Datagram Packet Switching

- No call setup
- Each packet can travel across a different route from sender to receiver
- Delivery and order of packets cannot be guaranteed
- Most common implementation of datagram packet switching is Internet Protocol (IP)

Virtual Circuit Packet Switching

- Similar to standard circuit-switched networks
- Call Setup required to define the route between Sender and Receiver
- Each route is assigned a Virtual Circuit Identifier (VCI)
- All packets using the same VCI will travel the same route and will arrive in sequence
- Circuit is "virtual" because resources are not dedicated to a single call
- Most common forms of virtual circuit packet switching are X.25 and Frame Relay

X.25 Basics

An X.25 network transfers data via packet switching.

➢ A primary advantage of the X.25 network is that packet switching offers a significant cost savings compared to circuit switching.

- With this method, information is taken from many different users and combined into discrete data packets.
- Each data packet is quickly routed through the network "cloud" to its destination using self contained routing information.

X.25 History and Overview

- Designed to provide a low cost alternative for data communication over public networks
  - Pay only for bandwidth actually used
- Ideal for "bursty" communication over low quality circuits
- Standard provides error detection and correction for reliable data transfer
- X.25 standard approved in 1976 by CCITT (now known as ITU)
- Can support speeds of 9.6 Kbps to 2 Mbps
- Can provide multiplexing of up to 4095 virtual circuits over on DTE-DCE link

X.25 Networks

- Originally designed as a secure method for the transport of voice traffic over analog lines.
- International Telegraph and Telephone Consultative Committee (CCITT), now known as the ITU-T X.25 (as well as X.3, X.28, X.29, X.75 and X.480) specifies:
- How terminals talk to packet forming devices.
- How these packet assemblers talk to packet switches
- How packet switching nodes talk to each other.

X.25 Applications

An X.25 network may be used in a variety of environments. For instance, X.25 is well suited in applications where:

1.Communications are primarily asynchronous (though frequent synchronous applications are now being used).

2.Line quality may not be good (X.25's error correction capabilities overcome poor line quality).

3.Data volume is relatively small and bursty.

4.A company wants to use packet switching to decrease transmission expenses.

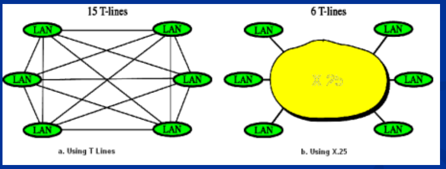
X.25 - Packet

- provides a logical connections (virtual circuit) between subscribers
- all data in this connection form a single stream between the end stations.
- established on demand

X.25

- ITU-T standard for Interface between host and packet switched network.
- Almost universal on packet switched networks and packet switching in ISDN
- Defines three layers
  - Physical
  - Link
  - Packet

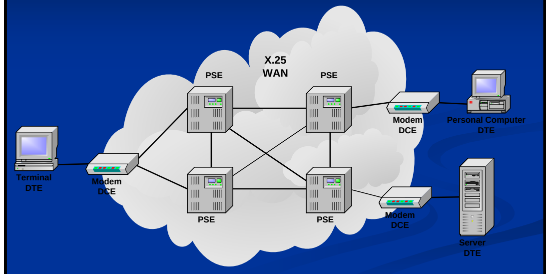
X.25 *versus* Mesh T-line Network



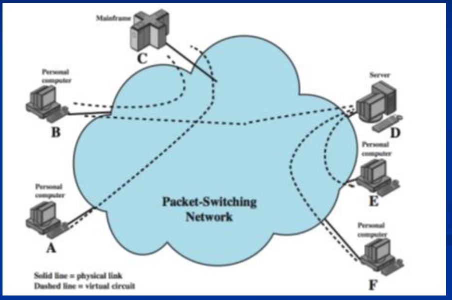
X.25 Devices

- Data Terminal Equipment (DTE)
  - Terminals, personal computers, and network hosts
  - Located on premises of subscriber
- Data Circuit-terminating Equipment (DCE)
  - Modems and packet switches
  - Usually located at carrier facility
- Packet Switching Exchange (PSE)
  - Switches that make up the carrier network

