The University of Sydney

AUSTRALIA

School of Electrical and Information Engineering

Advanced Communication Networks

Chapter 8

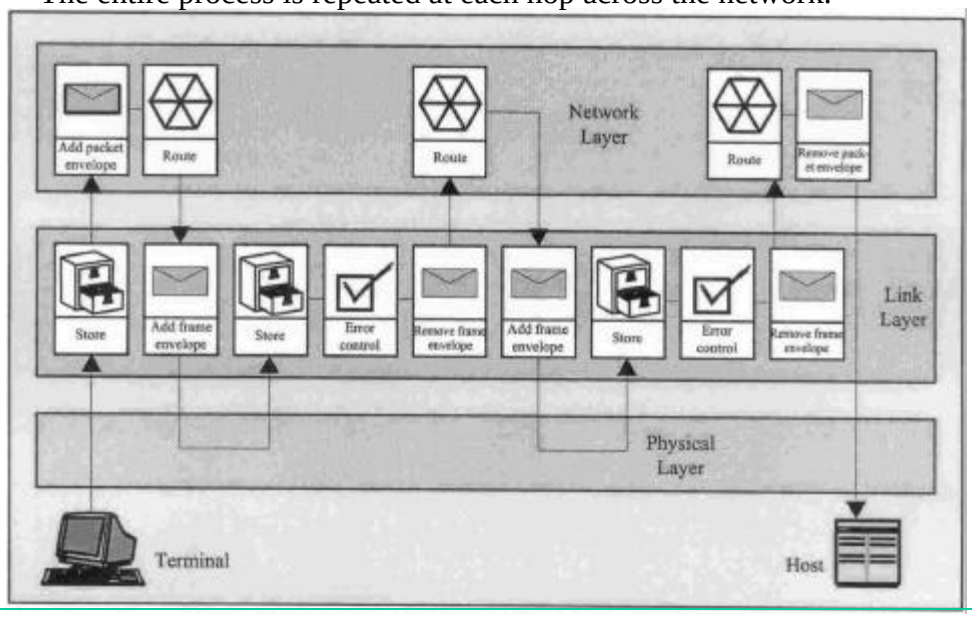
Frame Relay Protocols and Services

Based on chapter 12 of Stallings ISDN-4e book

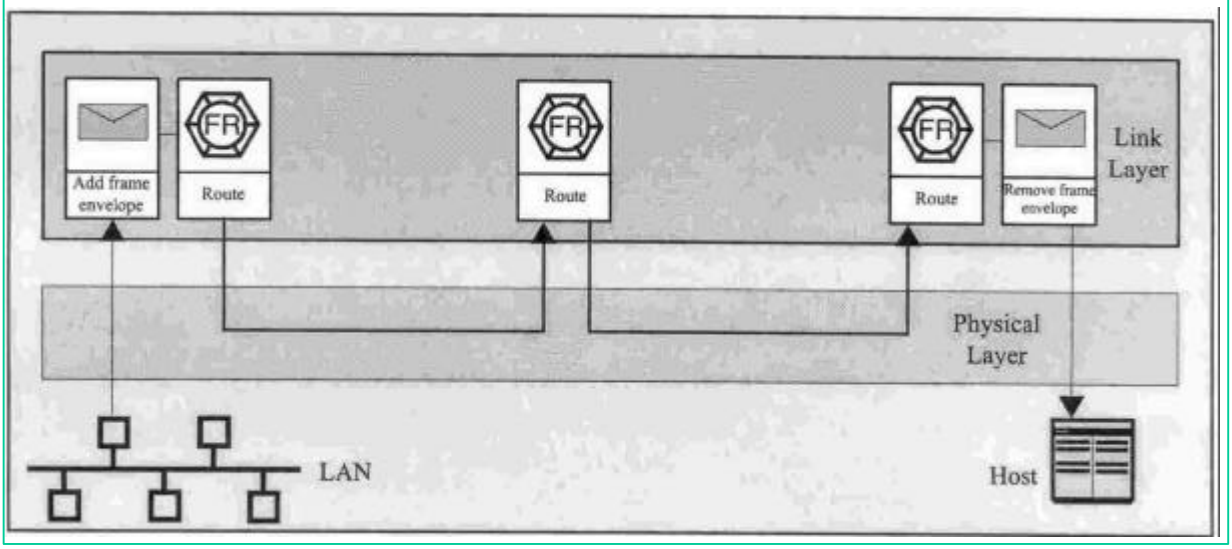
Abbas Jamalipour

8.1 Introduction

- The most technical innovation to come out of the standardization work on narrowband ISDN is the frame relay.
- Frame relay is a streamlined technique for packet switching that operates at the data link layer with much less overhead than packet switching X.25
- Standardization of the frame-mode bearer service, or frame relay, was done by both ITU-T and ANSI.
- Key features of the X.25 approach are:
  - Call control packets (for setup and clear VCs) are carried on the same channel and same VC as data packets (inband signaling).
  - Multiplexing of virtual circuits takes place at layer 3.
  - Both layer 2 and 3 include flow- and error-control mechanisms.
- Packet switching results in considerable overhead. For a simple network of just three nodes between source and destination (figure below):
  - Source data needs to be stored for possible retransmission.
  - X.25 header is added to blocks of data to form a packet.
  - Routing calculations are made.
  - Packets enclosed in a LAPB frame by adding LAPB header and trailer.
  - At intermediate node flow- and error-control are performed (ack back, re-Tx).
  - The node removes data link layer field for routing purposes
  - The entire process is repeated at each hop across the network.



