Computer Architecture and Organization

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Chapter 9 – Networking and Communication
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Modem Communication

- Communication over a telephone line with modems:
Modulation Schemes

- Three common forms of modulation:

  0 1 0 1 1 0

  Digital Signal

  AM

  FM

  PM
Pulse Code Modulation

- Conversion of an analog signal into a PCM binary sequence:

\[
\text{PCM sequence} = 011\ 110\ 011\ 001\ 100\ 111\ 101
\]
Ideal vs. Transmitted Waves

Amplitude

Time

Ideal wave

Transmitted wave

Sampling instants (at receiver)
Transmission Media

- Transmission media. (a) Two-wire open lines; (b) twisted-pair lines; (c) coaxial cable; (d) optical fiber; (e) satellite.
Tropospheric Scatter

The troposphere starts at the earth’s surface and extends six miles in altitude over polar regions and 10 miles over tropical regions. A transmitted beam is bounced one time through the troposphere to a receiving TROPO terminal up to 150 miles away.
Parity

- Even parity bits are assigned to a few ASCII characters:

<table>
<thead>
<tr>
<th>P</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>0</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

7-bit ASCII character code

- Even parity bit
- Character
Check Bits

- Check bits for a single error correcting ASCII code:

<table>
<thead>
<tr>
<th>Check bits</th>
<th>Bit position checked</th>
</tr>
</thead>
<tbody>
<tr>
<td>C8 C4 C2 C1</td>
<td></td>
</tr>
<tr>
<td>0 0 0 1</td>
<td>1</td>
</tr>
<tr>
<td>0 0 1 0</td>
<td>2</td>
</tr>
<tr>
<td>0 0 1 1</td>
<td>3</td>
</tr>
<tr>
<td>0 1 0 0</td>
<td>4</td>
</tr>
<tr>
<td>0 1 0 1</td>
<td>5</td>
</tr>
<tr>
<td>0 1 1 0</td>
<td>6</td>
</tr>
<tr>
<td>0 1 1 1</td>
<td>7</td>
</tr>
<tr>
<td>1 0 0 0</td>
<td>8</td>
</tr>
<tr>
<td>1 0 0 1</td>
<td>9</td>
</tr>
<tr>
<td>1 0 1 0</td>
<td>10</td>
</tr>
<tr>
<td>1 0 1 1</td>
<td>11</td>
</tr>
</tbody>
</table>
SEC Coded ‘a’

- Format for a single error correcting ASCII code:

ASCII ‘a’ = 1100001

<table>
<thead>
<tr>
<th>Bit position</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check bits</td>
<td>C8</td>
<td>C4</td>
<td>C2</td>
<td>C1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SEC Coded ‘d’

- Parity computation for an ASCII character in an SEC code:

```
Bit position: 11 10 9 8 7 6 5 4 3 2 1
Check bits: C8 C4 C2 C1
```

Location of error:

```
1 0 0 1 0 1 1 1 0 0 1
```

Parity:

- C1 checks: 1, 3, 5, 7, 9, 11 odd
- C2 checks: 2, 3, 6, 7, 10, 11 even
- C4 checks: 4, 5, 6, 7 odd
- C8 checks: 8, 9, 10, 11 even
3-Bit SEC Hypercube

- Hamming distance relationships among three-bit codewords. Valid codewords are 000 and 111. The remaining codewords represent errors.

Three changed bits between valid codewords results in a Hamming distance of 3.
LRC and VRC Checking

- Combined LRC and VRC checking. Checksum bits form even parity for each column.

<table>
<thead>
<tr>
<th>$P$</th>
<th>Code</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1 0 0 0 0 0 1</td>
<td>A</td>
</tr>
<tr>
<td>0</td>
<td>1 0 0 0 0 1 0</td>
<td>B</td>
</tr>
<tr>
<td>1</td>
<td>1 0 0 0 0 1 1</td>
<td>C</td>
</tr>
<tr>
<td>0</td>
<td>1 0 0 0 1 0 0</td>
<td>D</td>
</tr>
<tr>
<td>1</td>
<td>1 0 0 0 1 0 1</td>
<td>E</td>
</tr>
<tr>
<td>1</td>
<td>1 0 0 0 1 1 0</td>
<td>F</td>
</tr>
<tr>
<td>0</td>
<td>1 0 0 0 1 1 1</td>
<td>G</td>
</tr>
<tr>
<td>0</td>
<td>1 0 0 1 0 0 0</td>
<td>H</td>
</tr>
<tr>
<td>1</td>
<td>0 0 0 1 0 0 0</td>
<td>Checksum</td>
</tr>
</tbody>
</table>
Cyclic Redundancy Checking

G(x), of degree $n = 4$

Bitwise exclusive OR (XOR), is the same as modulo-2 addition and modulo-2 subtraction.

Quotient is discarded for the calculation of the original CRC.

$n = 4$ zeros

$R(x)$ is the CRC for $M(x)$

Transmitted frame $T(x) = \overline{11010110111110}$

$M(x)$

$R(x)$
The Seven Layers of the OSI Model
A Few Network Topologies

- (a) Bus; (b) ring; and (c) star network topologies.
Ethernet

- Coax-based Ethernet local area network—bus topology (left), and unshielded twisted pair (UTP)-based Ethernet local area network—star topology (right).
Internet Protocol Stack

- Layering in the TCP/IP protocol suite:

```
1. Physical
  Link
    Network
      Transport
        Application
          7. Application
            6. Presentation
                5. Session
                    4. Transport
                        3. Network
                            2. Data Link
                                1. Physical
```

## IPv4 Address Classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Prefix</th>
<th>Number of Networks</th>
<th>Number of Hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>126</td>
<td>16777214</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>16</td>
<td>65534</td>
</tr>
<tr>
<td>C</td>
<td>110</td>
<td>254</td>
<td>254</td>
</tr>
<tr>
<td>D</td>
<td>1110</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>E</td>
<td>11110</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

- **Class A**: 7 bits for the network ID and 24 bits for the host ID.
- **Class B**: 14 bits for the network ID and 16 bits for the host ID.
- **Class C**: 21 bits for the network ID and 8 bits for the host ID.
- **Class D**: 28 bits for multicast group ID.
- **Class E**: 27 bits, reserved for future use.
Encapsulation

- Encapsulation in the TCP/IP protocol suite:

```
User data
TCP header
IP header
Ethernet header
```

Application layer
Transport layer
Network layer
Link layer
A hub is a central connection point for end systems. A hub simply copies packets from one network interface to all of the others. For the most part, hubs are falling into disuse since the prices of switches have dropped dramatically.
Architecture of an Ethernet Switch

- A switch, formerly referred to as a bridge, does more than simply restore signal levels to logical 1 or 0, like a hub. Switches have some level of intelligence, and can typically interpret the destination address of a packet and route it to the appropriate subnetwork.
A storage area network (SAN) is made up of storage devices, backup devices, access servers, and a specialized network that connects the devices.
Cisco Router Architecture

- A router by definition has two or more network interfaces (such as for Ethernet) and forwards packets among its interfaces. Each interface handles a network segment, identified by a unique network address.
Cisco Router Architecture (Cont’)

- The internal architecture of a router is very similar to that of an ordinary computer. In fact, for years, many routers were simply computers that had multiple network interfaces and routing application software. Present-day routers are specialized to handle the network traffic loads and routing functions more efficiently, but still take the basic von Neumann form. Identify the von Neumann parts of the Cisco 3600: