Lecture 10: X.25 & Frame Relay

CS 5516
Computer Architecture
Networks

VA Tech

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The Telephone Network

• The telephone network was developed to provide two-way, real-time transmission of voice signals
  – nominal 4 kHz bandwidth analog signal
  – across a sequence of transmission and switching facilities

• The telephone network is an essential component of computer communications due its ubiquity and low-cost

Telephone networks operate on the basis of circuit switching

• Evolution of telephone networks
  – Operators at telephone offices making physical connections from one telephone to another
  – Electromechanical switches making physical connections across a physical network
  – Digital transmission and switches making virtual connections across a logical topology
The Telephone Network 2

- Three phases of connection-oriented Telephone call

- Setup Phase
  - User picks up the phone, initiating a current flow that alerts a switch at the local telephone office of a call request
  - The switch prepares to accept the dialed digits and provides the user with a dial tone
  - The user enters the telephone number which the switch equipment converts into a telephone number
    - Either, by turning a dial which generates a sequence of electrical pulses
    - by pushing a series of buttons which generates a sequence of audio tones
    - North American 10-digit telephone number:
      - three digit area code
      - three digit central office code
      - four digit station number

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<tr>
<th>Source</th>
<th>Signal</th>
<th>Setup</th>
<th>Signal</th>
<th>Go</th>
<th>Message</th>
<th>Transfer</th>
<th>Signal</th>
<th>Release</th>
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Phases of a Telephone Call
The US telephone network is divided into Local Access and Transport Areas (LATAs) served by the local exchange carriers (LECs)
- LECs: Regional Bell Operating Companies (e.g. BellSouth, Bell Atlantic, etc.), and independent carriers (e.g. GTE)
Independent interexchange carriers (IXCs) provide long-distance service between LATAs
- IXCs: AT&T and MCI, etc
The Telephone Network 4

– The destination office next alerts the destination user of an incoming call by ringing the phone
– A ringing signal is also sent back to the source telephone

• **Message Transfer Phase**
  – Conversation can begin when the destination phone is picked up (off hook condition)
  – End-to-end path between the source and the destination telephones
    • Mostly, telephones are connected to their local telephone office with a twisted pair copper wires transmitting an analog voice signal
    • At the local telephone switch, line interface cards terminate the copper wires and digitize the signal
    • The call is now a sequence of PCM samples flowing along a path that has been set up across the network
    • This path consists of reserved time slots in TDM transmission links connecting TSI digital
    • The PCM signal is received at the destination switch and converted back to analog form
    • Finally, the call is transmitted to the destination telephone over a copper wire pair

• **Release Phase**
  – When either user hangs up end (on hook)
  – The call is terminated and the resources released
Transmission Facilities

• "The Local Loop" connects telephones to a local office by twisted pair copper wires in a hierarchical star topology
  – Wire pairs are stranded into groups
  – Groups combined in cables of up to 2700 pair

• Wire pairs originate at the telephone office distribution frame
  – Feeder cables extend to the various geographic Serving Area Interfaces
    • Some Feeder Cables now use optical fiber carrying TDM traffic (PCM conversion at the service area interface)
  – Distribution cables extend to the pedestals that connect to the user's telephone
A single pair of local loop wires carries information in both directions
- Inside the network a separate pair of wires is used for each direction of signal flow
- A Hybrid Transformer interfaces to the switch and converts the signals of the 2 wire local loop to the 4 wire network connection

Hybrid transformers tend to reflect some of the arriving signal
- Under certain conditions resulting echoes can be disturbing to speakers and can impair digital transmission
- Echo cancellation devices estimate the echo delay and use a properly-delayed and scaled version of the transmitted signal to cancel the arriving echoes

Hybrid Transformer in the telephone network
Transmission Facilities 3

- Local telephone switching office handles a variety of transmission types
  - analog telephone traffic
  - Digital lines of various speeds from customers’ premises, private lines, and high-speed digital lines (e.g. ADSL)
  - Lines to cellular telephone networks and backbone networks

- Digital Cross-Connect systems organize the various line types
  - Digital time-division switches that manage the longer-term flows in a network
  - Not controlled by the signaling process associated with call setup
  - Controlled by the network operator to meet network configuration requirements

Digital Cross Connect System

- Local analog
- Local digital
- Digital trunks

A/D

Permanent Tie lines
Foreign exchange

Channel switched traffic (digital leased lines)

