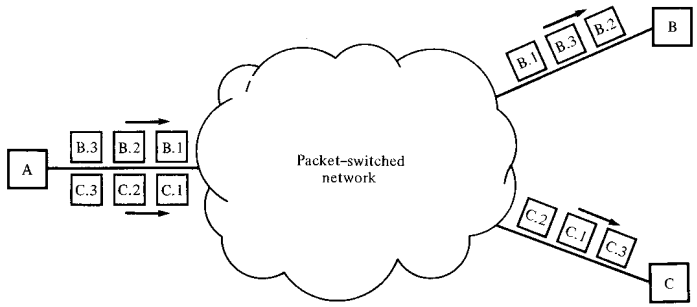
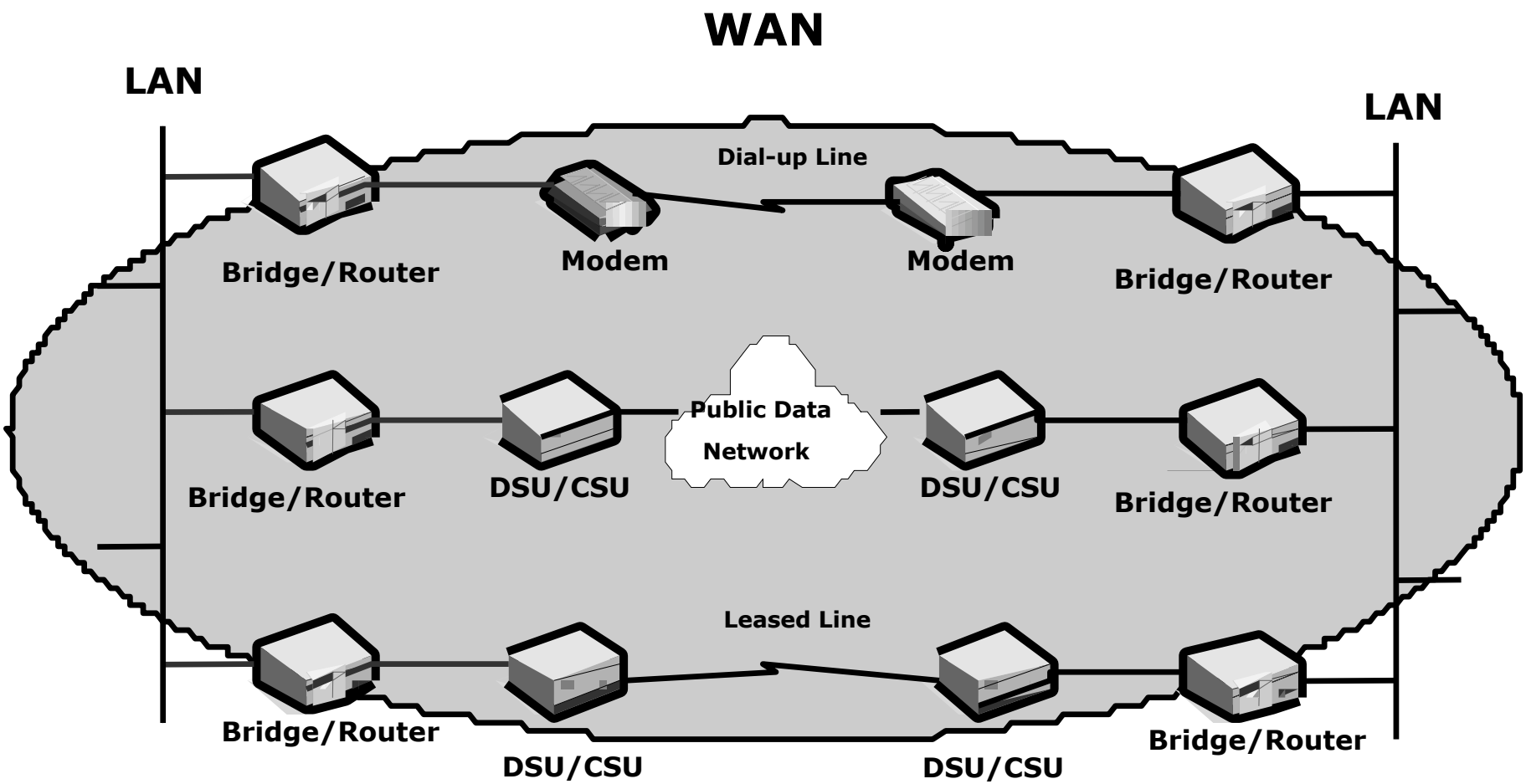
X.25 Packet Switching Data Network



