Principles of Computer Architecture

Chapter 9: Communication
Chapter 9: Communication

Chapter Contents

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Modem Communication

- Communication over a telephone line with modems.
Modulation Schemes

- Three common forms of modulation.

Digital Signal

AM

FM

PM
Pulse Code Modulation

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

PCM sequence = 011 110 011 001 100 111 101
Ideal vs. Transmitted Waves

Sampling instants (at receiver)

Ideal wave

Transmitted wave

0 1 0 1 1 0 0 1
Transmission Media

- Transmission media. (a) Two-wire open lines; (b) twisted-pair lines; (c) coaxial cable; (d) optical fiber; (e) satellites.
The Seven Layers of the OSI Model

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

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

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

<table>
<thead>
<tr>
<th>Bit position</th>
<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></td>
<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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<tr>
<td></td>
<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>

Even parity bit

7-bit ASCII character code

Character

Even parity bit

Parity bit positions

Even parity bits are assigned to a few ASCII characters.
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

Bit position: 11 10 9 8 7 6 5 4 3 2 1

Check bits: C8 C4 C2 C1
SEC Coded ‘d’

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

Location of error

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

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>10000001</td>
<td>A</td>
</tr>
<tr>
<td>0</td>
<td>10000100</td>
<td>B</td>
</tr>
<tr>
<td>1</td>
<td>10000111</td>
<td>C</td>
</tr>
<tr>
<td>0</td>
<td>10001000</td>
<td>D</td>
</tr>
<tr>
<td>1</td>
<td>1000101</td>
<td>E</td>
</tr>
<tr>
<td>1</td>
<td>1000110</td>
<td>F</td>
</tr>
<tr>
<td>0</td>
<td>1000111</td>
<td>G</td>
</tr>
<tr>
<td>0</td>
<td>1001000</td>
<td>H</td>
</tr>
<tr>
<td>1</td>
<td>0001000</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

Transmitted frame $T(x) = 1101011011110$

$M(x)$ $R(x)$

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

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Internet Protocol Stack

- Application
- Transport
- Network
- Link
  - MAC
  - PHY
# IPv4 Address Classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Netid Bits</th>
<th>Hostid Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td>7 bits</td>
<td>24 bits</td>
</tr>
<tr>
<td>Class B</td>
<td>14 bits</td>
<td>16 bits</td>
</tr>
<tr>
<td>Class C</td>
<td>21 bits</td>
<td>8 bits</td>
</tr>
<tr>
<td>Class D</td>
<td>28 bits</td>
<td></td>
</tr>
<tr>
<td>Class E</td>
<td>27 bits</td>
<td></td>
</tr>
</tbody>
</table>

- **Class A**: 0 netid, 24 bits host id
- **Class B**: 10 netid, 16 bits host id
- **Class C**: 110 netid, 8 bits host id
- **Class D**: 1110 multicast group id
- **Class E**: 11110 reserved for future use
Encapsulation

- Encapsulation in the TCP/IP protocol suite.

```
User data

TCP header User data

IP header TCP header User data

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

Application layer
Transport layer
Network layer
Link layer
Hub vs. Router vs. Switch

- Configurations shown for (a) a hub; (b) a router; and (c) a switch.
Self-Routing Switch

- A $4 \times 4$ self-routing switch based on the bubblesort algorithm.
TDM vs. ATM

• (a) Time division multiplexing vs. (b) asynchronous transfer mode.

Station time slots

(a)  

[Diagram showing time slots with some shaded and some white, indicating data and no data]

= Station data  = Nothing to send

(b)  

[Diagram showing cells with source numbers]
Format of an ATM Packet

- Format of an ATM packet. (a) User-to-network interface (UNI) format; and (b) network-to-network interface (NNI) format.

![Diagram showing the format of an ATM packet with UNI and NNI formats.](image)
**Simple ATM Network**

<table>
<thead>
<tr>
<th>VPI&lt;sub&gt;IN&lt;/sub&gt;</th>
<th>VPI&lt;sub&gt;OUT&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>VPI = 7</td>
<td>VCI = 1, 2, 3</td>
</tr>
<tr>
<td>VPI = 9</td>
<td>VCI = 3, 4</td>
</tr>
<tr>
<td>VPI = 7</td>
<td>VCI = 3, 4</td>
</tr>
<tr>
<td>VPI = 7</td>
<td>VCI = 1, 2, 3</td>
</tr>
</tbody>
</table>

**ATM Switch #1**

**ATM Switch #2**

**ATM Switch #3**