- With highly reliable digital transmission technology, such as one used in ISDN, with a low probability of error, the above approach is not the best.
- Moreover, such overheads degrades effective utilization of the links.
- Frame relay eliminates overhead of X.25 by having these characteristics:
  - Call control signaling is carried on a separate logical connection from user data. Thus, the necessities of maintaining state tables at intermediate nodes canceled.
  - Multiplexing and switching of logical connections are in layer 2.
  - There is no hop-to-hop flow- and error-control (performed at a higher layer).
- Disadvantage of frame relay compared to X.25:
  - The ability of link-by-link flow and error control has been lost.
  - In X.25 multiple VCs are carried on a single physical link and LAPB is available at link layer for providing reliable transmission.
- Advantage of frame relay is streamlining the communication process.
  - Protocol functionality required at user-network interface and internal network processing are reduced.
  - Thus, lower delay and higher throughput can be expected.
- Four applications for frame relay over a high-speed H channel (ANSI)
  - Block-interactive data applications-e.g. high-resolution graphics such as video-tex, CAD/CAM (low delay and high throughput desirable)
  - File transfer-for large files high throughput is required.
  - Multiplexed low bit rate-an economical access for large number of low-bit-rate applications.
  - Character-interactive traffic-e.g. text editing (short frames, low delay and throughput)



8.2 Frame-Mode Protocol Architecture

Frame-Mode Bearer Services

- Two different services defined in ITU-T I.233
  - frame relaying
  - frame switching
- **Frame relaying bearer service**

basic network service for transfer of data link frames over a D, B, or H ch.

- User-network interface allows for establishment of multiple virtual calls and/or permanent virtual circuits to multiple destinations.
- For virtual calls, control signaling is performed in a logically separate manner via a D channel signaling protocol.
- User data are transmitted in form of frames, using a data link protocol (LAPF).
- The network preserves the order of frames transmitted at one S or T reference point when they are delivered at the other end.
- The network detects transmission, format, and operational errors and discards the affected frames.

- **Frame-switching bearer service**

enhanced network service for transfer of data link frames over a D, B, or H ch.

- Having all characteristics of frame-relaying service plus:
- Frames are transmitted with acknowledgement returned to the transmitter user.
- Flow control is supported across the user-network interface in both directions.
- Network detects and recovers from transmission, format, and operation errors.
- Network detects and recovers from lost or duplicated frames.

A Comparison between two services

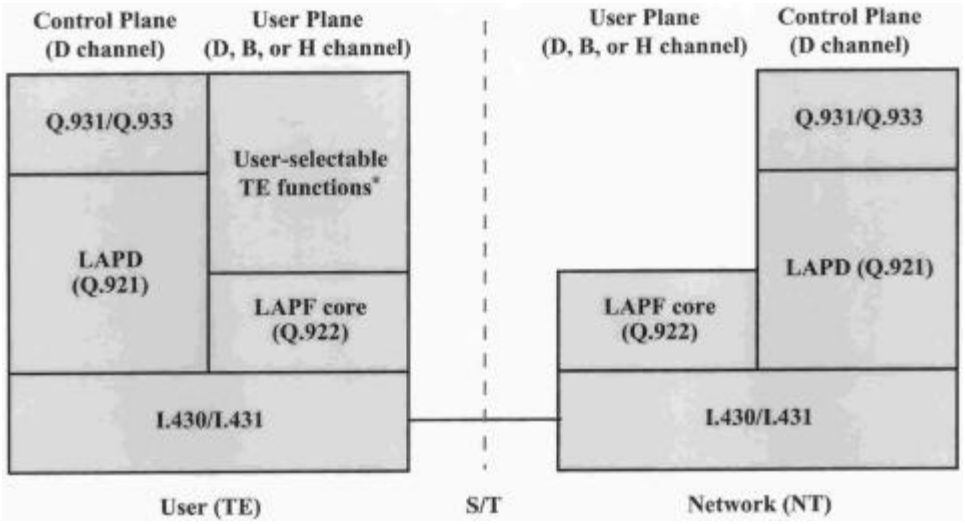
- Frame-relaying is an unreliable multiplexed service (unacknowledged service-lost frames are possible-with no flow control across user-network interface).
- Frame-relaying service provides sequenced delivery of frames.
- Frame-switching service is a reliable multiplexed service, providing flow control and error control (more analogous to X.25).
- Frame-relaying services are widely available.
- Because of existence of higher-layers software for end-to-end reliability, frame-switching is not used much.

Protocol Architecture at the User-Network Interface

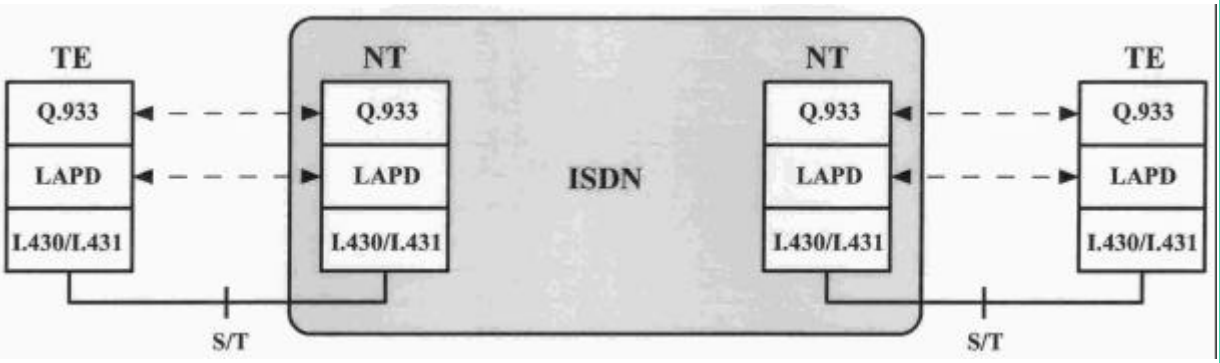
- Again two separate planes of operation:
  - **control plane (C-plane)**
    - for establishment and termination of logical connections
    - protocols between a subscriber and the network
  - **user plane (U-plane)**
    - responsible for the transfer of user data between subscribers
    - protocols provide end-to-end functionality

C-Plane

- similar to that for control of packet-mode and circuit-switching services
- control signaling over the D channel to control establishment and termination of frame-mode virtual calls on the D, B, and H channels
- error- and flow-control between TE and NT over D channel provides by LAPD



User-network interface protocol architecture



Protocols implemented in TE and NT equipment for control signaling over D channel for frame-mode bearer services)