Sample X.25 Network



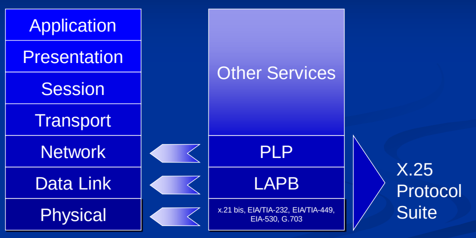
X.25 Use of Virtual Circuits



Packet Assembler/Disassembler (PAD)

- Used for DTE devices that are too simple to implement X.25 (such as character-mode terminals)
- Acts as intermediary device between DTE and DCE
- Performs three functions
  - Buffering to store data until a device is ready to process it
  - Packet Assembly
  - Packet Disassembly

X.25 mapping to OSI Model



LAPB: Ensures that frames are error free and in the right sequence.

- Packet Layer Protocol (**PLP**) is basically Network Layer Protocol for **X. 25** protocol suite and handles the virtual circuit.
- It also provides multiplexing capability. This layer is also responsible for call setup and termination and for handling transmission of data packets

- Link Access Procedure, Balanced implements the data link layer as defined in the X.25 protocol suite.
- LAPB is a bit-oriented protocol derived from HDLC that ensures that frames are error free and in the correct sequence.

X.25 Physical Layer

- Several well-known standards are used for X.25 networks
  - X.21bis – supports up to 2 Mbps
    - 15-pin connector
  - RS-232 (EIA/TIA-232) – supports up to 19.2 Kbps
    - 25-pin connector
  - RS-449 (EIA/TIA-449) – supports up to 64 Kbps
    - 37-pin connector
  - V.35 – supports up to 2 Mbps
    - 34-pin connector
- Uses serial communications in either asynchronous or synchronous modes

- ANSI Electronic Industries Association/Telecommunication Industry Association TIA/EIA-232.
- Telecommunications standards from the Telecommunications Industry Association (**TIA**).
- Energy Information Administration - **EIA**

X.25 Data Link Layer

- Link Access Procedure, Balanced (LAPB) is the protocol used for this layer
- LAPB is a version of HDLC
  - HDLC in Asynchronous Balanced Mode (ABM)
  - DTE and DCE are peers and can both perform all functions
- LAPB manages communication and packet framing between DTE and DCE devices
- Makes sure that frames are delivered in sequence and error-free
  - Uses sliding window of 8 or 128 frames

LAPB Frame Types

- Three types of frames
  - I-Frames (Information Frames)
    - Carry data as well as Next Send (NS) and Next Receive (NR) counts
  - S-Frames (Supervisory Frames)
    - Controls flow of data with Receiver Ready (RR), Receiver Not Ready (RNR), and Reject (REJ) frames
  - U-Frames (Unnumbered Frames)
    - Establish and maintain communications with Set Asynchronous Balanced Mode (SABM), Unnumbered Acknowledgment (UA), Disconnect (DISC), Disconnect Mode (DM) and Frame Reject (FRMR)

LAPB Frame Format

Flag	Address	Control	Data	FCS	Flag

Flag: (8 bits) Indicates start and end of frame (01111110)

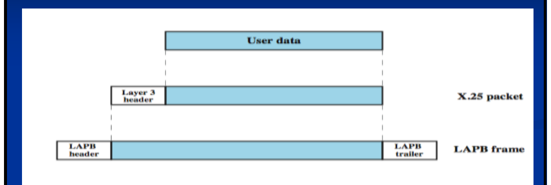
Address: (8 bits) DTE address is maintained in higher layer so this field is used to identify command and responses between DTE and DCE. A value of 0x01 indicates a command from DTE and responses from DCE while a value of 0x03 indicates commands from DCE and responses from DTE.

Control: (8 bits) Contains sequence numbers, commands and responses for controlling data flow

Data: (varies is size) Contains upper layer data

FCS: (16 bits) Frame Check Sequence used to determine if an error has occurred in transmission (variation of CRC)

User Data and X.25 Protocol Control Information

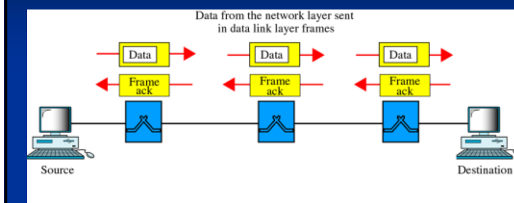


LAPB is a data link layer protocol that manages communication and packet framing between DTE and DCE devices.