Local Switch
Transmission Facilities 4

- SONET-based optical transmission facilities between switches

- Combined with Digital Cross-Connect systems to configure the logical topology "seen" by telephone switches during call setup

  Physical SONET Topology using ADMs & DCCs

  Logical Topology seen by Switches

  - The maximum number of hops between any pair of switches is two hops instead of the four hops in the physical topology
  - Decreasing the number of hops simplifies the routing procedure implemented in switches

- Digital Cross-Connect and SONET equipment also provide network recovery from faults via "standby" tributaries
  - Activated to restore the original logical topology
  - Simplifies response actions in switches
Signaling

- A series of signaling messages must be exchanged to establish a telephone call

- Two basic types of signal exchanges must work together to establish the call.
  1. Between the user and the network
  2. Within the network

- Signaling messages generate control signals that determine the input/output configuration of switches
  - Traditionally, networks signaling information arrives on telephone lines and is be routed to a control system
  - Hard-wired electromechanical or electronic logic was used to process signaling messages

- Stored Program Control Switches emerged as computers began control of switches
Signaling 2

• The stored-program control computer
  – Accepts an incoming call request
  – Checks availability of the destination
  – Makes the appropriate connection
  – Provides great flexibility in modifying the control and in introducing new features

• Control computers must also communicate with each other to exchange the signaling information
  – Separate computer communications network

Telephone network consists of two parts:
1. A Signaling Network which carries the information to control switch connections
2. A Transport Network which carries end-to-end user information
   – Signaling network does not extend to the user because of security concerns
Signaling 3

• User communications is split into two streams at the Service Switching Point
  1. Signaling information is directed towards the signaling network
  2. User information which is directed to the transport network

• Control computers communicate through the exchange of discrete messages
  – Implemented with a *packet switching network*
  – Evolution of telephony converges with the evolution of computer networks
  – Packet switching provided needed reliability

SSP: Service Switching Point (signal to message)
STP: Signal Transfer Point (message transfer)
SCP: Service Control Point (processing)
Signaling 4

• All regions have two packet switching nodes (Signal Transfer Points) that can reach any given office

• Processing a connection request involves the *databases* and *special purpose processors* at the "Service Control Points"
  – In the early 1970s telephone companies began using the computer controlled signaling network to enhance the basic service
    • Credit card calls, 800-calls, etc.
  – “Intelligent Network” denote the use of an enhanced signaling network that provides a broad array of services
    • Caller ID, call screening, callback, call forwarding, voice mail, etc.
Signaling System #7 Architecture

- Signaling System #7 network is a packet network that controls set up, management, and release of telephone calls
  - Also supports for intelligent networks, mobile cellular networks, and ISDN

<table>
<thead>
<tr>
<th>OSI Reference Model</th>
<th>TUP</th>
<th>TCAP</th>
<th>ISUP</th>
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</thead>
<tbody>
<tr>
<td>Application</td>
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<tr>
<td>Presentation</td>
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<td>Session</td>
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<td>Transport</td>
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<td>Network</td>
<td>TUP</td>
<td>TCAP</td>
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<tr>
<td>Physical</td>
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</table>

SS7 network architecture

- The architecture uses "parts" instead of "layers"
• The Message Transfer Part (MTP) corresponds to the lower three OSI layers
  – MTP Level 1 corresponds to the physical layer of the signaling links in SS7 networks
  – MTP Level 2 ensures that messages are delivered reliably across a signaling link
  – MTP Level 3 ensures that messages are delivered between signaling points
    • Provides routing and congestion control
    • Re-routes traffic away from failed links and signaling points

• The Signaling Connection Control Part (SCCP) provides connectionless and connection-oriented service for applications
  – Applications include 800-call processing, calling card processing, and other intelligent network services
  – SCCP also translates "global titles" (e.g. a dialed 800 number) into an application identifier
The Transaction Capabilities Part (TCAP) defines the messages and protocols that are used to communicate between applications. It uses the connectionless service provided by SCCP to support database queries in intelligent networks.

The ISDN User Part (ISUP) protocols are used for the basic setup, management, and release of telephone calls.

