Data Link Control Requirements - Revisited

- The first three of the six *Data Link Control* requirements have been examined through an exploration of various techniques:
  - Frame Synchronization (recall *Asynchronous*/*Synchronous* communications),
  - Flow Control (recall *Stop-and-Wait* and *Sliding Windows* Flow Control),
  - Error Control (recall *Stop-and-Wait*, *Go-back-N* and *Selective Reject* ARQ),
  - Addressing,
  - Control and Data on same link.
  - Link Management.
- Recall the reason for using these techniques:
  - To transform a *transmission link* into a fully functioning, reliable and effective *data communications link.*
- The remaining requirements can be considered using a real protocol that fulfils all of the requirements together namely :
  - *High Level Data Link Control* (HDLC).

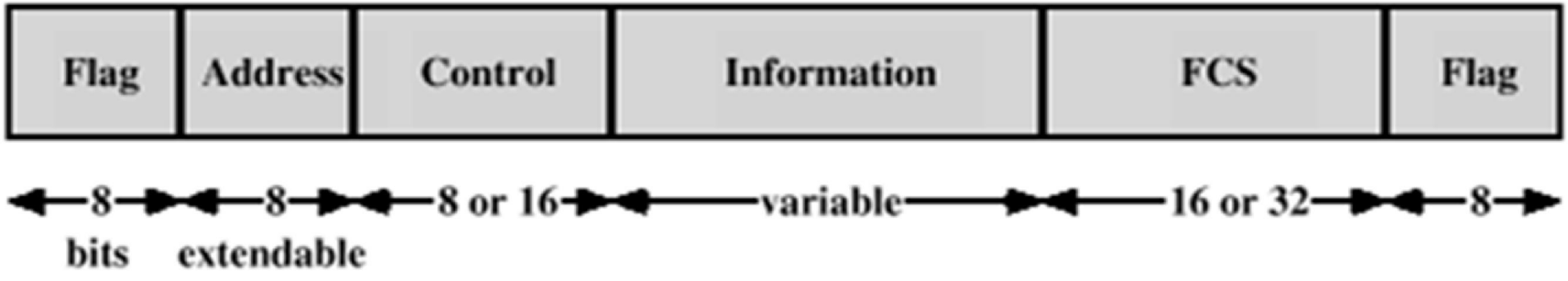
High-Level Data Link Control

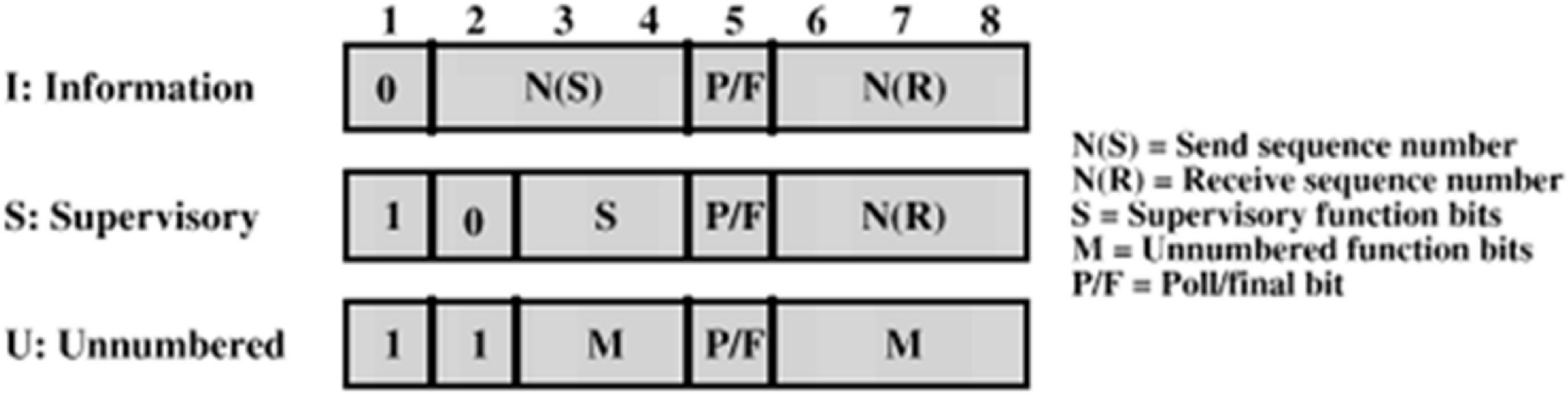
- This is a very important Data Link Control Protocol:
  - As well as being widely used it also forms the basis for many other data link control protocols such as PPPoE which is used by many ISPs and by Cisco.
- The protocol defines the following:
  - The role of each station attached to the link i.e. is there a Master-Slave or Peer-to-Peer relationship?
  - The mode of data transfer i.e. can any station initiate a data transfer?
  - The structure of the frame i.e. the location of each field.
  - The exchange of data during each phase of communication.