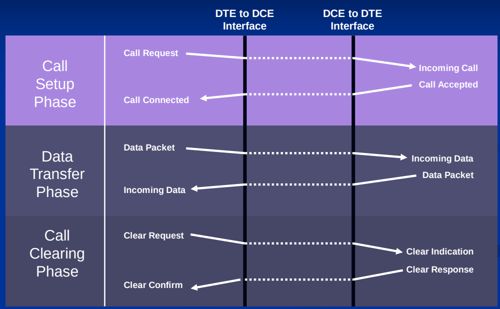
X.25 Network Layer

- Packet Layer Protocol (PLP) is the X.25 network layer protocol
- PLP manages calls between a pair DTE devices using a Permanent Virtual Circuit (PVC) or a Switched Virtual Circuit (SVC)
- PLP handles segmentation, reassembly, bit padding and error and flow control
- PLP uses X.121 Addressing Scheme to setup a virtual circuit

X.25 Traffic



X.25 Call Setup



PLP Operates in Five Modes

- Call Setup
  - Used to setup virtual circuit for SVC
- Data Transfer
  - Used for transferring data with both SVC and PVC
- Idle
  - Used when SVC call has been established but no data is currently being transferred
- Call Clearing
  - Used to end communication between DTEs for a SVC
- Restarting
  - Used to synchronize DTE and DCE for all virtual circuits that exist between them

Issues with X.25

- key features include:
  - multiplexing of virtual circuits at layer 3
  - layers 2 and 3 include flow and error control
- hence have considerable overhead
- not appropriate for modern digital systems with high reliability

Frame Relay History and Overview

- Frame Relay was originally designed for use on Integrated Services Digital Network (ISDN)
- Usually considered a replacement for X.25 using more advanced digital and fiber optic connections
- Does not perform error correction at intermediate nodes making it faster than X.25
  - When an error is detected (FCS) the frame is discarded and correction is left up to higher layer protocols
- Original standard proposed in 1984 but widespread acceptance did not occur until the late 1980's
  - Service Description Standard (ITU-T I.233)
    - Overall service description and specifications, Connection Management
  - Core Aspects (ITU-T Q.922)
    - Frame Format, Field Functions, Congestion Control
  - Signaling (ITU-T Q.933)
    - Establishing and Releasing switched connections and status of permanent connections

Frame Relay Standardization

- Initial proposals for the standardization of Frame Relay were presented to the Consultative Committee on International Telephone and Telegraph (CCITT) in 1984.
- A major development in Frame Relay's history occurred in 1990 when Cisco, Digital Equipment Corporation (DEC), Northern Telecom, and StrataCom formed a consortium to focus on Frame Relay technology development.
- This consortium developed a specification that conformed to the basic Frame Relay protocol that was being discussed in CCITT.
- but it extended the protocol with features that provide additional capabilities for complex internetworking environments.
- Since the consortium's specification was developed and published, many vendors have announced their support of this extended Frame Relay definition.
- Internationally, Frame Relay was standardized by the International Telecommunication Union—Telecommunications Standards Section (ITU-T).
- In the United States, Frame Relay is an American National Standards Institute (ANSI) standard.

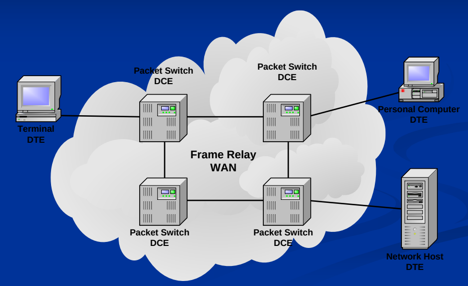
- Frame Relay often is described as a streamlined version of X.25.

  This is because Frame Relay typically operates over WAN facilities that offer more reliable connection services and a higher degree of reliability than the facilities available during the late 1970s and early 1980s that served as the common platforms for X.25 WANs.

