8. Network Devices
Typical network devices

- For separating networks or expanding network
  - Repeaters, hubs, bridges, routers, brouters, switches, gateways

- For remote access
  - Modems
  - ADSL modems
A. Devices for Expanding Network

- Networks cannot be made larger by simply adding new computers and more cables
- An engineer, however, can install components to
  - segment existing LAN to form more LANs
  - join two separate LANs
- The components are
  - Repeaters, bridges, routers, brouters, switches, gateways
a. Repeaters and Hubs

- Repeaters or hubs work at the OSI **physical layer** to regenerate the network’s signal and resend them to other segments.
- Primitive hub can be viewed as a multiport repeater.
- It regenerates data and broadcasts them to all ports.

![Diagram of a weakened signal entering a hub and being regenerated](image-url)
Limitations and Features

- Cannot link unlike segments
- Cannot join segments with different access methods (e.g. CSMA/CD and token passing)
- Do not isolate and filter packets
- Can connect different types of media
- The most economic way of expanding networks
b. Bridges

- Has one input and one output
- Used to isolate network traffic and computers
- Has the intelligent to examine incoming packet source and destination addresses
- But cannot interpret higher-level information
- Hence cannot filter packet according to its protocol
How Bridges Work

- Bridges work at the **Media Access Control Sub-layer** of the OSI model
- Routing table is built to record the segment no. of address
- If destination address is in the same segment as the source address, stop transmit
- Otherwise, forward to the other segment
Creating a Switching Table

- Based on the addresses of the sending computers
- New addresses are added if they are not in the table

Switching Table

<table>
<thead>
<tr>
<th>Seg 1</th>
<th>Seg 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>02</td>
</tr>
</tbody>
</table>

Add01
Add02  S 02  D 01
Add03  S 01  D 02

Segment 1
Segment 2
Bridge
Stop
Remote Bridges

- Bridges are often used in large networks that have widely dispersed segments.
- Remote bridges can be used to connect remote segments via data-grade telephone line.
# Differences Between Bridges and Repeaters

<table>
<thead>
<tr>
<th></th>
<th><strong>Repeaters</strong></th>
<th><strong>Bridges</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OSI layer</strong></td>
<td>Physical layer</td>
<td>Data link layer</td>
</tr>
<tr>
<td><strong>Data regeneration</strong></td>
<td>Regenerate data at the signal level</td>
<td>Regenerate data at the packet level</td>
</tr>
<tr>
<td><strong>Reduce network traffic</strong></td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
c. Switches

- Switches operate at the **Data Link layer** (layer 2) of the OSI model
- Can interpret address information
- Switches resemble bridges and can be considered as **multiport bridges**
- By having multiports, can better use limited bandwidth and prove more cost-effective than bridge
• Switches divide a network into several isolated channels
• Packets sending from 1 channel will not go to another if not specify
• Each channel has its own capacity and need not be shared with other channels
Advantages of Switches

- Switches divide a network into several isolated channels (or collision domains)
  - Reduce the possibility of collision
    - Collision only occurs when two devices try to get access to one channel
    - Can be solved by buffering one of them for later access
  - Each channel has its own network capacity
    - Suitable for real-time applications, e.g. video conferencing
  - Since isolated, hence secure
    - Data will only go to the destination, but not
Limitations of Switches

- Although contains buffers to accommodate bursts of traffic, can become overwhelmed by heavy traffic
  - Device cannot detect collision when buffer full
    - CSMA/CD scheme will not work since the data channels are isolated, not the case as in Ethernet
  - Some higher level protocols do not detect error
    - E.g. UDP
  - Those data packets are continuously pumped to the switch and introduce more problems
Method of Switching - Cut Through Mode

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Des. Add</th>
<th>Sour. Add</th>
<th>Length</th>
<th>Data</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1</td>
<td>2/6</td>
<td>2/6</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Bytes</td>
<td>Byte</td>
<td>Bytes</td>
<td>Bytes</td>
<td>Bytes</td>
<td>Bytes</td>
</tr>
</tbody>
</table>

- Read the first 14 bytes of each packet, then transmit
- Much faster
- Cannot detect corrupt packets
- Can propagate the corrupt packets to the network
- Best suited to small workgroups
Method of Switching - Store and Forward Mode

- **Read the whole packet before transmit**
- **Slower than the cut-through mode**
- **More accurate since corrupt packets can be detected using the FCS**
- **More suit to large LAN since they will not propagate error packets**
- **Facilitate data transfer between segments of different speed**
Using Switches to Create VLANs