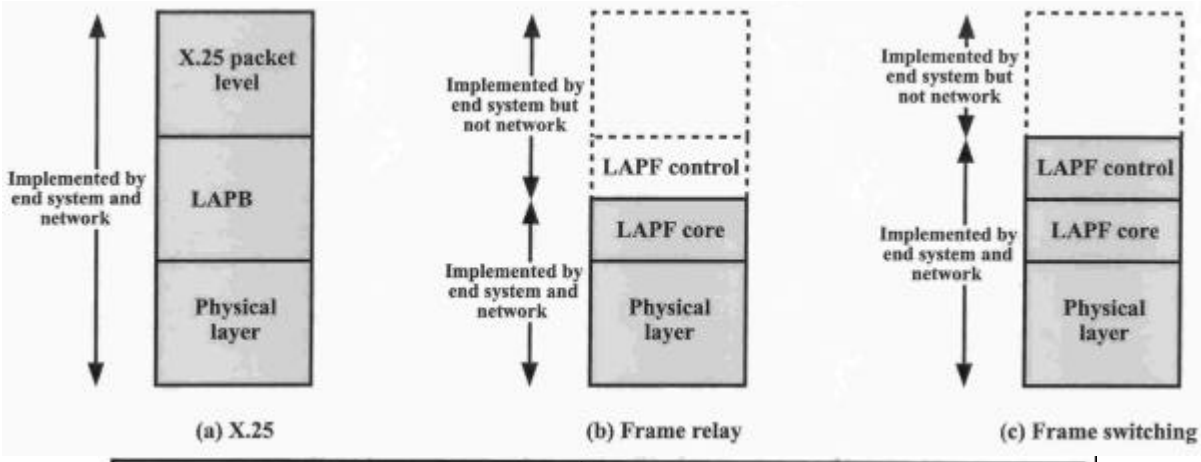
U-Plane

- LAPF (link access procedure for frame-mode bearer services) is for actual transfer of information between end users (Q.922).
- Core functions of LAPF used for frame relay
  - frame delimiting, alignment, and transparency
  - frame multiplexing/demultiplexing using the address field
  - inspection of the frame to ensure that it consists of an integer number of octets prior to zero bit insertion or following zero bit extraction
  - inspection of the frame to ensure that it is neither too long nor too short
  - detection of transmission errors
  - congestion control functions
- The core functions of LAPF constitute a sublayer of the data link layer
  - to provide the bare service of transferring data link frames from one subscriber to another, with no flow control or error control
  - user may select additional data link or network-layer end-to-end functions
  - based on core functions, ISDN offers frame relaying as a connection-oriented link layer service with the following properties:
    - preservation of the order of frame transfer from one edge of the network to the other
    - a small probability of frame loss

Comparison with X.25

- In **X.25** packet-switching
  - packet-handling functions operate at layer 3 of the OSI model
  - at layer 2 LAPB (for B channel) and LAPD (for D channel) is used
  - processing burden on the network is considerably higher than for frame relay
- Network architecture of frame relay minimizes the amount of work accomplished by the network.
- User data are transmitted in frames with virtually no processing by the intermediate nodes, other than to check for errors and to route based on connection numbers.
- A frame in error is simply discarded; error recovery at higher layers

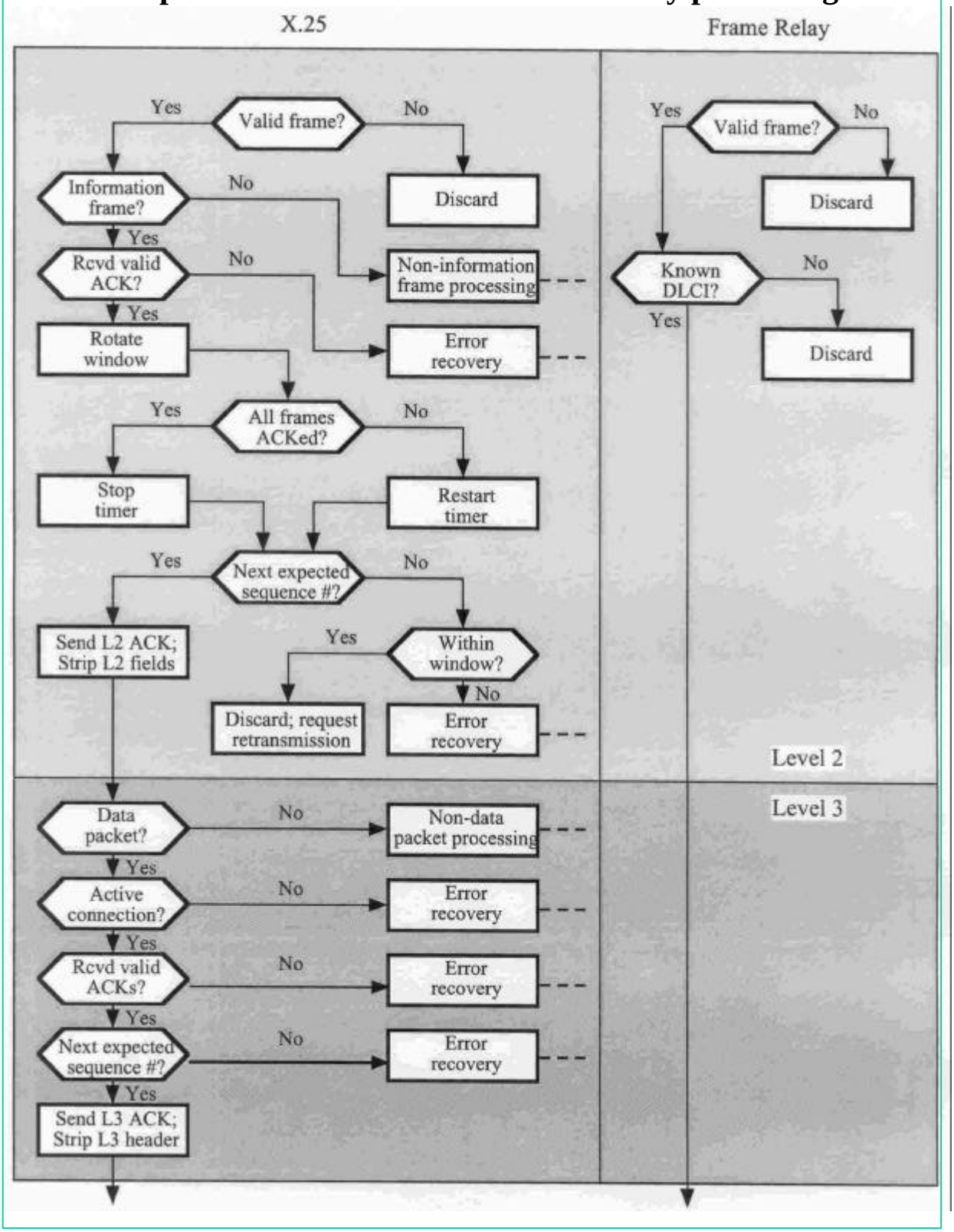
Comparison of X.25 and frame relay (stacks and functions)