The Telephone User Part (TUP) is used instead in some countries.
High-level Data Link Control (HDLC)

• Corresponds to ISO the Data Link Layer
  – Responsible for the error-free movement of data between network nodes
    • Ensures that data passed up to the next layer has been received exactly as transmitted (i.e. error free, without loss and in the correct order)
  – Provides flow control
    • Ensures that data is transmitted only as fast as the receiver can receive it

• Different HDLC implementations:
  – HDLC-Normal Response Mode (NRM) or (SDLC)
  – HDLC-Link Access Procedure-Balanced (LAP-B)
  – HDLC-Link Access Procedure-D channel (LAP-D)

• LAPB is a bit-oriented synchronous protocol
  – Provides complete data transparency in a full-duplex point-to-point operation
  – Supports a peer-to-peer link
    • Neither end of the link plays the role of the permanent master station

• NRM or SDLC uses a permanent primary station with one or more secondary stations
Synchronous Data Link Control (SDLC)

- **SDLC Protocol**
  - Essentially the same as HDLC-NRM
  - Invented by IBM to replace the older Binary Synchronous Communications (BSC) protocol for wide area connections in 1976
  - Integral part of IBM's System Network Architecture (SNA) for WAN applications

- **SDLC is not a peer to peer protocol like HDLC, Frame Relay or X.25**

- **An SDLC network**
  - A primary station that controls all communications
    - Usually a mainframe or midrange central computer
  - One or more secondary stations
    - Usually terminals, or controllers which act as concentrators for numbers of local terminals.
    - Where multiple secondaries are connected to a single primary, this is known as a multipoint or multidrop network
SDLC

• SDLC, provides link integrity
  – All frames terminate with Cyclic Redundancy Check (CRC) used to detect any data errors
  – Frames received correctly are acknowledged by the receiver while erroneous frames are ignored

• SDLC provides error recovery
  – One line error can cause many frames to be retransmitted
  – Therefore, a noisy line causes low throughput and long response times

• A window of up to 7 frames can be sent before acknowledgement is required
  – Acknowledgement is encoded in the control field of data frames
  – No additional acknowledgement frames are needed

• SDLC also provides automatic flow control
Operation of SDLC Multipoint Networks

- SDLC is based on dedicated leased lines with permanent physical connections.
  - Capable of full duplex operation
  - Almost all practical applications are half duplex
    - Either the primary or one of the secondaries can be transmitting at any one time, but not both
    - Very Efficient and run over higher speed lines

- SDLC Multipoint Addressing
  - Each secondary has a unique address
  - Each secondary sees all transmissions from the primary but only responds to frames with its own address.
  - Only one secondary can be transmitting at any time
    - Secondaries can only transmit when told to do so by the primary
    - Secondaries can only transmit a limited number of frames before passing control back to the primary
HDLC LAPB

- HDLC LAPB is a very efficient protocol
  - Minimum overhead is required to ensure flow control, error detection and recovery
  - In full duplex data flow, the data frames carry all the info required to ensure data integrity

- Frame windows are used to send multiple frames before receiving confirmation that the first frame has been correctly been received
  - Data transfer continues even where there are long communications time lags e.g. Satellite communication propagation delays

- Three categories of frames
  - Information frames
    - Transport data across the link and may encapsulate the higher layers of the OSI architecture
  - Supervisory frames
    - Perform the flow control and error recovery functions
  - Unnumbered frames
    - Provide the link initialization and termination facilities

<table>
<thead>
<tr>
<th>Flag</th>
<th>Address</th>
<th>Control</th>
<th>Data</th>
<th>CRC</th>
<th>CRC</th>
<th>Flag</th>
</tr>
</thead>
</table>

- HDLC LAPB used as the Data Link layer in X.25 Packet Switched Networks
Packet Switching

- Several needs drove the development of packet switching:
  - Provide standard interfaces between computing devices
  - Make more efficient use of expensive transmission bandwidth
  - Interconnect large numbers of terminal devices generating bursty data traffic
  - Extend computer communication over noisy analog transmission facilities

- Messages Packets
  - Include Cyclic Redundancy Check (CRC) fields that detected bit errors
  - May be resent until successfully received
  - Efficiently accommodates terminal to host communications
    - Small but busy data transfer requirements

- Packet switching has been widely implemented
  - Constitutes the majority of public and private data services in Europe