- Switches can logically group together some ports to form a virtual local area network (VLAN).
d. Routers

- Layer 2 Switches cannot take advantage of multiple paths
- **Routers work at the OSI layer 3 (network layer)**
- They use the “logical address” of packets and routing tables to determine the best path for data delivery
How Routers Work

• As packets are passed from routers to routers, Data Link layer source and destination addresses are stripped off and then recreated

• Enables a router to route a packet from a TCP/IP Ethernet network to a TCP/IP token ring network

• Only packets with known network addresses will be passed - hence reduce traffic

• Routers can listen to a network and identify its busiest part

• Will select the most cost effective path for transmitting packets
How Routing Table is formed

• Routing table is formed based on communications between routers using “Routing Protocols”
  • Routing Protocols ≠ Rutable Protocol

• Routing Protocols collect data about current network status and contribute to selection of the best path
Routing Protocol Example - RIP for IP Routing

- **RIP (Routing Information Protocol)** — the oldest one
- Use no. of hops between nodes to determine best path
- Does not consider the network congestion condition
- Broadcast every 30 sec the routing table to neighbouring routers to convey routing information
- RIP is limited to interpreting a maximum of 16 hops
- Not suitable for large network (e.g. Internet)
- Can create excessive network traffic due to broadcasting
- May take a long time to reach the far reaches
Routing Protocol Example - OSPF for IP

- **OSPF - Open Shortest Path First**
- Make up the limitations of RIP - can coexist with RIP
- In general case, best path refers to the shortest path
- In case of traffic congestion, can go a longer path
- Each router maintains a database of other router’s links
- If link failure notice is received, router can rapidly compute an alternate path
- Require more memory and CPU power
## Static and Dynamic Routers

<table>
<thead>
<tr>
<th>Static Routers</th>
<th>Dynamic Routers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always use the same route</td>
<td>Can select the best route</td>
</tr>
<tr>
<td>More secure</td>
<td>Need manual configuration to improve security</td>
</tr>
</tbody>
</table>
Routers are layer 3 devices which recognize network address.
Bridges are layer 2 devices which look at the MAC sublayer node address.

- **Bridges** forward everything they don’t recognize.
- **Routers** select the best path.
Layer-3 Switches

- Layer-3 switches operate in both layer 2 (data link layer) and 3 (network layer)
- Can perform both MAC switching and IP routing
- A combination of switch and router but much faster and easier to configure than router

Why Layer-3 switches?

- Traffic of LAN is no longer local
- Speed of LAN is much faster
- Need a much faster router, however, very expensive
Summary

• **Repeaters** are the least expensive way to expand a network, but they are limited to connecting two segments

• **Bridges** function similar to repeaters, but can understand the node addresses

• **Switches** can be considered as multiport bridges, can divide a network into some logical channels

• **Routers** interconnect networks and provide filtering functions. They can determine the best route
B. Remote Access Devices

1. Modems

- Allow computers to communicate over a telephone line
- Enable communication between networks or connecting to the world beyond the LAN
• Cannot send digital signal directly to telephone line
• Sending end: **MODulate** the computer’s digital signal into analog and transmits
• Receiving end: **DEM**odulate the analog signal back into digital form
Amplitude Modulation

Frequency Modulation

Phase Modulation

Normal sine wave
Modems typically have the following I/O interface:
- A serial RS-232 communication interface
- An RJ-11 telephone-line interface (a telephone plug)
## Modem Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>bps</th>
<th>Introduced</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>V.22bis</td>
<td>2,400</td>
<td>1984</td>
<td></td>
</tr>
<tr>
<td>V.32</td>
<td>9,600</td>
<td>1984</td>
<td></td>
</tr>
<tr>
<td>V.32bis</td>
<td>14,400</td>
<td>1991</td>
<td></td>
</tr>
<tr>
<td>V.32terbo</td>
<td>19,200</td>
<td>1993</td>
<td>Communicate only with another V.32terbo</td>
</tr>
<tr>
<td>V.FastClass</td>
<td>28,800</td>
<td>1993</td>
<td>(V.FC)</td>
</tr>
<tr>
<td>V.34</td>
<td>28,800</td>
<td>1994</td>
<td>Improved V.FC</td>
</tr>
<tr>
<td>V.42bis</td>
<td>115,200</td>
<td>1995</td>
<td>With compression</td>
</tr>
<tr>
<td>V.90</td>
<td>56,000</td>
<td>1998</td>
<td>Resolved competition between X2 and Flex56k</td>
</tr>
</tbody>
</table>
Modem Performance Measures