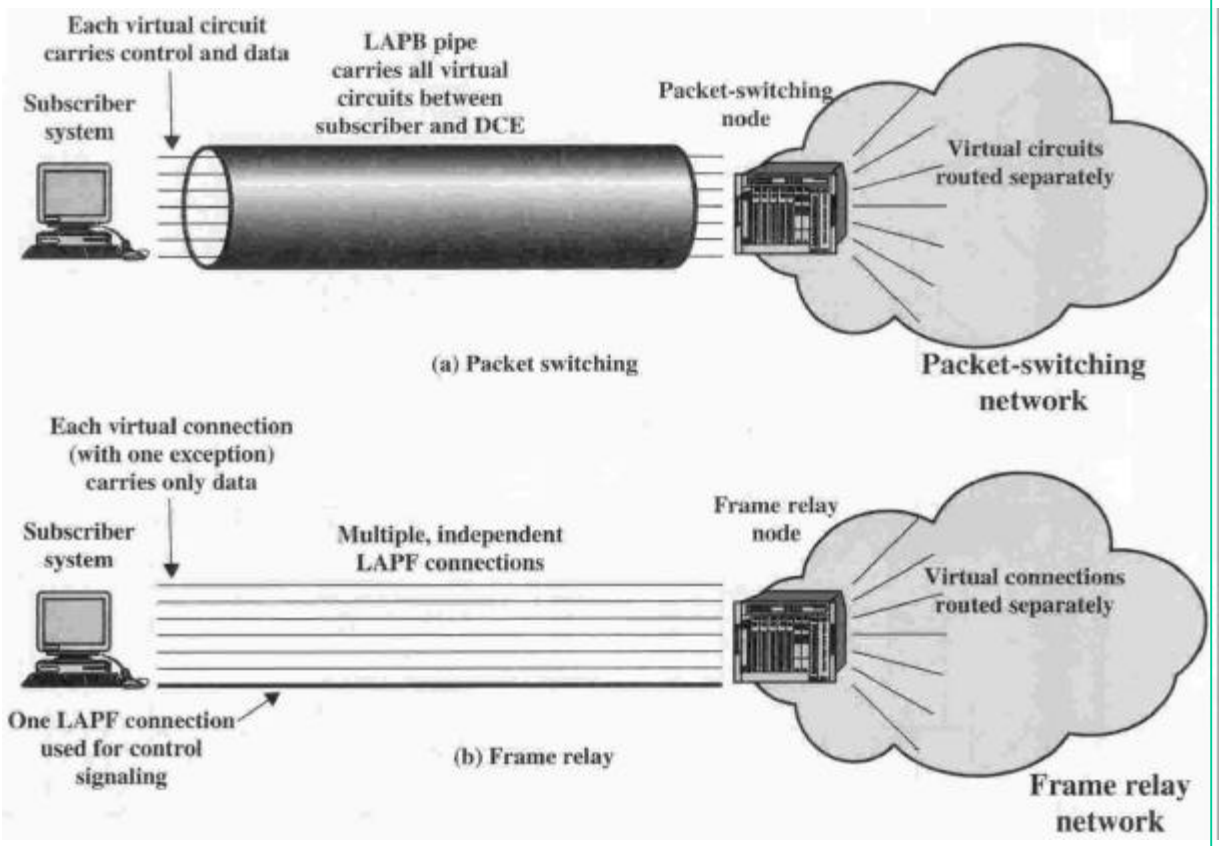
(a) X.25 (b) Frame relay (c) Frame switching

Function	X.25 in ISDN (X.31)	Frame Relay
Flag generation/recognition	X	X
Transparency	X	X
FCS generation/recognition	X	X
Recognize invalid frames	X	X
Discard incorrect frames	X	X
Address translation	X	X
Fill interframe time	X	X
Multiplexing of logical channels	X	X
Manage V(S) state variable	X	
Manage V(R) state variable	X	
Buffer packets awaiting acknowledgment	X	
Manage retransmission timer T1	X	
Acknowledge received I-frames	X	
Check received N(S) against V(R)	X	
Generation of REJ (rejection message)	X	
Respond to P/F (poll/final) bit	X	
Keep track of number of retransmissions	X	
Act upon reception of REJ	X	
Respond to RNR (receiver not ready)	X	
Respond to RR (receiver ready)	X	
Management of D bit	X	
Management of M bit	X	
Management of Q bit	X	
Management of P(S)	X	
Management of P(R)	X	
Detection of out-of-sequence packets	X	
Management of network layer RR	X	
Management of network layer RNR	X	

Simplified model of X.25 and frame relay processing



- In **X.25**, between the subscriber device (DTE) and packet-switching node, LAPB protocol is used to assure reliable transfer of frames.
- Each frame contains a packet that includes a virtual circuit number.
- Virtual circuits can have different routes through the network going to different destinations.
- A subscriber can maintain a number of virtual circuits to different other subscribers on the network.
- In **Frame Relay**, *virtual connections* provide logical connections.
- The frames transmitted over VCs are not protected by a data link control pipe with flow and error control.
- Frame relay devotes a separate VC to call control.
- Setting up and tearing down of VCs is done over this permanent control-oriented virtual connection.