Frame Relay Devices

- Data Terminal Equipment (DTE)
  - Terminals, Personal Computers, routers, and bridges typically at the customer location
- Data Circuit-terminating Equipment (DCE)
  - Typically packet switches owned by the carrier that transmit data through the WAN

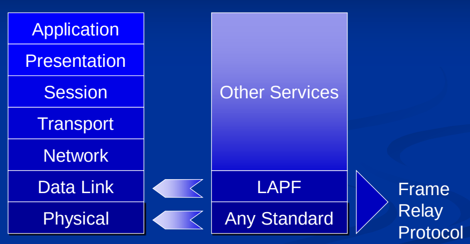
Sample Frame Relay Network



Frame Relay Assembler/Disassembler (FRAD)

- To handle frames from other protocols a FRAD is used to provide conversion to Frame Relay packets
- A FRAD can either be a separate device or part of a router/switch

Frame Relay mapping to OSI Model



- In wide area network computing, **Link Access Procedure for Frame Relay** (or **LAPF**) is part of the network's communications protocol which ensures that frames are error free and executed in the right sequence.

Frame Relay Physical Layer

- No specific protocol is defined
- Any protocol recognized by ANSI can be implemented

Frame Relay Data Link Layer

- Link Access Protocol for Frame Modes Services (LAPF) is the protocol defined for Frame Relay Layer 2 services
- LAPF is a version of HDLC
  - Does not provide flow or error control
  - Uses Address field for DLCI (addressing) as well as for congestion control

LAPF Frame Format

Flag	Address	Information	FCS	Flag

DLCI	C/R	EA	DLCI	FECN	BECN	DE	EA

DLCI: (10 bits) Data Link Connection Identifier is used to identify the Virtual Circuit number

C/R: (1 bit) Provided for up layers to determine commands and responses

EA: (1 bit) Determines if this byte is last byte of address (0=more, 1=last)

FECN: (1 bit) Forward Explicit Congestion Notification indicates congestion in the direction the frame is traveling

BECN: (1 bit) Backward Explicit Congestion Notification indicates congestion in the opposite direction the frame is traveling

DE: (1 bit) Discard Eligibility indicates that a frame is low priority when set

Extended Addresses

- To increase the number of virtual circuits the DLCI can be expanded from 10 bits to 16 bits and 23 bits
- The EA field is set to 0 to indicate that additional address bytes are present. The last address byte will have a 1 in the EA field

Three Address Formats

Two-byte Address (10 bit DLCI)

DLCI			C/R	0
DLCI	FECN	BECN	DE	1

Three-byte Address (16 bit DLCI)

DLCI			C/R	0
DLCI	FECN	BECN	DE	0
DLCI			0	1

Four-byte Address (23 bit DLCI)

DLCI			C/R	0
DLCI	FECN	BECN	DE	0
DLCI				0
DLCI			0	1

Frame Relay Operating States

- Original Frame Relay standard only covered PVC
- SVC support was added but does not have widespread implementation
- PVC States
  - Data Transfer – data is being transmitted between DTE devices
  - Idle – connection is still active but no data is being transferred
- SVC required the addition of two additional states
  - Call Setup – virtual circuit between DTE devices is established
  - Call Termination – virtual circuit between DTE devices is terminated

Congestion Management

- Because of the shared resources of a virtual circuit, congestion can cause the loss of packets as buffers become full
- Frame Relay defines a congestion control mechanism using the FECN and BECN bits in the address field
- When a switch determines that congestion has occurred it will set the FECN bit on packets traveling in the direction of the congestion to alert the receiver to slow down requests for data. The BECN bit will be set for packets going in the opposite direction of the congestion to let the sender know to send data more slowly
- The FECN and BECN bits will allow higher layer protocols to manage flow.
- Discard Eligible bit is used to identify frames that are low priority and can be discarded in the event of congestion

- **BECN** is used to notify the sender that congestion has occurred. **FECN** is used to inform the receiver of the traffic that congestion.
- In a frame relay network, FECN (forward explicit congestion notification) is a header bit transmitted by the source (sending) terminal requesting that the destination (receiving) terminal slow down its requests for data.
- BECN (backward explicit congestion notification) is a header bit transmitted by the destination terminal requesting that the source terminal send data more slowly.