- Forms the basis of many advanced data communications
History of X.25

• Packet switching was first published by RAND Corporation in 1964 as a secure method of transmitting military voice communications
  – Providing the United States with survivable military communications during a nuclear war

• With multiple independent packets
  – Messages are transmitted over multiple paths and diverse facilities
  – Also, voice wiretapping was virtually impossible

• Advanced Research Projects Agency (ARPA)’s ARPANET
  – Implemented packet switching to handle computer communications
  – First use of layered protocols and a meshed backbone topology

• Soon after ARPANET, many commercial companies also developed packet networks
  – Especially in Europe, which had lower quality telecommunications lines
X.25 Packet Switching

- Public Packet-Switched Networks have defined and redefined every 4 years by the CCITT in a series of recommendations referred to as the X-standards
  - These recommendations provide a common network-to-subscriber (or network-to-user) interface allowing data transfer between two end-users anywhere in the world

- X.25 is the 25th network-to-user interface recommendation in the X-series

- X.25 encompasses the first three layers of the OSI Reference Model

- X.25 routes individual packets of HDLC data between nodes based on addressing within each packet
X.25 Layers

- X.25 defined by the CCITT to be a close implementation of the first three OSI layers:
  - Layer 1: Includes several well-known standards:
    - V.35, RS-232, X.21bis
  - Layer 2: LINK ACCESS PROCEDURE BALANCED (LAPB)
    - An implementation of the ISO High-Level Data Link Control (HDLC) standard
    - HDLC/LAPB and provides an error free link between two connected devices.
  - Layer 3: Packet Layer Protocol (PLP)
    - Primarily concerned with network routing functions
    - Multiplexing of simultaneous logical connections over a single physical connection
X.25 Packet Switching

• X.25 provides a virtual high quality digital network at low cost.
  – Usually paid for by a monthly base fee plus packet charges with no holding charge,
  – Ideal for organizations that need to be on line all the time but transfer a relatively small amount of data

• X.25 operates with store-and-forward procedures at each node and provides excellent flow control
  – Allows speed matching to DTE needs
    e.g. a host connects at 56kbps while numerous remote sites connect with 19.2kbps lines

• X.25 has been around since the mid 1970's and so is well debugged and stable
  – Literally no data errors on modern X.25 networks

• X.25 drawbacks
  – Inherent delay & large buffering requirements caused by the store-and-forward mechanism
  – With fiber optics, the extra X.25 packet switching overhead is no longer needed
X.25 Packet Switching

- Data Terminal Equipment (DTE)
  - End user of the network

- Data Communications Equipment (DCE)
  - The communications carrier's equipment
  - Packet Assembly Disassembly Devices (PADs)

- X.25 is a data pump: there has to be some higher level that is making sense of the bits
  - Standards for allowing higher level protocols and certain applications to make use of X.25
X.25 Packet Layer Protocol

- Implementation of the OSI Network layer
  - Primarily concerned with network routing functions

- X.25 PLP provides a standard Layer 3 Networking Interface Between the Subscriber or Logical DTE and the network entry point or Logical DCE

- User and protocol information is encapsulated inside Packets to be passed down to the data link Layer

- The X.25 PLP exists between two DTE devices attached to the X.25 network
  - The PLP layer communicates in units called Packets
  - The Data Link layer communicates in units called Frames

- User devices and host computers may or may not be capable of handling X.25 protocol procedures
  - If not, a PAD performs DTE functions
    - Protocol conversion
    - Multiplexing
    - X.25 protocol handling
X.25 PLP

- Both DTE endpoints use X.25 PLP, but the activities at each end of the Virtual Circuit between DTE and DTE are independent
  - Referred to as LOCAL SIGNIFICANCE

- The protocols used inside packet networks are not specified by X.25, since X.25 is a network-access protocol only

- The paths set up between network DCE units may be shared by many DTE-to-DTE connections
  - Reason for the term "Virtual Circuit"
  - PLP provides the means for two end users to intelligently share limited network communication capacity

- The protocol allows network end users to temporarily or permanently own a piece of network capacity of determined quality and type

- PLP allows recovery from severe or mild errors at the network level and provides flow control information on a VC
X.25 PLP

• To improve throughput PLP has the ability to send more than one packet before requiring an acknowledgment
  – “Window function”
  – Store and forward operations prevent loss

• A set of sequence numbers provides the acknowledgment, flow-control, error-recovery, and window functions