X.25 Packet Switched Networks allow remote devices to communicate with each other across high speed (?) digital links using Packet Switching Technology without the expense of individual leased lines.

WAN Connection Alternatives



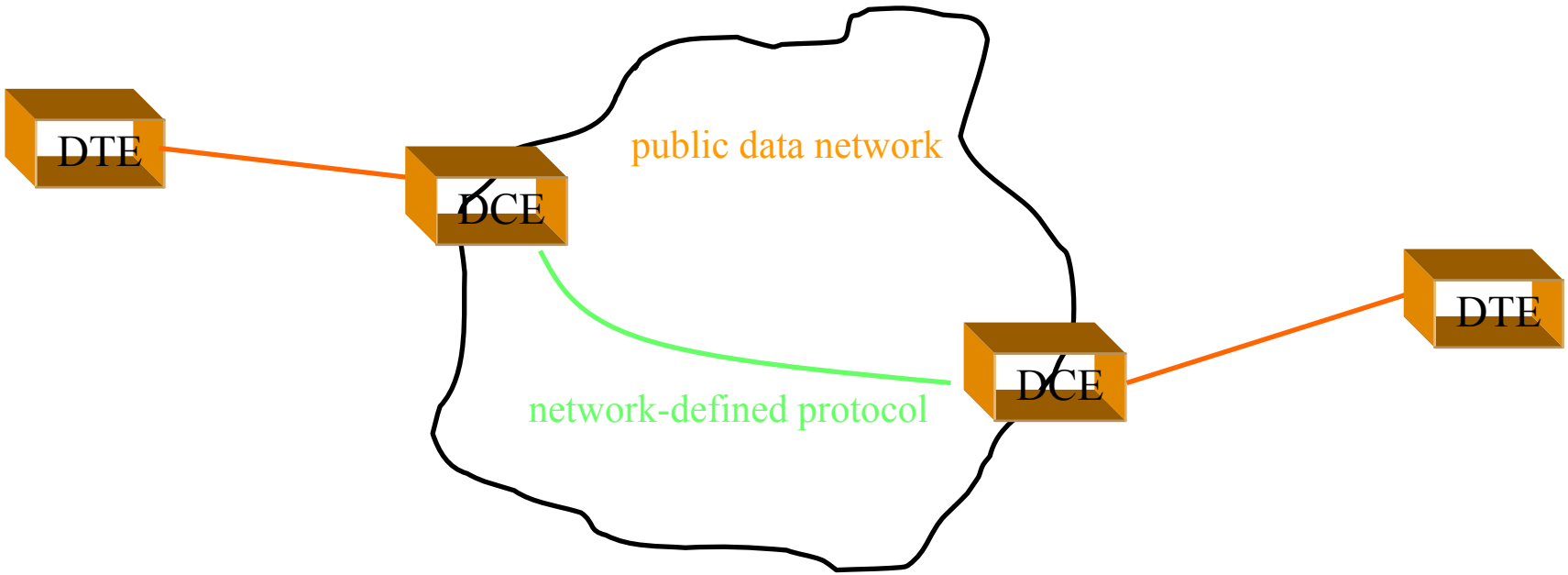
Introduction

- The most widely used network access protocol which has been defined to interface a DTE to a packet switched data network is X.25 (however X.25 can be used on private networks as well, it isn't limited to PDNs).
- The protocol known as X.25 encompasses the first three layers of the OSI 7-layered architecture as defined by the International Standards Organization (ISO) as follows:

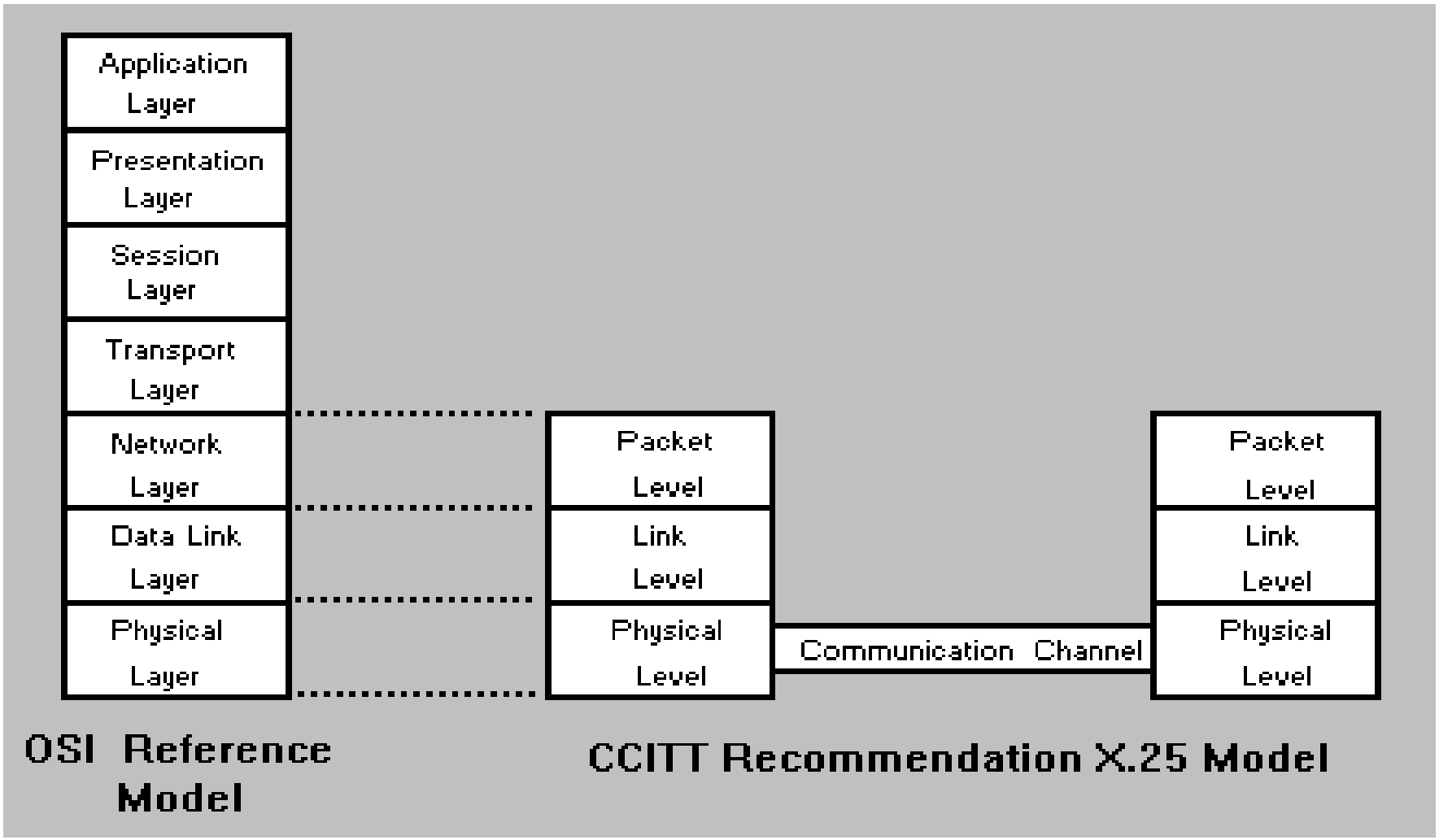
The X.25 - Public Data Network Interface Standard

- X.25 defined in 1976
- Almost universal on packet switched networks and packet switching in ISDN
- X.25 is not a network protocol.
  - Rather it defines the protocol between a DTE and a DCE connected to a public network.
  - Recent versions also define peer-to-peer communications between two DTEs.
- X.25 defines a synchronous transmission analogous to the lower three layers of the OSI model.