HDLC

- The protocol defines three types of station:
  - *Primary station*. Controls the operation of the link through the use of *commands*.
  - *Secondary Station*. Operates under the control of primary station. It *responds* to commands.
  - *Combined Station* combines features of both. It can send *commands* and *responses.*
- *Synchronous* transmission is used i.e. transmissions are in the form of *frames.*
- A *frame* is a block of data delineated by a special *flag* character/sequence (01111110).
- *Data* and *Control* frames have the same basic frame format with some minor differences in relation to the control fields.

HDLC Frame Format





(c) 8-bit control field format

HDLC – The Flag fields

- All *active* stations scan incoming bit streams:
  - Initially to determine “start of a frame”,
  - The station continues to scan the bits looking for the “end of the frame”.
- The same flag pattern may be used to signify end and start of two consecutive frames.
- The flag pattern (01111110) must not be allowed to occur inside frame.
- This is prevented by *bit stuffing.*

Bit Stuffing Example

Original Pattern:

111111111111011111101111110

After bit-stuffing

1111101111110110111110101111010

HDLC – The Address Field

- Used to identify the stations:
  - Only relevant on a *multi-point* link (not on a *point-to-point* link) but it is always included.
- Usually 8 bits long but can be extended.

HDLC – The Control field

- There are three *types* of frame and each has its own control field format:
  - *Information* (I) frames carry **Data**. They can also carry *piggybacked* frame sequence numbers for Flow and Error control.
  - *Supervisory* (S) frames carry Flow and Error control data when not *piggybacked.*
  - *Unnumbered* (U) frames provide link control functions such as set-up and disconnect.

HDLC – The Information field

- Present in *I*-frames:
  - This is where the **Data** is stored.
- Its length is variable up to some predefined system specific limit:
  - However, it must be a multiple of 8 bits.

HDLC – The FCS field

- Used in *error detection*:
  - This is an *Error Detection* code. It is calculated using all bits within the frame excluding flags.
  - Recall Cyclic Redundancy Check (CRC).
- Normally a 16-bit CRC technique is used.

HDLC Commands/Responses

HDLC COMMANDS AND RESPONSES			
FRAME TYPE	**NAME**	**COMMAND/ RESPONSE**	**DESCRIPTION**
INFORMATION (I)	Information	C/R	Exchange user data
SUPERVISORY (S)	Receive ready (RR)	C/R	Positive ack; ready to receive I-frame
SUPERVISORY (S)	Receive not ready (RNR)	C/R	Positive ack; not ready to receive I-frame
SUPERVISORY (S)	Reject (REJ)	C/R	Negative ack; go back N
SUPERVISORY (S)	Selective Reject (SREJ)	C/R	Negative ack; selective reject
UNNUMBERED (U)	SNRM	C	Set Mode
UNNUMBERED (U)	SARM	C	Set Mode
UNNUMBERED (U)	SABM	C	Set Mode
UNNUMBERED (U)	DISC	C	Terminate logical link
UNNUMBERED (U)	UA	R	Acknowledge U-frame command
UNNUMBERED (U)	DM	R	Station is logically disconnected
UNNUMBERED (U)	UI	C/R	Used to exchange control information
UNNUMBERED (U)	RSET	C	Resets N(S), N(R)
UNNUMBERED (U)	FRMR	R	Reports receipt of invalid frame

HDLC Operation

- All HDLC interactions follow three distinct phases of operation:
  - Phase 1 - ***Initialisation***. This is where the 'link' is set-up prior to actual communications. Certain parameters are agreed by each station.
  - Phase 2 - ***Data Transfer***. This is where the **Data** is exchanged.
  - Phase 3 - ***Termination*** or ***Disconnect***. This is where the 'link' is decommissioned.

