located.
- If the bridge does know that the destination is on the same side as the source, it will forward the frame.

**Bridge Learning**

1. **A sends a frame to B**
   - The bridge forwards the frame to the lower segment because it does not know the location of B.
   - Upper nodes: A
   - Lower nodes: X, Y

2. **B sends a frame to A**
   - The bridge does not forward the frame because it knows A is on the upper segment.
   - Upper nodes: A, B
   - Lower nodes: X, Y
A sends a frame to X

The bridge forwards the frame to the lower segment because it does not know the location of X

Upper nodes: A, B
Lower nodes: X, Y

X sends a frame to A

The bridge forwards the frame to the upper segment because it knows the location of A

Upper nodes: A, B
Lower nodes: X

Y sends a frame to X

The bridge does not forward the frame to the upper segment because it knows the location of X

Upper nodes: A, B
Lower nodes: X, Y

Cycles of Bridges

- **Cycles** of bridges have to be avoided.
- A packet could circulate forever.
- Sometimes it is advantageous to have extra bridges for robustness and performance.
- When a Bridge starts, it communicates with other bridges to learn the configuration.
- Bridges form a *Distributed Spanning Tree* to determine how frames will be forwarded.
An Ethernet switch is very similar to a bridge.

Layer 2 switches operate on the MAC Data Link layer.

Interconnecting LANs

**Bridge Cycle**

- Bridge 1
- Bridge 2

**Switches**

- A switch usually has several ports.

**Layer 2 Switches**

- Computers connected to the switch.
- Conceptual organization of a switched LAN.

**On what OSI layer does a switch operate?**

1. Physical
2. MAC Data Link
3. Network
4. Transport
5. Application
Routers

- Routers operate at the Network Layer.
- Can store and forward frames between dissimilar networks.
- May perform protocol conversion.
- A router is located at any gateway (where one network meets another).
- The name Router and Gateway are sometimes used synonymously.

PCs as Routers

- A computer with two or more network interfaces can function as a router.
- Microsoft Windows Server and Linux Server have options to function as a router.
- Hardware routers can be used for high performance.
- Routers are used throughout the Internet.

Visibility

- A router is visible to the network.
- All nodes in a network need to know the IP address of their local router.
- Packets must be sent to the router.
- Repeaters and bridges are invisible.
  - Nodes do not know they are on the network.
  - Packets are never addresses to a bridge.

On what OSI layer does a router operate?

1. Physical
2. MAC Data Link
3. Network
4. Transport
5. Application
How long does it take to send 100 bytes over a 100 Mb/s Ethernet to another node when there is a **repeater** between the nodes?

1. 8.0 nsec
2. 10.1 nsec
3. 16.0 nsec
4. 20.2 nsec

How long does it take to send 100 bytes over a 100 Mb/s Ethernet to another node when there is a **bridge** between the nodes?

1. 8.0 nsec
2. 10.1 nsec
3. 16.0 nsec
4. 20.2 nsec