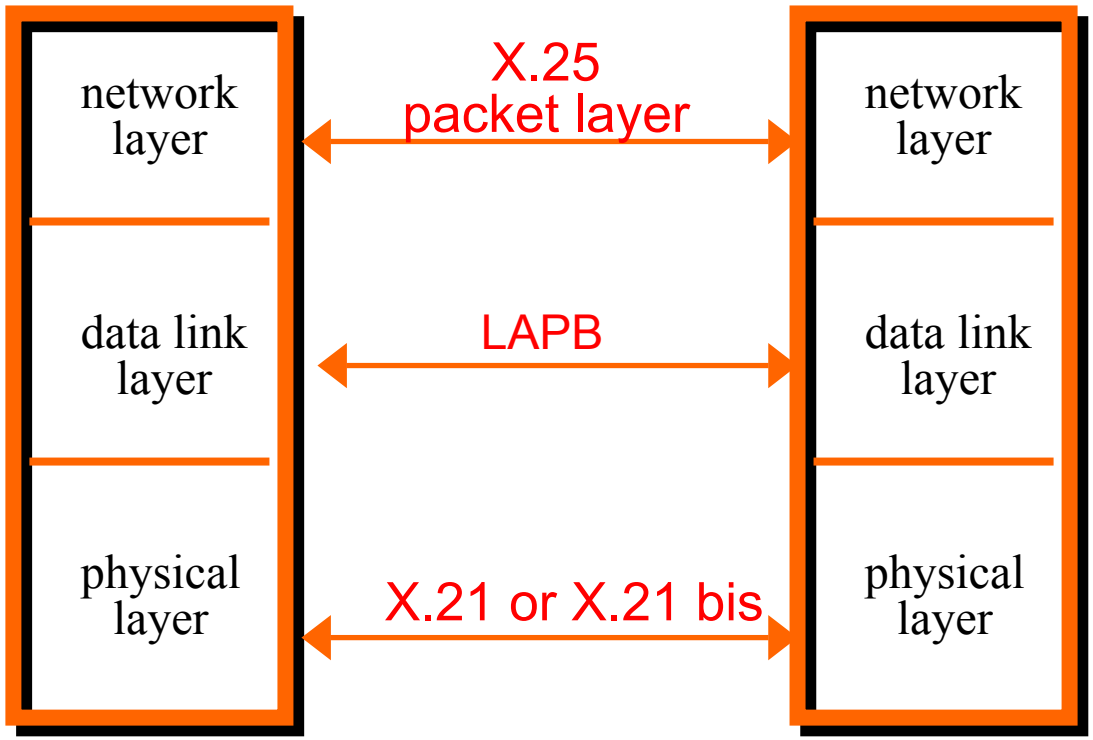
X.25 Public Data Network Interface



X.25 Protocol Layers



X.25 Protocol Layers



Layer 1: The Physical Layer

- Layer 1: The Physical Layer is concerned with electrical or signaling. It includes several standards such as V.35, RS232 and X.21bis.
- The physical layer performs the transfer of serial data streams between the DTE and the DCE (which is supplied by the network operators). The protocol is defined in CCITT Recommendation X.21 .