HDLC Operation - Initialisation

- Initialisation:
  - Either station may initialise the link by sending one of 6 *set mode* commands depending on the mode required.
  - Most commonly used is SABM i.e. Set Asynchronous Balanced Mode. Used with two *combined* stations.
  - The *receiving* station responds with an *Unnumbered Acknowledgement* (UA) to accept or, *Disconnect Mode* (DM) to reject the request.
  - Only ‘U’ frames are used during this phase.

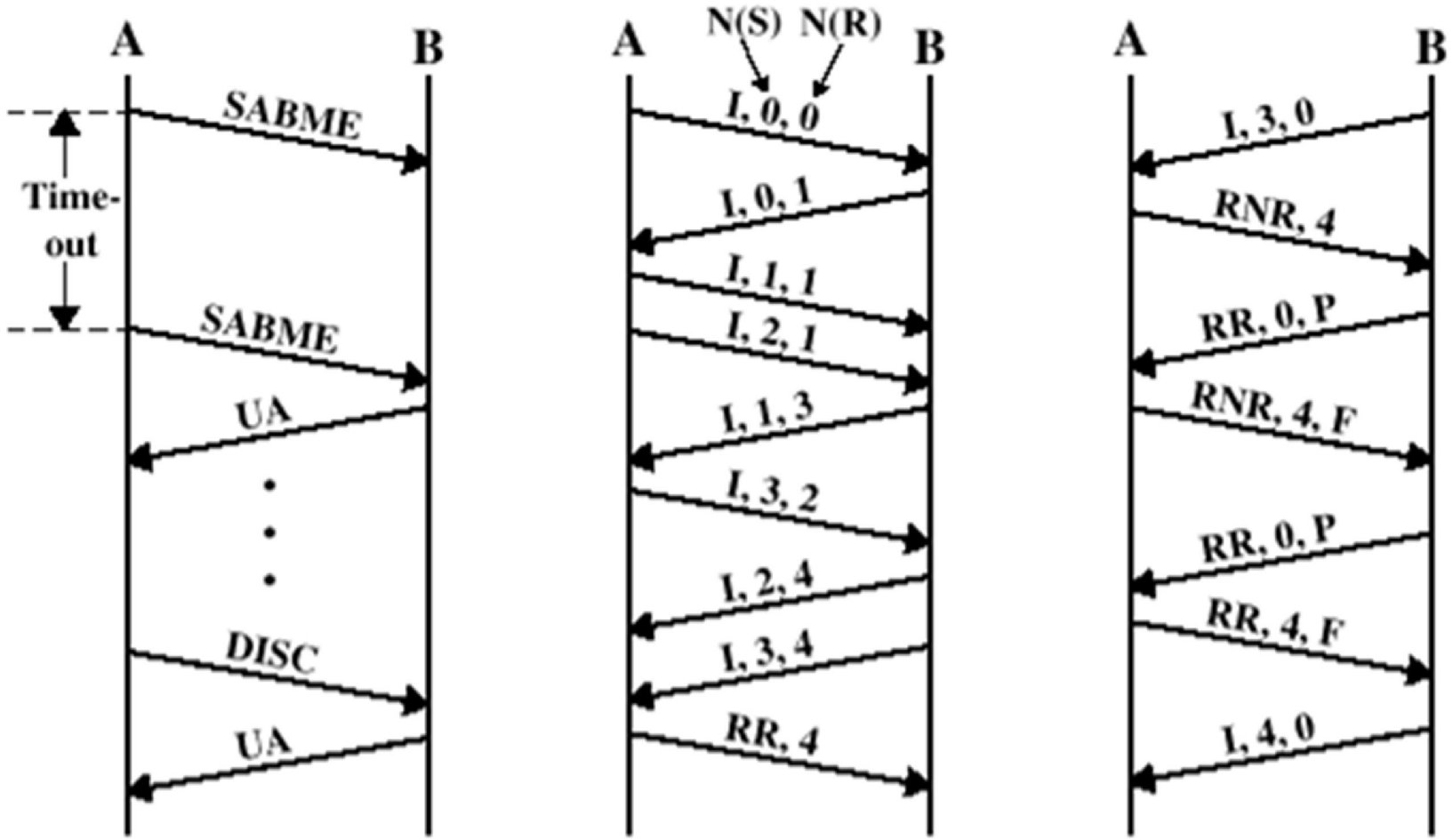
HDLC Operation - Data Transfer

- After *initialisation*, data exchange takes place using *I*-frames:
  - Recall that I-frames carry ***Data.***
- Each *I*-frame also contains two sequence numbers:
  - One relates to the outgoing frame i.e. this frame number.