• The normal method of sequencing uses a Modulo 8 (MOD 8) counter for tracking maximum window size (number of unacknowledged packets)
  – 3-bit counter which rotates the count from 0 to a 7 then restarts at 0
  – Most networks have a default window size of 2
  – An extended mode uses a 7-bit counter which rotates the count from 0 to 127 and is referred to as Modulo 128 (MOD 128)
X.25 PLP Frame

- X.25 PLP relies on the underlying robustness of HDLC LAPB to get data from node to node
- An X.25 PLP packet makes up the data field of an HDLC frame
- Additional flow control and windowing are provided for each Logical Channel at the X.25 level.
- Maximum packet sizes vary from 64 bytes to 4096 bytes
  - 128 or 256 bytes is the default on most networks.
  - Both maximum packet size and packet level windowing may be negotiated between DTEs on call set up

```
1 4 10 16 24 32
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<table>
<thead>
<tr>
<th>Source Port</th>
<th>Destination Port</th>
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<tbody>
<tr>
<td>Sequence Number</td>
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<tr>
<td>Acknowledgement Number</td>
<td></td>
</tr>
<tr>
<td>HLEN</td>
<td>Reserved</td>
</tr>
<tr>
<td>Checksum</td>
<td></td>
</tr>
<tr>
<td>Options</td>
<td></td>
</tr>
<tr>
<td>Data</td>
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</table>

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Basic X.25 Operations

X.25 Packet Switching Nodes

DTE

DCE

DTE
X.25 Store-and-Forward Operation

LD = Link Data
ACK(RSN, SSN) = Acknowledgement (Receive Sequence Number, Send Sequence Number)
• X.25 PLP supports communications with a number of remote DTEs simultaneously
X.25 Connections

• Connections occur on two types of logical channels

• Switched Virtual Circuits (SVCs)
  – Established each time the DTE needs the network communication resource
  – Some of the parameters of the SVC are determined each time the DTE establishes the SVC (makes a logical X.25 CALL REQUEST).
  – Other qualities of the SVC are determined by user subscription to network offerings.
  – Similar to the establishment and use of a telephone connection
  – Each DTE on the network is given a unique DTE address

• Permanent Virtual Circuits (PVCs)
  – Established by user subscription and is always available to the DTE as a permanent resource
  – Similar to a leased line in that the connection is always present
  – Data is sent without further call setup

• The identification of the VC at each local interface is the Logical Channel Identifier (LCI) or Logical Channel Number (LCN)
SVC Procedures

• A calling DTE sends a *Call Request Packet* to establish a connection on an SVC
  – Includes the address of the calling and the destination DTE
    • The destination is identified by the Logical Channel Identifier (LCI) or Logical Channel Number (LCN)
  – The destination DTE decides whether or not to accept the call

• A call is accepted by issuing a *Call Accepted packet*, or cleared by issuing a *Clear Request packet*

• Once the originating DTE receives the Call Accepted packet, the virtual circuit is established and data transfer may take place

• The DTE sends a *Clear Request packet* to the remote to terminate the call
  – The remote responds with a *Clear Confirmation packet*
X.25 Packets

- X.25 packet types are divided into categories based on function:
  - CALL ACTIVATION and DEACTIVATION
  - DATA and INTERRUPT
  - FLOW CONTROL
  - RESET, RESTART, DIAGNOSTIC, and REGISTRATION packets

- Packet types are indicated by specific bit patterns in the packet header

- CALL ACTIVATION
  - A DTE sends a *Call Request* packet
  - A Logical Channel Number (LCN) is independently assigned at each end of the virtual circuit
  - The *Call Request* travels end-to-end between two DTE devices establishing the connection
  - The DTE selects the LCN for outgoing calls, while the DCE selects the LCN for incoming calls

- CALL DEACTIVATION
  - Imitated by one of the connected DTE devices sending a *Clear Request* packet to the other connected DTE