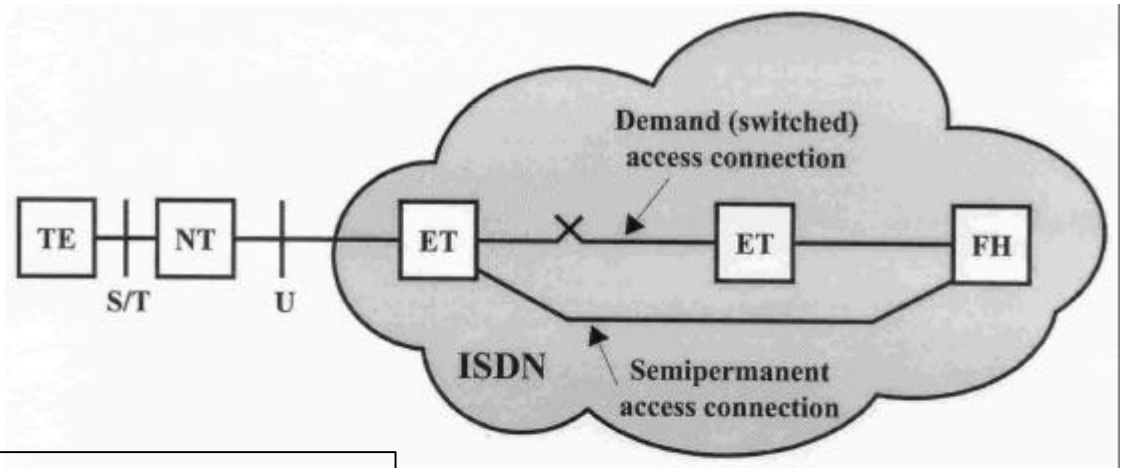


X.25 *virtual circuits* and frame relay *virtual connections*

8.3 Frame-Mode Call Control

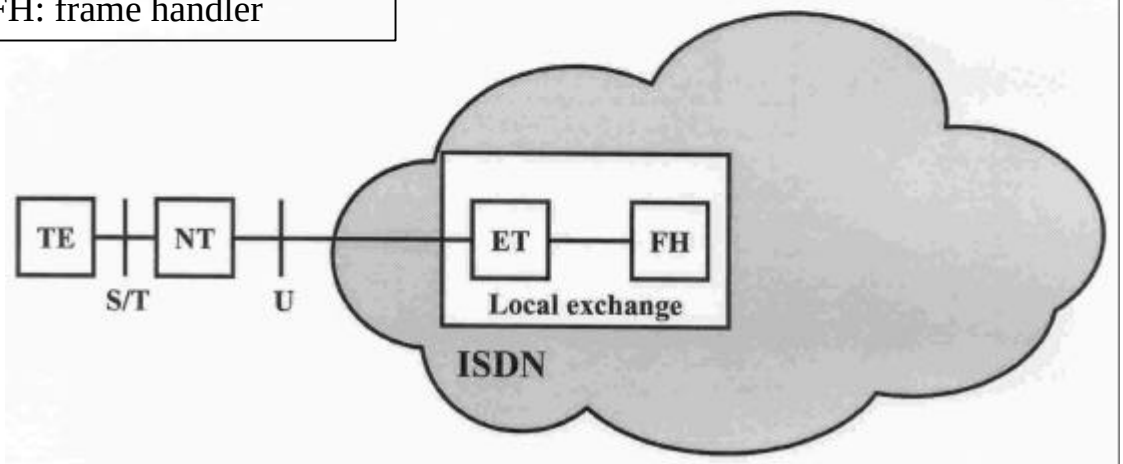
Call control alternatives

- For frame relay operation, a user is connected to a frame handler, and not directly to another ISDN user (similar to packet handler in X.25).
- **Case A-switched access:** local exchange does not provide frame handling capability, thus switched access is provided between TE and frame handler (demand connection or a semipermanent connection). Frame relay service provided over a B or H channel.
- **Case B-integrated access:** local exchange does provide frame handling capability. The frame relay service provided on a B, H, or D channel. In either case, a demand connection or a semipermanent service may be used.



TE: terminal equipment
NT: network equipment
ET: exchange termination
FH: frame handler

(a) Case A: switched access



(b) Case B: integrated access

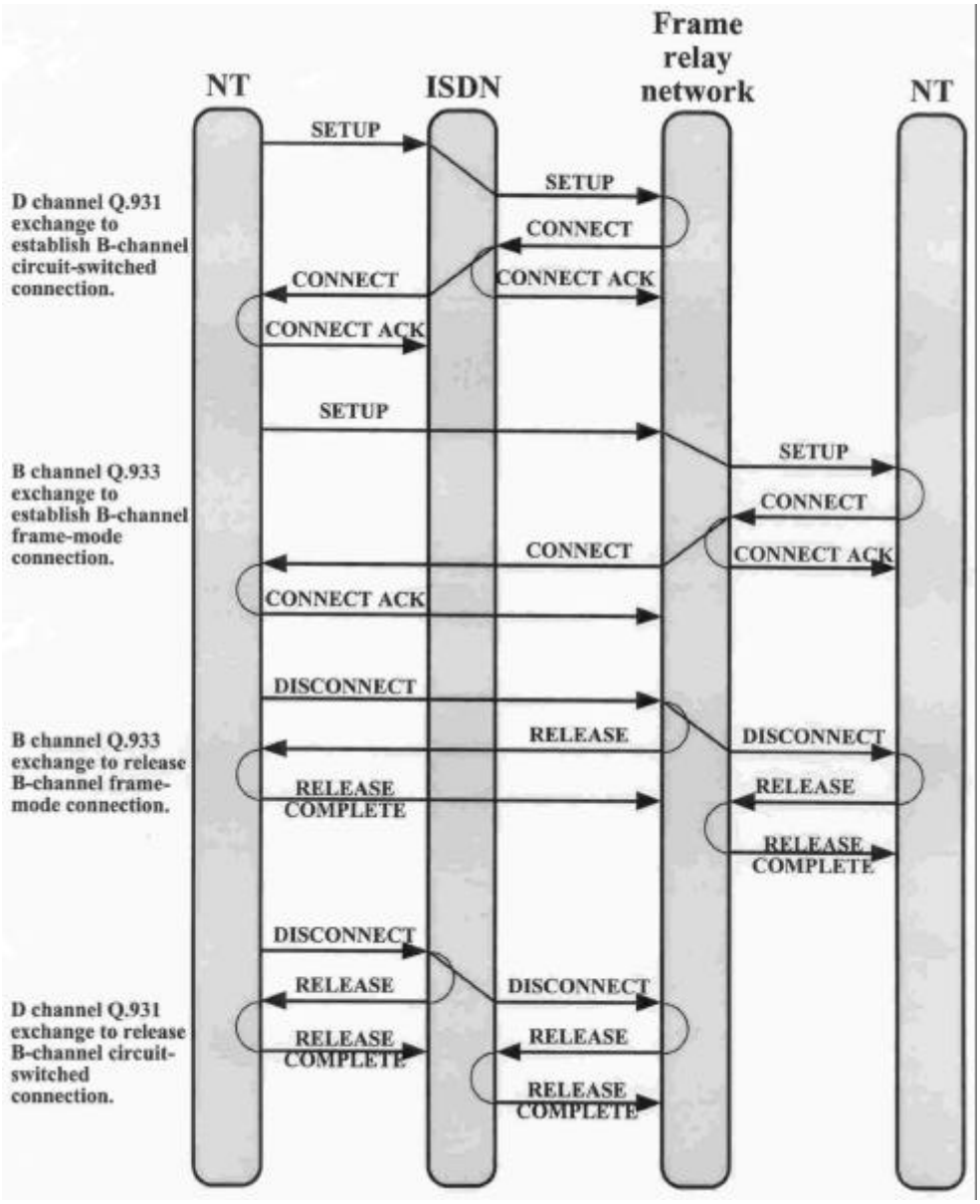
- In the establishment of an access, if the connection is semipermanent, then no call control protocol is required. If set up on demand, then two alternatives:
  - **Case A-**access connection is to be set up on a B or H channel to a remote frame handler. Normal ISDN call-control protocol (Q.931) is used on D channel.
  - **Case B-**access connection is to be set up to the local exchange. If on B or H channel, then normal ISDN call control protocol on D channel; if D channel is to be used, again Q.931 is used on the D channel to set up access connection.
- For establishment of frame relay connection, if semipermanent connection, no call control protocol is required; if connection is to be set up on demand, then two alternatives:
  - **Case A-**it is possible to use Q.931 call control messages on frame relay connection DLCI=0. The messages are carried in the information field of the data link frame.
  - **Case B-**it is also possible to use the same call control messages embedded in LAPD frames on the D channel. For this purpose, SAPI 0 is used, as for Q.931 messages.

