Data and Computer Communications

Chapter 7 – Data Link Control Protocols
High Level Data Link Control (HDLC)

- an important data link control protocol
- specified as ISO 33009, ISO 4335
- station types:
  - Primary - controls operation of link - frames sent by primary are called commands
  - Secondary - under control of primary station - frames sent by secondary are called responses
  - Combined - issues commands and responses
- link configurations
  - Unbalanced - 1 primary, multiple secondary
  - Balanced - 2 combined stations
Configurations and Transfer Modes

Frames

Frame Format

Examples
Normal Response Mode (NRM)
- unbalanced config, primary initiates transfer
- used on multi-drop lines, eg host + terminals

Asynchronous Balanced Mode (ABM)
- balanced config, either station initiates transmission, has no polling overhead, widely used

Asynchronous Response Mode (ARM)
- unbalanced config, secondary may initiate transmit without permission from primary, rarely used
11.15 NRM

a. Point-to-point

b. Multipoint
HDLC Frame Structure

- synchronous transmission of frames
- single frame format used

(a) Frame format
11.17 HDLC frame

Flag Address Control Information FCS Flag

Only in I- and U-frames
Flag Fields and Bit Stuffing

- delimit frame at both ends with 01111110 seq
- receiver hunts for flag sequence to synchronize
- bit stuffing used to avoid confusion with data containing flag seq 01111110
  - 0 inserted after every sequence of five 1s
  - if receiver detects five 1s it checks next bit
  - if next bit is 0, it is deleted (was stuffed bit)
  - if next bit is 1 and seventh bit is 0, accept as flag
  - if sixth and seventh bits 1, sender is indicating abort

Original Pattern:
1111111111101111101111110

After bit-stuffing
1111101111101101111101011111010
Framing

- Mapping stream of physical layer bits into frames
- Mapping frames into bit stream
- Frame boundaries can be determined using:
  - Character Counts
  - Control Characters
  - Flags
  - CRC Checks
Framing & Bit Stuffing

HDLC frame

<table>
<thead>
<tr>
<th>Flag</th>
<th>Address</th>
<th>Control</th>
<th>Information</th>
<th>FCS</th>
<th>Flag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>any number of bits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Frame delineated by flag character
- HDLC uses *bit stuffing* to prevent occurrence of flag 01111110 inside the frame
- Transmitter inserts extra 0 after each consecutive five 1s *inside* the frame
- Receiver checks for five consecutive 1s
  - if next bit = 0, it is removed
  - if next two bits are 10, then flag is detected
  - If next two bits are 11, then frame has errors
Example: Bit stuffing & de-stuffing

(a) Data to be sent

0110111111111100

After stuffing and framing

011111100110111110111110001111110

(b) Data received

011111110000111011111011111011001111110

After destuffing and deframing

*000111011111-11111-110*
Bit stuffing is the process of adding one extra 0 whenever there are five consecutive 1s in the data so that the receiver does not mistake the data for a flag.

Note:
# 11.24 Bit stuffing and removal

<table>
<thead>
<tr>
<th>Flag</th>
<th>Address</th>
<th>Control</th>
<th>Data sent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>00011111101001111101000</td>
</tr>
</tbody>
</table>

Frame sent

Stuffed

<table>
<thead>
<tr>
<th>Flag</th>
<th>Address</th>
<th>Control</th>
<th>Data received</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>0001111110110011111001000</td>
</tr>
</tbody>
</table>

Frame received

Extra 2 bits

Unstuffed

<table>
<thead>
<tr>
<th>Flag</th>
<th>Address</th>
<th>Control</th>
<th>Data received</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>000111111001111101000</td>
</tr>
</tbody>
</table>

FCS | Flag
--- | ---
11.25 Bit stuffing in HDLC

Start

After one 0 and five continuous 1s

7th bit?

0

Unstuff zero.

1

It is part of the data.

8th bit?

0

It is a flag.

1

Continue counting 1s until the next 0

Total 1s?

,15

It is an abort.

.5

It means an idle channel.

Stop
Address Field

- identifies secondary station that sent or will receive frame
- usually 8 bits long
- may be extended to multiples of 7 bits
  - LSB indicates if is the last octet (1) or not (0)
- all ones address 11111111 is broadcast

(b) Extended Address Field
Control Field

- different for different frame type
  - Information - data transmitted to user (next layer up)
    - Flow and error control piggybacked on information frames
  - Supervisory - ARQ when piggyback not used
  - Unnumbered - supplementary link control
- first 1-2 bits of control field identify frame type

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![Diagram of 8-bit control field format](image)

- I: Information
  - 0: N(S)
  - 1: P/F
  - 2: N(R)
- S: Supervisory
  - 1: S
  - 2: P/F
  - 3: N(R)
- U: Unnumbered
  - 1: M
  - 2: P/F
  - 3: M

- N(S) = Send sequence number
- N(R) = Receive sequence number
- S = Supervisory function bits
- M = Unnumbered function bits
- P/F = Poll/final bit
11.18 HDLC frame types

- **I-frame**
  - Flag
  - Address
  - Control
  - User information
  - FCS
  - Flag