Local Management Interface (LMI)

- LMI is a set of extensions to Frame Relay developed in 1990 by Cisco Systems, StrataCom, Northern Telecom, and Digital Equipment Corporation
- LMI provides global addressing which allows additional management capability such as standard address resolution and discovery
- LMI allows status messages to be passed between DCE and DTE devices to provide communication and synchronization (uses DLCI 1023 on a 2-byte address)
- LMI specifies multicast capability to allow creation of multicast groups to limit bandwidth use

Comparison of X.25 and Frame Relay

	X.25	Frame Relay
Layer 1 Specification	Yes	None
Layer 2 Protocol Family	HDLC	HDLC
Layer 3 Support	PLP	None
Error Correction	Node to Node	None
Propagation Delay	High	Low
Ease of Implementation	Difficult	Easy
Good for Interactive Applications	Too Slow	Yes
Good for Voice	No	Yes
Good for LAN File Transfer	Slow	Yes

X.25 and Frame Relay Today

- Many X.25 networks have been replaced by Frame Relay or X.25 over Frame Relay Networks
- X.25 still in use for low bandwidth applications such as credit card verification
- It is likely that ATM Networks will ultimately replace Frame Relay and X.25 Networks

X.25 vs Frame Relay

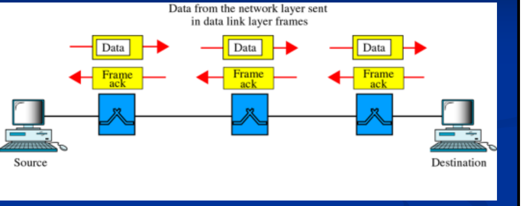
- Frame Relay is strictly a Layer 2 protocol suite.
- Whereas X.25 provides services at Layer 3 (the network layer) as well.
- This enables Frame Relay to offer higher performance and greater transmission efficiency than X.25.
- Makes Frame Relay suitable for current WAN applications, such as LAN interconnection.

X.25 vs Frame Relay

- X.25: interface between host and packet-switching network
  - 3 layers: phy, link, packet
  - Heavyweight: error control at *every link* as well as layer 3:
  - X.25 offers no QoS capability
- Frame relay breaks up link-layer into two parts:
  - *LAPF-core* and *LAPF-control*
  - Network nodes only implement LAPF-core
  - Frame Switching is a service that implements both
- Frame relay uses a *separate VC for control channel*

- Frame relay is similar to X.25, but removes the error detection/correction at each of the packet switches.
  - this improves performance, but requires that error detection/correction be built into the network protocol being transported.
  - bad frames are simply discarded, and must be re-generated.

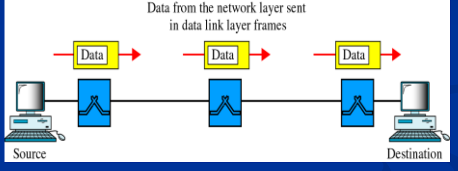
X.25 Traffic



Frame Relay

- designed to eliminate most X.25 overhead
- key differences:
  - call control carried in separate logical connection
  - multiplexing and switching at layer 2
  - no hop by hop error or flow control
  - hence end to end flow and error control (if used) are done by higher layer
- a single user data frame is sent from source to destination and higher layer ACK sent back

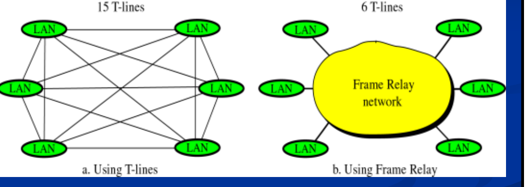
Frame Relay Traffic: *Less Overhead*



Comparison: X.25 & Frame Relay

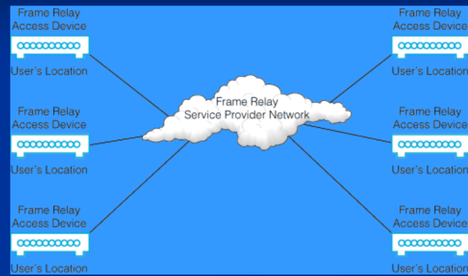
Feature	X.25	Frame Relay
Connection establishment	At the network layer	None
Hop-by-hop flow control and error control	At the data link layer	None
End-to-end flow control and error control	At the network layer	None
Data rate	Fixed	Bursty
Multiplexing	At the network layer	At the data link layer
Congestion control	Not necessary	Necessary