Establishment of connection for frame relay services

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">Access connection/frame relay connection</th></tr>
<tr><th>Demand/demand</th><th>Semipermanent/ demand</th><th>Semipermanent/ semipermanent</th></tr>
<tr><td rowspan="2">Case A: Switched access to frame handler</td><td>Establishment of access connection</td><td>I.451/Q.931 on D channel to set up connection on B or H channel</td><td colspan="2">Semipermanent</td></tr>
<tr><td>Establishment of frame relay connection</td><td colspan="2">Inchannel frame relay messages on B or H channel, DLCI = 0</td><td>Semipermanent</td></tr>
<tr><td rowspan="2">Case B: Integrated access to frame handler</td><td>Establishment of access connection</td><td>I.451/Q.931 on D channel to set up connection on D, B or H channel</td><td colspan="2">Semipermanent</td></tr>
<tr><td>Establishment of frame relay connection</td><td colspan="2">Frame relay messages on D channel, SAPI = 0</td><td>Semipermanent</td></tr>
</table>

Call control protocol

- involves the exchange of messages between the user and a frame handler over a previously created access connection.
- **Case A-switched access:** call control messages are transmitted in frames over the same channel (B or H) as the frame relay connections, using the same frame structure, with a data link connection identifier of DLCI = 0.
- **Case B-integrated access:** call control messages are transmitted in LAPD frames with SAPI = 0 over the D channel.
- Q.933 (a subset of Q.931) defines set of messages used in frame relay to setup and manage logical frame relay connections rather than actual circuits.