  - The local DCE finishes the local deactivation by confirming the *Clear Request* with *Clearing* packets
# Packet Types

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<tr>
<th>PACKET TYPE</th>
<th>DIRECTION</th>
<th>DESCRIPTION</th>
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</thead>
<tbody>
<tr>
<td>CALL REQUEST</td>
<td>DTE--&gt;DCE</td>
<td>Requests the DTE-to-DTE connection and the type of facilities for the call</td>
</tr>
<tr>
<td>INCOMING CALL</td>
<td>DCE--&gt;DTE</td>
<td></td>
</tr>
<tr>
<td>CALL ACCEPTED</td>
<td>DTE--&gt;DCE</td>
<td>Confirms the establishment of the DTE-to-DTE connection with facilities permitted</td>
</tr>
<tr>
<td>CALL CONNECTED</td>
<td>DCE--&gt;DTE</td>
<td></td>
</tr>
<tr>
<td>CLEAR REQUEST</td>
<td>DTE--&gt;DCE</td>
<td>Requests the tear down of network capacity assigned to a specified call</td>
</tr>
<tr>
<td>CLEAR INDICATION</td>
<td>DCE--&gt;DTE</td>
<td>Informs DTE of teardown request</td>
</tr>
<tr>
<td>DTE CLEAR CONFIRMATION</td>
<td>DTE--&gt;DCE</td>
<td>Informs network that DTE has ended specified call</td>
</tr>
<tr>
<td>DCE CLEAR CONFIRMATION</td>
<td>DCE--&gt;DTE</td>
<td>Informs DTE that network has ended specified call</td>
</tr>
<tr>
<td>RESET REQUEST</td>
<td>DTE--&gt;DCE</td>
<td>Requests reinitialization of DATA packets sequence numbers on a specified PVC or SVC LCN and informs DTE that network has reset its numbers</td>
</tr>
<tr>
<td>RESET INDICATION</td>
<td>DCE--&gt;DTE</td>
<td></td>
</tr>
<tr>
<td>DTE/DCE RESET CONFIRMATION</td>
<td>DTE--&gt;DCE</td>
<td>Informs DTE or DCE that numbering has been reinitialized</td>
</tr>
<tr>
<td>DTE RESTART REQUEST</td>
<td>DTE--&gt;DCE</td>
<td>Requests clearing of all calls on interface</td>
</tr>
<tr>
<td>DTE RESTART INDICATION</td>
<td>DCE--&gt;DTE</td>
<td>Informs DTE that network will be clearing all calls on this interface</td>
</tr>
</tbody>
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### Packet Types (cont)

<table>
<thead>
<tr>
<th>PACKET TYPE</th>
<th>DIRECTION</th>
<th>DESCRIPTION</th>
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</thead>
<tbody>
<tr>
<td>DIAGNOSTIC</td>
<td>DCE--&gt;DTE</td>
<td>Network provided diagnostic information typically following error recovery</td>
</tr>
<tr>
<td>DTE INTERRUPT</td>
<td>DTE--&gt;DCE</td>
<td>Unsequenced, expedited, one-time, end-to-end information from DTE or DCE</td>
</tr>
<tr>
<td>DCE INTERRUPT</td>
<td>DCE--&gt;DTE</td>
<td>End-to-end response from DCE passing on a DTE INTERRUPT packet</td>
</tr>
<tr>
<td>DTE INTERRUPT CONFIRMATION</td>
<td>DTE--&gt;DCE</td>
<td>End-to-end response from DTE to the INTERRUPT packet</td>
</tr>
<tr>
<td>DCE INTERRUPT CONFIRMATION</td>
<td>DCE--&gt;DTE</td>
<td>End-to-end response from DCE passing on a DTE INTERRUPT packet</td>
</tr>
<tr>
<td>DTE DATA</td>
<td>DTE--&gt;DCE</td>
<td>User data or higher-layer protocol from the source DTE</td>
</tr>
<tr>
<td>DCE DATA</td>
<td>DCE--&gt;DTE</td>
<td>User data or higher-layer protocol passed from the remote DTE by way of the local DCE</td>
</tr>
<tr>
<td>DTE RR</td>
<td>DTE--&gt;DCE</td>
<td>Acknowledgment of DATA packets and permission to send more from DTE</td>
</tr>
<tr>
<td>DCE RR</td>
<td>DCE--&gt;DTE</td>
<td>Acknowledgment of DATA packets and permission to send more from DCE</td>
</tr>
<tr>
<td>DTE RNR</td>
<td>DTE--&gt;DCE</td>
<td>DTE request for DCE to shut off flow of DATA packets</td>
</tr>
<tr>
<td>DCE RNR</td>
<td>DCE--&gt;DTE</td>
<td>DCE request for DTE to shut off flow of DATA packets</td>
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<td>PACKET TYPE</td>
<td>DIRECTION</td>
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<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>DTE REJECT</td>
<td>DTE---&gt;DCE</td>
<td>Request to the DCE to retransmit DATA packets beginning from a specified sequence number</td>
</tr>
<tr>
<td>REGISTRATION REQUEST</td>
<td>DTE---&gt;DCE</td>
<td>Request to the network from the user to subscribe to specified network capabilities</td>
</tr>
<tr>
<td>REGISTRATION CONFIRMATION</td>
<td>DCE---&gt;DTE</td>
