Chapter 5

Data-Link Layer:
5-1 INTRODUCTION

The Internet is

- a combination of networks glued together by connecting devices

- If a datagram is to travel from a host to another host, it needs to pass through these networks.
Communication at the data-link layer
Nodes and Links

- Communication at the application, transport, and network layers $\rightarrow$ end-to-end

- Communication at the data-link layer $\rightarrow$ node-to-node.

- It is customary to refer to the two end hosts and the routers as nodes and the networks in between as links.
**Nodes and Links**

*a. A small part of the Internet*

*b. Nodes and links*
Error Detection and Correction

- At the data-link layer, if a frame is corrupted between the two nodes, it needs to be corrected before it continues its journey to other nodes.

- Most link-layer protocols simply discard the frame and let the upper-layer protocols handle the retransmission of the frame.
Single-bit and burst error

a. Single-bit error

Sent: 0 0 0 0 0 0 1 0

Corrupted bit

Received: 0 0 0 0 1 0 1 0

b. Burst error

Length of burst error (8 bits)

Sent: 0 1 0 0 1 1 0 1 0 1 0 0 0 0 1 1

Corrupted bits

Received: 0 1 0 1 0 1 0 0 0 1 1 0 0 0 1 1
Division in CRC encoder

Dataword 1 0 0 1

Encoding

Quotient
1 0 1 0

Discard

Divisor 1 0 1 1

1 0 0 1

0 1 0 0

0 0 0 0

1 0 0 0

1 0 1 1

0 1 1 0

0 0 0 0

1 1 0

Leftmost bit 0: use 0000 divisor

Leftmost bit 0: use 0000 divisor

Dividend

Remainder

Codeword 1 0 0 1 1 1 0

Dataword plus remainder

Note:
Multiply: AND
Subtract: XOR

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Division in the CRC decoder for two cases

**Uncorrupted**

Codeword: 1 0 0 1 1 1 0

Decoder:

\[
\begin{array}{c}
1 0 1 0 \\
\hline
1 0 1 1 \\
0 1 0 1 \\
0 0 0 0 \\
\hline
1 0 1 1 \\
1 0 1 1 \\
0 0 0 0 \\
0 0 0 0 \\
\end{array}
\]

Zero Syndrome: 0 0 0

Dataword accepted: 1 0 0 1

**Corrupted**

Codeword: 1 0 0 0 1 1 0

Decoder:

\[
\begin{array}{c}
1 0 1 1 \\
\hline
1 0 1 1 \\
0 1 1 1 \\
0 0 0 0 \\
\hline
1 1 1 1 \\
1 0 1 1 \\
1 0 0 0 \\
1 0 1 1 \\
\end{array}
\]

Non-Zero Syndrome: 0 1 1

Dataword discarded

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Standard polynomials

<table>
<thead>
<tr>
<th>Name</th>
<th>Binary</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRC-8</td>
<td>100000111</td>
<td>ATM header</td>
</tr>
<tr>
<td>CRC-10</td>
<td>11000110101</td>
<td>ATM AAL</td>
</tr>
<tr>
<td>CRC-16</td>
<td>10001000000100001</td>
<td>HDLC</td>
</tr>
<tr>
<td>CRC-32</td>
<td>100000100110000001000111011011011</td>
<td>LANs</td>
</tr>
</tbody>
</table>
Checksum

Sender

Message

m bits m bits • • • m bits

Generator

m bits m bits • • • m bits m bits

Message plus checksum

Receiver

Message

m bits m bits • • • m bits

All 0’s [yes]

Discard [no]

m bits

Checker

m bits m bits • • • m bits m bits m bits

Message plus checksum
MULTIPLE ACCESS PROTOCOLS
Taxonomy of multiple-access protocols

Multiple-access protocols

Random-access protocols
- ALOHA
- CSMA/CD
- CSMA/CA

Controlled-access protocols
- Reservation
- Polling
- Token passing

Channelization protocols
- FDMA
- TDMA
- CDMA
Random Access

- A station that has data to send uses a procedure defined by the protocol to make a decision on whether or not to send.

- This decision depends on the state of the medium (idle or busy).
Frames in a pure ALOHA network

- Station 1
- Station 2
- Station 3
- Station 4

Collision duration

Time
Frames in a slotted ALOHA network

- Station 1: Collision duration, Collision duration
- Station 2: Collision duration, Collision duration
- Station 3: Collision duration
- Station 4: Collision duration

Time

Slot 1, Slot 2, Slot 3, Slot 4, Slot 5, Slot 6
Space/time model of a collision in CSMA (Part I: model)
Behavior of three persistence methods

a. 1-persistent

b. Nonpersistent

c. p-persistent
Collision of the first bits in CSMA/CD

Collision occurs
Collision and abortion in CSMA/CD
Energy level during transmission, idleness, or collision
Address Resolution Protocol (ARP)
ARP operation

Request: Looking for link-layer address of a node with IP address N2

a. ARP request is broadcast

Reply: I am the node and my link-layer address is L2

b. ARP reply is unicast
**Ethernet frame**

**Preamble**: 56 bits of alternating 1s and 0s  
**SFD**: Start frame delimiter, flag (10101011)

<table>
<thead>
<tr>
<th>Preamble</th>
<th>SFD</th>
<th>Destination address</th>
<th>Source address</th>
<th>Type</th>
<th>Data and padding</th>
<th>CRC</th>
</tr>
</thead>
</table>
| 7 bytes  | 1 byte | 6 bytes            | 6 bytes        | 2 bytes | Minimum payload length: 46 bytes  
Maximum payload length: 1500 bytes |

| Physical-layer header | Minimum frame length: 512 bits or 64 bytes  
Maximum frame length: 12,144 bits or 1518 bytes |
|-----------------------|-------------------------------------------------|
Virtual LANs

- A station is considered part of a LAN if it physically belongs to that LAN.

- The criterion of membership is geographic.

- What happens if we need a virtual connection between two stations belonging to two different physical LANs? We can roughly define a virtual local area network (VLAN) as a local area network configured by software, not by physical wiring.
A switch connecting three LANs
switch using VLAN software
Two switches in a backbone using VLAN software