Frame Relay *versus* Mesh T-line Network



Frame Relay

- *Frame Relay* is a high-performance WAN protocol that operates at the physical and data link layers of the OSI reference model.
- Frame Relay originally was designed for use across Integrated Services Digital Network (ISDN) interfaces.
- Frame Relay is an example of a packet-switched technology.
- Packet-switched networks enable end stations to dynamically share the network medium and the available bandwidth.



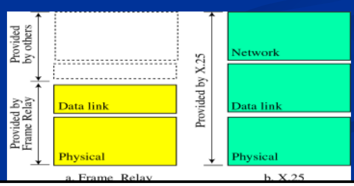
Frame Relay: Key Features

- X.25 simplified
- No flow and error control
- Two layers
- Protocol multiplexing in the second layer
- Congestion control added
- Higher speed possible.

- X.25 Switching = Relaying + Ack + Flow control + Error recovery +loss recovery

Comparing Layers: X.25 & Frame Relay

- packet switching systems have large overheads to compensate for errors.
- modern systems are more reliable
- errors can be caught in end system
- Frame Relay provides higher speeds
- with most error control overhead removed



The following two techniques are used in packet-switching technology:

- Variable-length packets
- Statistical multiplexing

- ***Variable-length packets:*** Variable-length packets are used for more efficient and flexible data transfers.
- These packets are switched between the various segments in the network until the destination is reached.
- ***Statistical multiplexing***: This techniques control network access in a packet-switched network..
- The advantage of this technique is that it accommodates more flexibility and more efficient use of bandwidth.
- Most of today's popular LANs, such as Ethernet is packet-switched network.

Frame Relay Devices

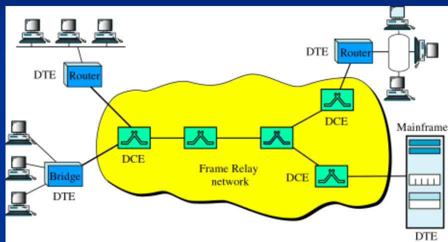
- ***Devices attached to a Frame Relay WAN fall into the following two general categories:***
  - **Data terminal equipment (DTE)**
  - **Data circuit-terminating equipment (DCE)**

DTEs generally are considered to be terminating equipment for a specific network and typically are located on the premises of a customer.

In fact, they may be owned by the customer. Examples of DTE devices are terminals, personal computers, routers, and bridges.

DCEs are carrier-owned internetworking devices. The purpose of DCE equipment is to provide clocking and switching services in a network, which are the devices that actually transmit data through the WAN..
In most cases, these are packet switches.

Frame Relay Network

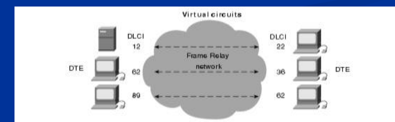


Frame Relay Virtual Circuits

- Frame Relay provides connection-oriented data link layer communication.
- Virtual circuits provide a bidirectional communication path from one DTE device to another and are uniquely identified by a data-link connection identifier (DLCI).
- A number of virtual circuits can be multiplexed into a single physical circuit for transmission across the network..
- This capability often can reduce the equipment and network complexity required to connect multiple DTE devices.
- A virtual circuit can pass through any number of intermediate DCE devices (switches) located within the Frame Relay PSN.

Data-Link Connection Identifier

- Frame Relay virtual circuits are identified by *data-link connection identifiers (DLCIs)*.
- DLCI values typically are assigned by the Frame Relay service provider (for example, the telephone company).
- Frame Relay DLCIs have local significance, which means that their values are unique in the LAN, but not necessarily in the Frame Relay WAN.