<td>Information regarding network action taken on user</td>
</tr>
</tbody>
</table>
Frame Relay Fast Packet Switching

- Frame Relay is a simplified form of Packet Switching
  - Similar in principle to X.25
  - Synchronous data frames are routed to different destinations depending on header information

- Differences between Frame Relay and X.25
  - X.25 guarantees data integrity
  - X.25 manages network flow control at the cost of some network delays
  - Frame Relay provide no guarantee of data integrity
  - Frame Relay switches packets end to end much faster

- Frame Relay is cost effective
  - Network buffering is minimal compared to X.25
  - Since network buffering requirements are carefully optimized

- Frame Relay uses the synchronous HDLC frame format

<table>
<thead>
<tr>
<th>Flag</th>
<th>Address</th>
<th>Control</th>
<th>Data</th>
<th>CRC</th>
<th>CRC</th>
<th>Flag</th>
</tr>
</thead>
</table>

Flag Address Control Data CRC CRC Flag
Virtual Circuits

- Packets are routed through one or more Virtual Circuits known as Data Link Connection Identifiers (DLCIs)
  - Each DLCI has a permanently configured switching path to a certain destination
  - With several DLCIs configured, several different sites can communicate simultaneously (multipoint operation)
  - All DLCI connections are set up by the network provider at subscription time
Data Integrity

- There is none!!!!
  - The network delivers frames, whether the CRC check matches or not
  - It does not even necessarily deliver all frames
  - Frames are discarded whenever there is network congestion

- If used on analog lines, it is imperative to run an upper layer protocol above Frame Relay that is capable of recovering from errors
  - Such as HDLC, IPX or TCP/IP
  - X.25 was designed for use along analog lines

- However, modern digital lines have very low error rates and the network delivers data quite reliably

- In practice, very few frames are discarded by the network
  - Particularly when the networks are operating at well below design capacity
Flow control and Information rates

• There is no flow control on Frame Relay
  – The network discards frames it cannot deliver

• You specify the line speed (e.g. 56kbps or T1) and a Committed Information Rate (CIR) for each DLCI
  – CIR specifies the maximum average data rate that the network undertakes to deliver under "normal conditions"
  – If you send faster than that on a given DLCI, the network will flag some frames with a Discard Eligibility (DE) bit
    • The network will try to deliver all packets but will discard any DE packets first if there is congestion
  – Many inexpensive Frame Relay services are based on a CIR of zero

• Frame Relay provides indications that the network is becoming congested
  – Forward Explicit Congestion Notification (FECN) and Backward Explicit Congestion Notification (BECN) bits in data frames
  – These bits tell the application to slow down, hopefully before packets start to be discarded
Status polling

• The Frame Relay CPE polls the switch at set intervals to find out the status of the network and DLCI connections

• A *Link Integrity Verification (LIV)* packet exchange takes place about every 10 seconds, which verifies that the connection is still good
  – It also provides information to the network that the CPE is active
  – This status is reported at the other end

• About every minute, a *Full Status (FS)* exchange occurs, which passes information on which DLCIs are configured and active
  – Until the first FS exchange, the CPE does not know which DLCIs are active, and so no data transfer can take place
Frame Relay Applications

• Frame Relay used mostly to route LAN or TCP/IP over wide areas
  – Can also carry asynchronous traffic, SNA or voice data

• In North America it has the role that X.25 had in Europe
  – The cost effective way to hook up multiple stations with high speed digital links
  – Flexibility in bandwidth allocation (“bandwidth on demand”)

• Frame Relay networks do not have the reliability of X.25 networks.
  – Expect problems with new installations
  – Lack of guaranteed transfer