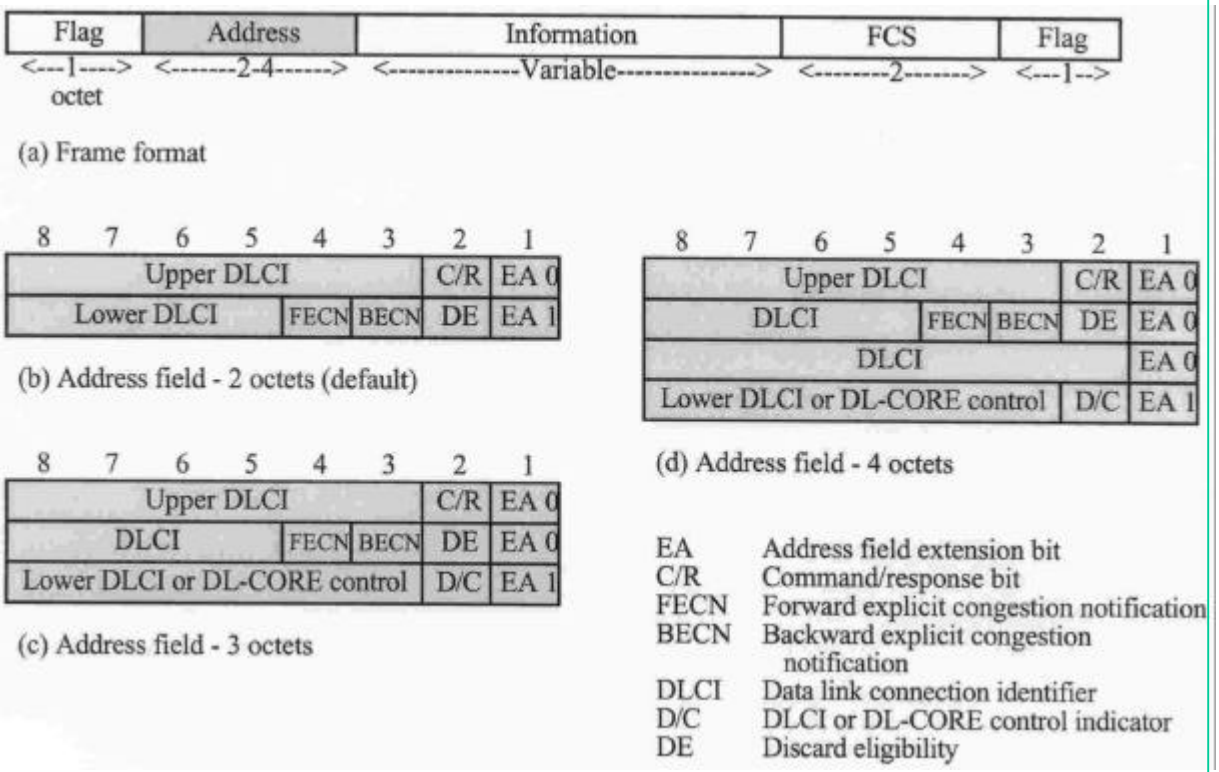


8.4 LAPF

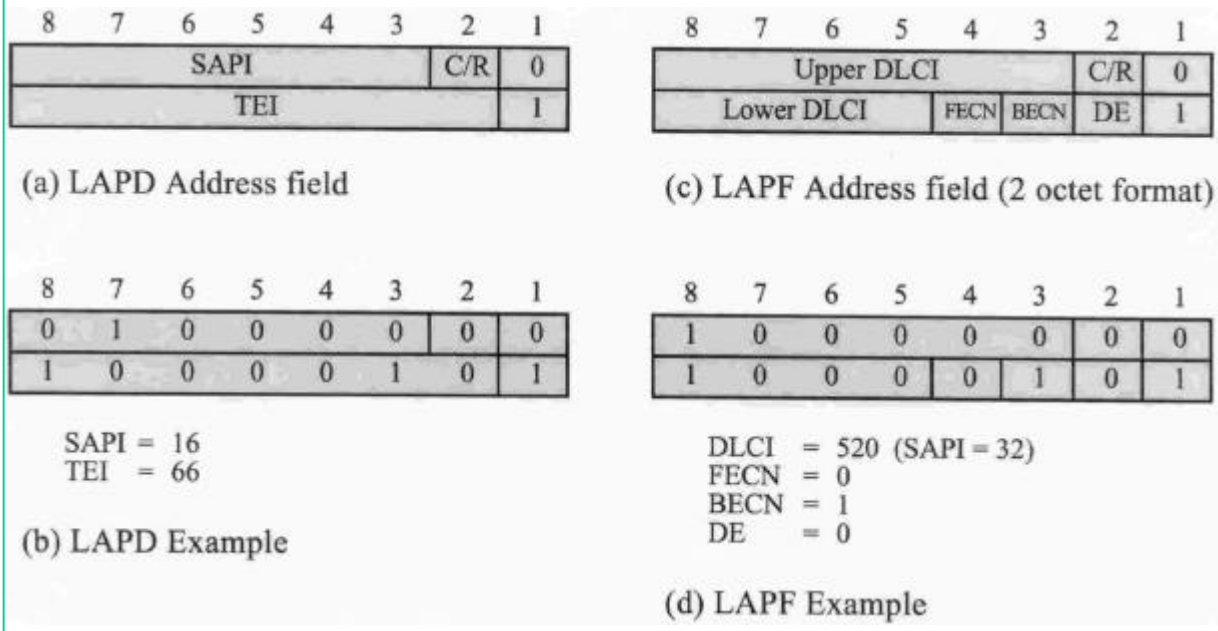
- LAPF (Link Access Procedure for Frame-Mode Bearer Services): a new data link protocol defined in Q.922 for supporting frame relay, based on an extension of LAPD, for frame transfer on B, D, and H channels.

LAPF Core Protocol

- A subset of LAPF providing a streamlined data link service
- The frame format is similar to that of LAPD and LAPB w/o control field
- Implications of the frame format:
  - only one frame type for carrying user data; no control frames
  - no possibility of using inband signaling
  - no possibility of flow and error control (no sequence numbers provided)
- *Flag* and *FCS* functions are similar to that of LAPD and LAPB.

