Overview

- What is Frame Relay?
- Why not leased lines or X.25?
- Frame formats and protocols
- Signaling
Problems with Leased Lines

- Multiple logical links $\Rightarrow$ Multiple connections
- Four nodes $\Rightarrow$ 12 ports,
  12 local exchange carrier (LEC) access lines,
  6 inter-exchange carrier (IXC) connections
- One more node $\Rightarrow$ 8 more ports, 8 more LEC lines, 4 more IXC circuits
Solution: X.25/Frame Relay

- Four nodes: 4 ports, 4 LEC access lines, 6 IXC circuits
- One more node: 1 more port, 1 more access line, 4 more IXC circuits
- Share leased lines $\Rightarrow$ Virtual Private Networks
X.25

- In-band signaling. VC setup and clearing messages in the same channel as data.
- Three layer protocol. Third layer for multiplexing.
- Flow control
- Error control

⇒ 12 messages for one packet transfer
Only 6 messages without flow control and error control
Frame Relay: Key Features

- X.25 simplified
- No flow and error control
- Out-of-band signaling
- Two layers
- Protocol multiplexing in the second layer
- Congestion control added
  ⇒ Higher speed possible.
  X.25 suitable to 200 kbps. Frame relay to 2.048 Mbps.
Relay vs Switching

- Switching = Relaying + Ack + Flow control + Error recovery + loss recovery
- Switching = X.25
- Relay = Unreliable multiplexing service
Datalink Control Identifiers

- DLCI: Similar to Logical Channel Numbers in X.25
Data Link Control Identifier

- Only local significance
- Allows multiple logical connections over one circuit
- Some ranges preassigned
- DLCI = 0 is used for signaling
Frame Relay UNI Architecture

- UNI = User-network Interface
- LAPF = Link Access Protocol - Frame Mode Services
- LAPD = Link Access Protocol - D Channel

<table>
<thead>
<tr>
<th>Network</th>
<th>Control</th>
<th>User Selectable</th>
<th>Datalink</th>
<th>LAPD</th>
<th>Q.921/Q.922</th>
<th>LAPF</th>
<th>Q.922 Core</th>
<th>Physical</th>
<th>I.430/I.431</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Q.931/Q.933</td>
<td>User</td>
<td></td>
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</tbody>
</table>

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Control Plane

- Signaling over D channel (D = Delta = Signaling)
- Data transfer over B, D, or H (B = Bearer)
- LAPD used for reliable signaling
- ISDN Signaling Q.933 + Q.931 used for signaling messages
- Service Access Point Identifier (SAPI) in LAPD = 0
  ⇒ Q.933 + Q.931 Frame relay message
User Plane

- Link Access Procedure for Frame-Mode bearer services (LAPF)
- Q.922 = Enhanced LAPD (Q.921) = LAPD + Congestion
- LAPF defined in Q.922
- Core functions defined in Q.922 appendix:
  - Frame delimiting, alignment, and flag transparency
  - Virtual circuit multiplexing and demultiplexing
  - Octet alignment $\Rightarrow$ Integer number of octets before zero-bit insertion
  - Checking min and max frame sizes
User Plane (Cont)

- Error detection, Sequence and non-duplication
- Congestion control

- LAPF control may be used for end-to-end signaling

Network Layer
LAPF Control
LAPF Core
I.430/I.431

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LAPF-Core Frame Format

- LAPF is similar to LAPD: Flag, bit stuffing, FCS
- No control frames in LAPF-Core ⇒ No control field
- No inband signaling
- No flow control, no error control, no sequence numbers
- Logical Link Control (LLC) may be used on the top of LAPF core

<table>
<thead>
<tr>
<th>Flag</th>
<th>Address</th>
<th>Information</th>
<th>FCS</th>
<th>Flag</th>
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<tbody>
<tr>
<td>01111110</td>
<td>1B</td>
<td>2-4B</td>
<td>2B</td>
<td>01111110</td>
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### LAPF Address Field

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<tr>
<th>Octet</th>
<th>Description</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
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<tbody>
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<td>Upper DLCI</td>
<td>C/R</td>
<td>EA 0</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower DLCI</td>
<td>FECNBECN</td>
<td>DE</td>
<td>EA 1</td>
<td></td>
<td></td>
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<tr>
<td>3 Octet:</td>
<td>Upper DLCI</td>
<td>C/R</td>
<td>EA 0</td>
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<tr>
<td></td>
<td>DLCI</td>
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<td>DE</td>
<td>EA 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Lower DLCI or DL-Core control</td>
<td>D/C</td>
<td>EA 1</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Octet:</td>
<td>Upper DLCI</td>
<td>C/R</td>
<td>EA 0</td>
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LAPF Address Field

- Address length = 2, 3, or 4 bytes
- Data Link Control Identifier (DLCI) = 10, 16, 17, or 23 bits
- Address Extension (EA) bits: 0 ⇒ More bytes
- D/C = Remaining bits for DLCI or for core control protocol (No use for core control has been defined)
- C/R = Command/response (not used)
- FECN = Forward Explicit Congestion Indication
- BECN = Backward Explicit Congestion Indication
Local Management Interface (LMI)

- Extension designed by a group of vendors
- To overcome problems observed in early implementations
- May be standardized by both ANSI and ITU-T
- Status Enquiry (SE) message from user to network
- Status (S) message from network to user
- Uses HDLC UI frames (with sequence numbers)
- Uses protocol ID=00001001, DLCI=1023
LMI Operation

User

Network

SE, S = 4, R = 3
S, S = 4, R = 4

SE

FS (All PVCs)

SE

S (New PVCs)
DLCI Extensions

- Global DLCI
  ⇒ DLCI points to the same destination at all time and points
  (OK for small networks)

- Multicasting
  - One-way multicasting: 1 to N
  - Two-way multicasting: 1 to N and N to 1
  - N-way Multicasting: N to N
Network-to-Network Interface (NNI)

- Developed by frame relay forum: FRF 92.08R1, FRF 92.62
- Working draft of ANSI T1S1.2
- Adding/deleting PVCs between networks
- Diagnosing PVC failures
Major NNI Operations

- Notification of adding a PVC
- Notification of deleting a PVC
- Notification of UNI or NNI failures
- Notification of a PVC segment availability or unavailability
- Verification of links between frame relay nodes
- Verification of frame relay nodes
Summary

- X.25 designed for unintelligent devices over error-prone networks ⇒ Slow
- Frame relay = Simplified X.25
- Higher data rates than X.25
- Developed for ISDN but runs in non-ISDN environments
- Two layer protocol architecture
Homework

- Read Chapter 4 of Black’s “Emerging Communications Technologies.” Can skip sections on congestion control.
Additional References

- Chapter 11 of Stallings’ “ISDN and Broadband ISDN with Frame Relay and ATM”