  - The other is a *piggybacked* ACK for a frame received from the other side of the link i.e. the number of the next frame expected.
  - When *piggybacking* is not being used, *S*-frames are used for flow and error control.
  - The first frame transmitted is always numbered zero.

HDLC Operation - Disconnect

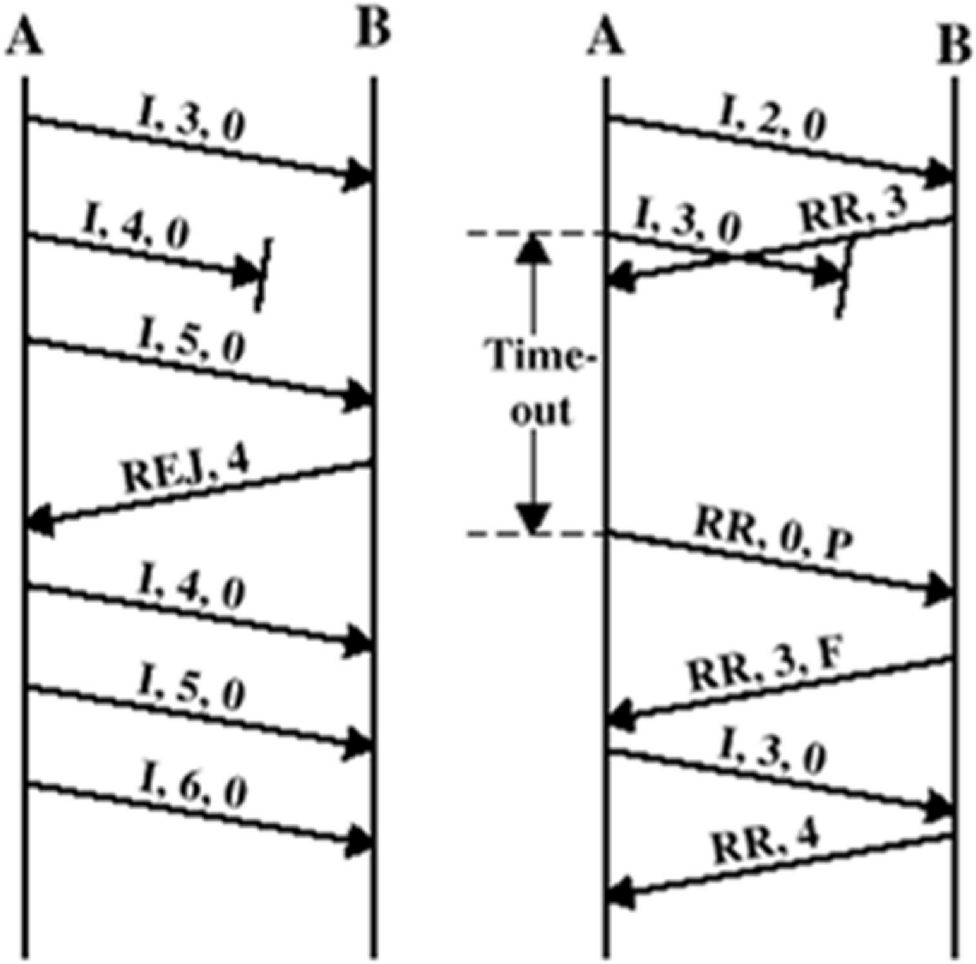
- Either station can initiate the *Disconnect* Phase:
  - This is achieved using a *U-frame* containing the *DISC* message.
  - The remote station must respond with a *U-frame* containing the *UA* message.

HDLC Operation - Example



(a) Link setup and disconnect (b) Two-way data exchange (c) Busy condition

HDLC Operation - Example



(d) Reject recovery

(e) Timeout recovery