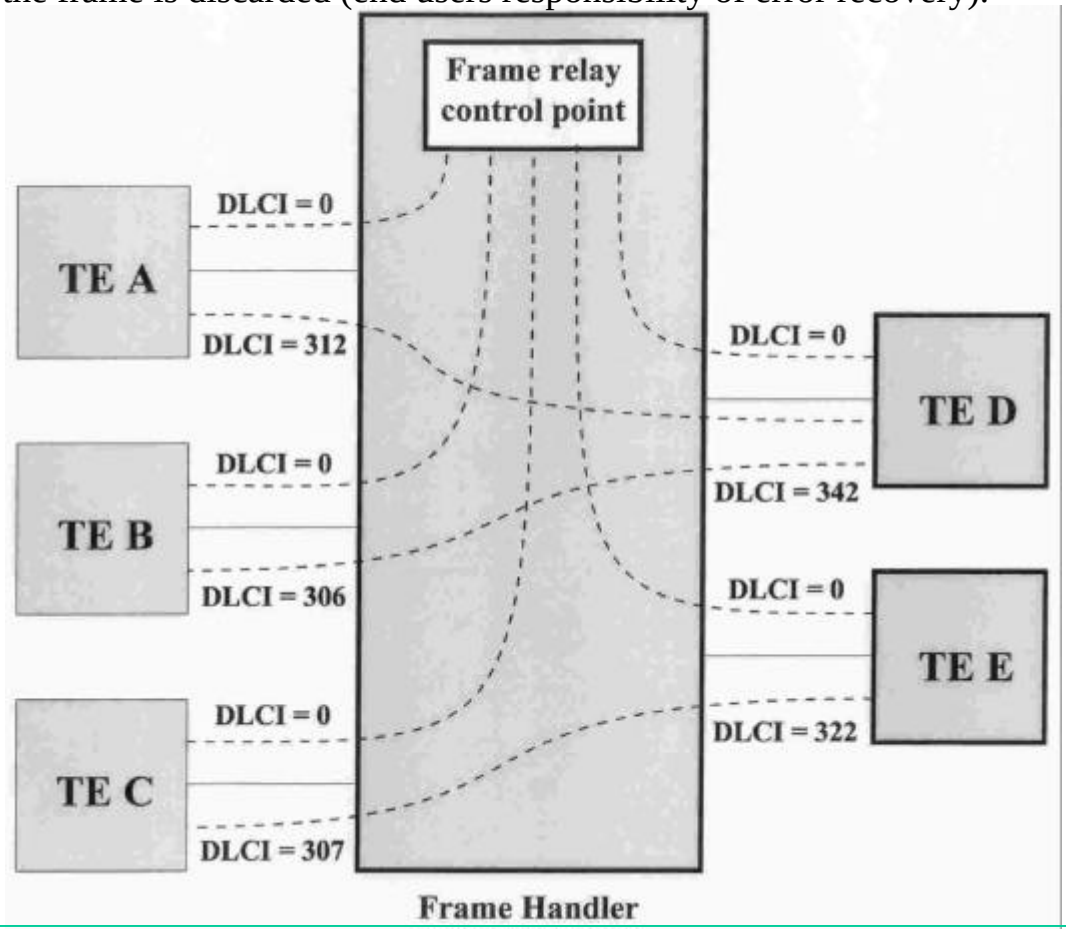


- *Address field* can have the length of 2, 3, or 4 octets (defined in EA).
  - Carries DLCI of 10, 16, 17, or 23 bits which serves the same function as the virtual circuit number in X.25; DLCI allows multiple logical frame relay connections to be multiplexed over a single channel.
  - Assignment of DLCI values may be local or on a global basis (Table 12.7)
- For D channel frame relay a 2-octets address field is used (DLCI=512~991)
- Frame relay frames can be multiplexed with LAPD frames on D channel. Two types of frames are distinguished on the basis of bits 8 to 3 in the first octet of the address field.
- *Example:* In (b) SAPI=16 and TEI=66. If this interpreted as a LAPD address field in (d), then SAPI=32. But this is one of the SAPI values reserved for frame relay, then it is interpreted as a LAPF address field of DLCI=520.
- In 3 and 4 octet address formats, D/C bit indicates whether the remaining six usable bits of that octet are to be interpreted as the lower DLCI bits or as data link core control protocol bits.
- C/R bit is application specific; not used by data link core control protocol.



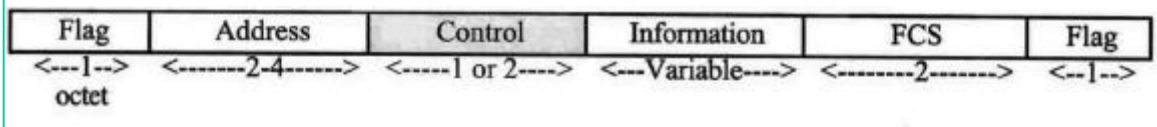
Example ¾ Frame Handler Function

- A number of users are directly connected to a frame handler over different physical channels. Frame relay control point is responsible for making routing decisions.
- Routing is controlled by entries in a connection table based on DLCI.
- For example, incoming frames from TE B on logical connection 306 are retransmitted to TE D on logical connection 342. This technique is referred to as *chained-link path routing*.
- Multiplexing is also possible; e.g. multiple logical connections to TE D are multiplexed over the same physical channel.
- All TEs have a logical connection to the frame relay control point with DLCI=0; these are reserved connections for inchannel call control to be used when Q.931 on D channel is not used for frame relay call control.
- FCS of each incoming frame is also checked and when an error detected, the frame is discarded (end users responsibility of error recovery).

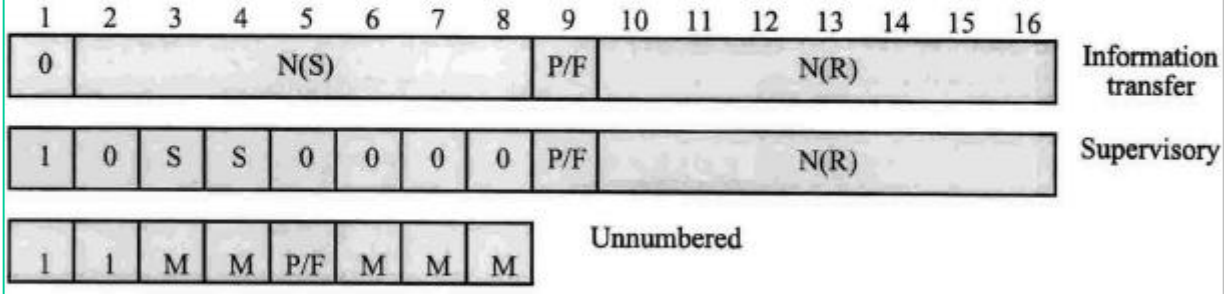


LAPF Control Protocol

- Full LAPF (Q.922) protocol implemented in end systems&frame handlers
- In LAPF control protocol frame, a control field, with the same format and interpretation as used for LAPD, also exists. This control field provides functions of error control and flow control.



(a) Frame format



N(S) Transmitter send sequence number
N(R) Transmitter receive sequence number
P/F Poll/final bit
S Supervisory function bit
M Modifier function bit

(b) Control filed formats

Comparison of ISDN data link layer specifications

	I.441/Q.921 (LAPD)	LAPB (Layer 2 of X.25)	I.465/V.120	Frame Mode Bearer Service
User Data Channel	D	B	B + H	D + B + H
Call Control for Logical Connections	N/A	N/A (X.25-3 uses inchannel call control)	I.451/Q.931 on D or LLI = 0 on bearer channel	I.451/Q.931 on D or DLCI = 0 on bearer channel
Multiplexing	Multiple TEs (TEI) Multiple Layer 3 Users (SAPI)	None (X.25-3 supports multiple virtual circuits)	Multiple users (LLI)	Multiple users (DLCI)
Logical Connections	N/A	N/A (X.25-3 supports multiplexing and switching)	Multiplexing	Multiplexing and switching
Peer Entities	Network	Multiple users on network	Multiple users on same circuit	Multiple users on network

- With frame switching, the control field in the LAPF frame is used between user and network for flow and error control
  - not an end-to-end function
- In (a), LAPF core protocol is used. The information field of the frame may contain a protocol data unit (PDU) for a higher-layer protocol(e.g. LLC) that provides end-to-end flow and error control.
- In (b), full LAPF control protocol is used for end-to-end flow and error control. In this case, the control field is added. This control field is transparent to the frame relay network and is only used by the two end systems. Information field may contain a higher-level PDU.
- In (c), for frame switching, the LAPF control field is visible to the network. Thus, flow and error control is exercised across the user-network interface. End-to-end flow and error control can be provided by a higher layer protocol.