- **Baud rate** - the number of symbol change per second on the transmission line
- **Bit per second (bps)** - number of bits transmitted per second
- In the past, they are identical
- With compression technique, a change of signal can mean more than one bits
- 28.8kbaud can mean 115.2kbps when using V.42bis
How V.90 Works

- Modem speed is determined by channel noise level.
- The noise level of traditional PSTN (public switch telephone network) limits data rate to \(~35\text{kbps}\).
- **56K modem technology** assumes only one analog link hence noise level is much lower.
Why V.90 cannot achieve 56kbps in practice?

• The actual data link is 64kbps
• To prevent interference and allow some overhead data in communication, ITU recommends a lower rate to 56 kbps
• However, 56 kbps is a theoretical number
• Depending on the quality and length of the analog link, the actual data rate can range from 30kbps to 53kbps
Types of Modem - Asynchronous Modems

- No clocking devices
- Commonly used in telephone networks
- Data is transmitted in a serial stream. Each character is turned into a string of 8 bits
- Each of these characters is separated by one start bit and one or two stop bits
Types of Modem - Synchronous Modems

- Need clocking devices
- Data are transmitted in blocks
- Used in digital networks
Comparison

- **Asynchronous modems** are relatively simple and economic
  - Large overhead - can be up to 20 to 27% of the data traffic
  - Error control is done by using parity bit or higher layer protocols, e.g. MNP, V.42

- **Synchronous modems** are relatively complicated and expensive
  - Seldom use in home market
  - Less overhead means higher efficiency
  - More sophisticated error control protocol is required
2. ADSL

- ADSL stands for Asymmetric Digital Subscriber Line
- Particularly suitable for high speed multimedia communications, general Internet applications
- Asymmetric - downstream 1.5 to 6.1Mbps
  upstream 16 to 640kbps
- Digital - mainly for transmitting digital data
  still require modulation and demodulation
- Subscriber line - make use of the analog connection between household and CO
ADSL Illustration

Normal voice

2 to 3 miles

Subcriber line

Local loop

Low speed

High speed

Telephone Company

Data

Splitter
Why Asymmetric?

- In general Internet applications, downstream often requires a higher data rate than upstream
  - **Downstream** - file download, video playback
  - **Upstream** - click a link, send a form

- Reducing the resource for upstream can provide more resource for downstream
Why Subscriber Line?

- By better controlling the length and quality of the analog connection between household and CO, a higher data rate can be achieved.

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Wire Gauge</th>
<th>Distance</th>
<th>Wire Size</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 or 2 Mbps</td>
<td>24 AWG</td>
<td>18,000 ft</td>
<td>0.5 mm</td>
<td>5.5 km</td>
</tr>
<tr>
<td>1.5 or 2 Mbps</td>
<td>26 AWG</td>
<td>15,000 ft</td>
<td>0.4 mm</td>
<td>4.6 km</td>
</tr>
<tr>
<td>6.1 Mbps</td>
<td>24 AWG</td>
<td>12,000 ft</td>
<td>0.5 mm</td>
<td>3.7 km</td>
</tr>
<tr>
<td>6.1 Mbps</td>
<td>26 AWG</td>
<td>9,000 ft</td>
<td>0.4 mm</td>
<td>2.7 km</td>
</tr>
</tbody>
</table>

- More than 80% of the current installed subscriber lines can fulfill this requirement.
- Hence no extra cabling is required.
Architecture of ADSL Services

**Customer Premises**

- NID
- ADSL Modem

**Central Office**

- Telephone Switch
- Copper Loop
- Telephony Splitter
- DSLAM

**ISP POP**

- Internet
- Firewall
- DHCP
- Router
- DNS
- SNMP
- TNI

**Transport Network Link**

- (DSx; OCx; frame; ATM)

**DSLAM** - Digital subscriber line access module (central office ADSL modem pool)
Other DSL Technologies

- **HDSL** – High speed DSL
  2 twisted pair, 12,000 feet
  1.5Mbps (DS1) full-duplex
  Symmetric

- **VDSL** – Very high bit rate DSL
  Downstream: 52 Mbps (SONET STS-1) over 1000 feet; or 15 Mbps over 3000 feet
  Upstream: 1.5 to 2.3 Mbps

- **RDSL** – Rate adaptive DSL
  Intelligent DSL to adjust data rate