A Single Frame Relay Virtual Circuit Can Be Assigned Different DLCIs on Each End of a VC

Frame Relay virtual circuits fall into two categories:

- Switched Virtual Circuits (SVCs)
- Permanent Virtual Circuits (PVCs)

- <u>Switched Virtual Circuits:</u>

Switched virtual circuits (SVCs) are temporary connections used in situations requiring only sporadic data transfer between DTE devices across the Frame Relay network..

A communication session across an SVC consists of the following four operational states:

• **Call setup**—The virtual circuit between two Frame Relay DTE devices is established.

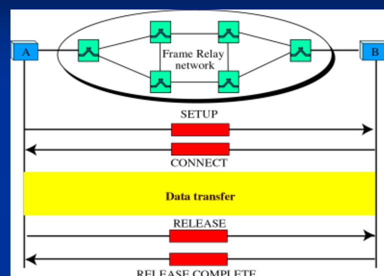
• **Data transfer**—Data is transmitted between the DTE devices over the virtual circuit.

• **Idle**—The connection between DTE devices is still active, but no data is transferred.

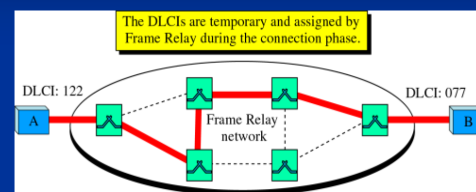
If an SVC remains in an idle state for a defined period of time, the call can be terminated.

• **Call termination**—The virtual circuit between DTE devices is terminated.

Virtual Circuits: SVC



Virtual Circuits: SVC DLCI



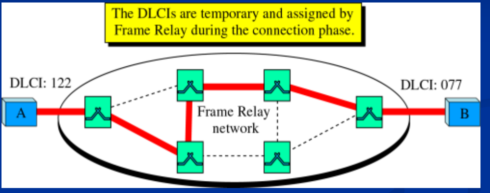
Permanent Virtual Circuits

- *Permanent virtual circuits (PVCs)* are permanently established connections that are used for frequent and consistent data transfers between DTE devices across the Frame Relay network.
- Communication across a PVC does not require the call setup and termination states that are used with SVCs. PVCs always operate in one of the following two operational states:

• **Data transfer**—Data is transmitted between the DTE devices over the virtual circuit.

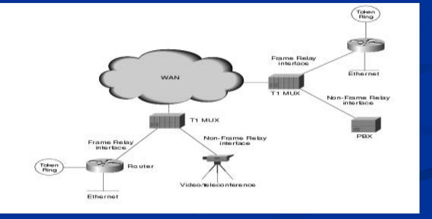
• **Idle**—The connection between DTE devices is active, but no data is transferred. Unlike SVCs, PVCs will not be terminated under any circumstances when in an idle state.

Virtual Circuits: PVC DLCI

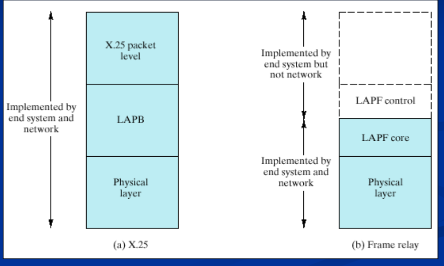


Frame Relay Network Implementation

- A typical Frame Relay network consists of a number of DTE devices, such as routers, connected to remote ports on multiplexer equipment via traditional point-to-point services such as T1, fractional T1, or 56-Kb circuits.



Frame Relay Architecture



LAPF Functionality

- LAPF (Link Access Procedure for Frame Mode Bearer Services) .
- only core functionality used:
  - frame delimiting, alignment and transparency
  - frame mux and demux using addressing field
  - ensure frame is neither too long nor short
  - detection of transmission errors
  - congestion control functions
- form sub-layer of data link layer
  - data transfer between subscribers only

Frame Relay Conclusion

- Packet switching systems have large overheads to compensate for errors
- Modern systems are more reliable
- Errors can be caught in end system
- Most overhead for error control is stripped out
- Frame is a variable size of data
- Intermediate node does not perform error detection & correction

Summary

- circuit verses packet switching network approaches
- X.25
- frame relay