- **S-frame**
  - Flag
  - Address
  - Control
  - FCS
  - Flag

- **U-frame**
  - Flag
  - Address
  - Control
  - Management information
  - FCS
  - Flag
11.19 I-frame

```
| Flag | Address | Control | Information | FCS | Flag |
```

```
0  0  0  0  P/F  N(S)  N(R)  N(S)  N(R)  FCS  Flag
```
S-frame control field in HDLC

Code

RR
RNR
REJ
SREJ
11.21 U-frame control field in HDLC

<table>
<thead>
<tr>
<th>Code</th>
<th>Command</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 001</td>
<td>SNRM</td>
<td></td>
</tr>
<tr>
<td>11 011</td>
<td>SNRME</td>
<td></td>
</tr>
<tr>
<td>11 100</td>
<td>SABM</td>
<td>DM</td>
</tr>
<tr>
<td>11 110</td>
<td>SABME</td>
<td></td>
</tr>
<tr>
<td>00 000</td>
<td>UI</td>
<td>UI</td>
</tr>
<tr>
<td>00 110</td>
<td></td>
<td>UA</td>
</tr>
<tr>
<td>00 010</td>
<td>DISC</td>
<td>RD</td>
</tr>
<tr>
<td>10 000</td>
<td>SIM</td>
<td>RIM</td>
</tr>
<tr>
<td>00 100</td>
<td>UP</td>
<td></td>
</tr>
<tr>
<td>11 001</td>
<td>RSET</td>
<td></td>
</tr>
<tr>
<td>11 101</td>
<td>XID</td>
<td>XID</td>
</tr>
<tr>
<td>10 001</td>
<td>FRMR</td>
<td></td>
</tr>
<tr>
<td>Command/response</td>
<td>Meaning</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------------</td>
<td></td>
</tr>
<tr>
<td>SNRM</td>
<td>Set normal response mode</td>
<td></td>
</tr>
<tr>
<td>SNRME</td>
<td>Set normal response mode (extended)</td>
<td></td>
</tr>
<tr>
<td>SABM</td>
<td>Set asynchronous balanced mode</td>
<td></td>
</tr>
<tr>
<td>SABME</td>
<td>Set asynchronous balanced mode (extended)</td>
<td></td>
</tr>
<tr>
<td>UP</td>
<td>Unnumbered poll</td>
<td></td>
</tr>
<tr>
<td>UI</td>
<td>Unnumbered information</td>
<td></td>
</tr>
<tr>
<td>UA</td>
<td>Unnumbered acknowledgment</td>
<td></td>
</tr>
<tr>
<td>RD</td>
<td>Request disconnect</td>
<td></td>
</tr>
<tr>
<td>DISC</td>
<td>Disconnect</td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>Disconnect mode</td>
<td></td>
</tr>
<tr>
<td>RIM</td>
<td>Request information mode</td>
<td></td>
</tr>
<tr>
<td>SIM</td>
<td>Set initialization mode</td>
<td></td>
</tr>
<tr>
<td>RSET</td>
<td>Reset</td>
<td></td>
</tr>
<tr>
<td>XID</td>
<td>Exchange ID</td>
<td></td>
</tr>
<tr>
<td>FRMR</td>
<td>Frame reject</td>
<td></td>
</tr>
</tbody>
</table>
Control Field

- use of Poll/Final bit depends on context
- in command frame is P bit set to 1 to solicit (poll) response from peer
- in response frame is F bit set to 1 to indicate response to soliciting command
- seq number usually 3 bits
  - can extend to 8 bits as shown below

(d) 16-bit control field format
Information & FCS Fields

- Information Field
  - in information and some unnumbered frames
  - must contain integral number of octets
  - variable length

- Frame Check Sequence Field (FCS)
  - used for error detection
  - either 16 bit CRC or 32 bit CRC
HDLC Operation

- consists of exchange of information, supervisory and unnumbered frames
- have three phases
  - initialization
    - by either side, set mode & seq
  - data transfer
    - with flow and error control
    - using both I & S-frames (RR, RNR, REJ, SREJ)
  - disconnect
    - when ready or fault noted
HDLC Operation Example
HDLC Operation Example

(d) Reject recovery

(e) Timeout recovery
Example 3

Figure 11.22 shows an exchange using piggybacking where there is no error. Station A begins the exchange of information with an I-frame numbered 0 followed by another I-frame numbered 1. Station B piggybacks its acknowledgment of both frames onto an I-frame of its own. Station B’s first I-frame is also numbered 0 [N(S) field] and contains a 2 in its N(R) field, acknowledging the receipt of A’s frames 1 and 0 and indicating that it expects frame 2 to arrive next. Station B transmits its second and third I-frames (numbered 1 and 2) before accepting further frames from station A. Its N(R) information, therefore, has not changed: B frames 1 and 2 indicate that station B is still expecting A frame 2 to arrive next.
Example 3
In Example 3, suppose frame 1 sent from station B to station A has an error. Station A informs station B to resend frames 1 and 2 (the system is using the Go-Back-N mechanism). Station A sends a reject supervisory frame to announce the error in frame 1. Figure 11.23 shows the exchange.
Summary

- introduced need for data link protocols
- flow control
- error control
- HDLC