Layer 2: The Data Link (Frame) Layer

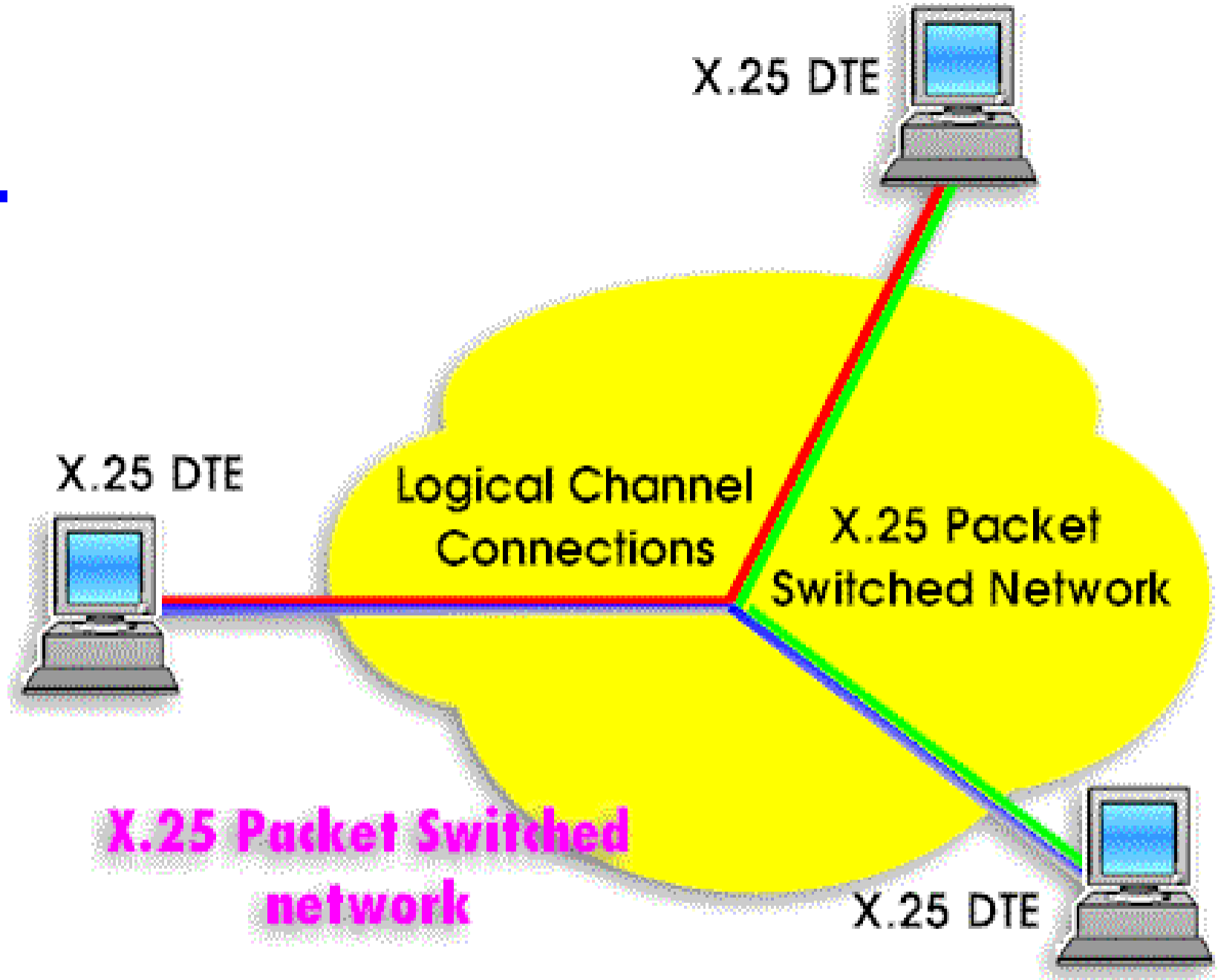
- **Layer 2:** The Data Link Layer, which is an implementation of the ISO HDLC standard called Link Access Procedure Balanced (LAPB) and provides an error free link between two connected devices.
- The link functions are:
  - Link setup to form a logical connection between the DTE & and DCE.
  - Error control.
  - Control the data flow over the physical connection.
  - Link disconnection.
- The link layer has no knowledge of the logical channel to which a packet may belong. The frame structure and error and flow control procedures used by the link layer are based on the HDLC protocol.

Layer 3: The Network (Packet) Layer

- Layer 3: The Network Layer which provides communications between devices connected to a common network. In the case of X.25, this layer is referred to as the X.25 Packet Layer Protocol (PLP) and is primarily concerned with network routing functions and the multiplexing of simultaneous logical connections over a single physical connection.
- The network layer's main functions are:
  - Call establishment
  - Data transfer
  - Call clearing
  - Restarting

DTEs and DCEs

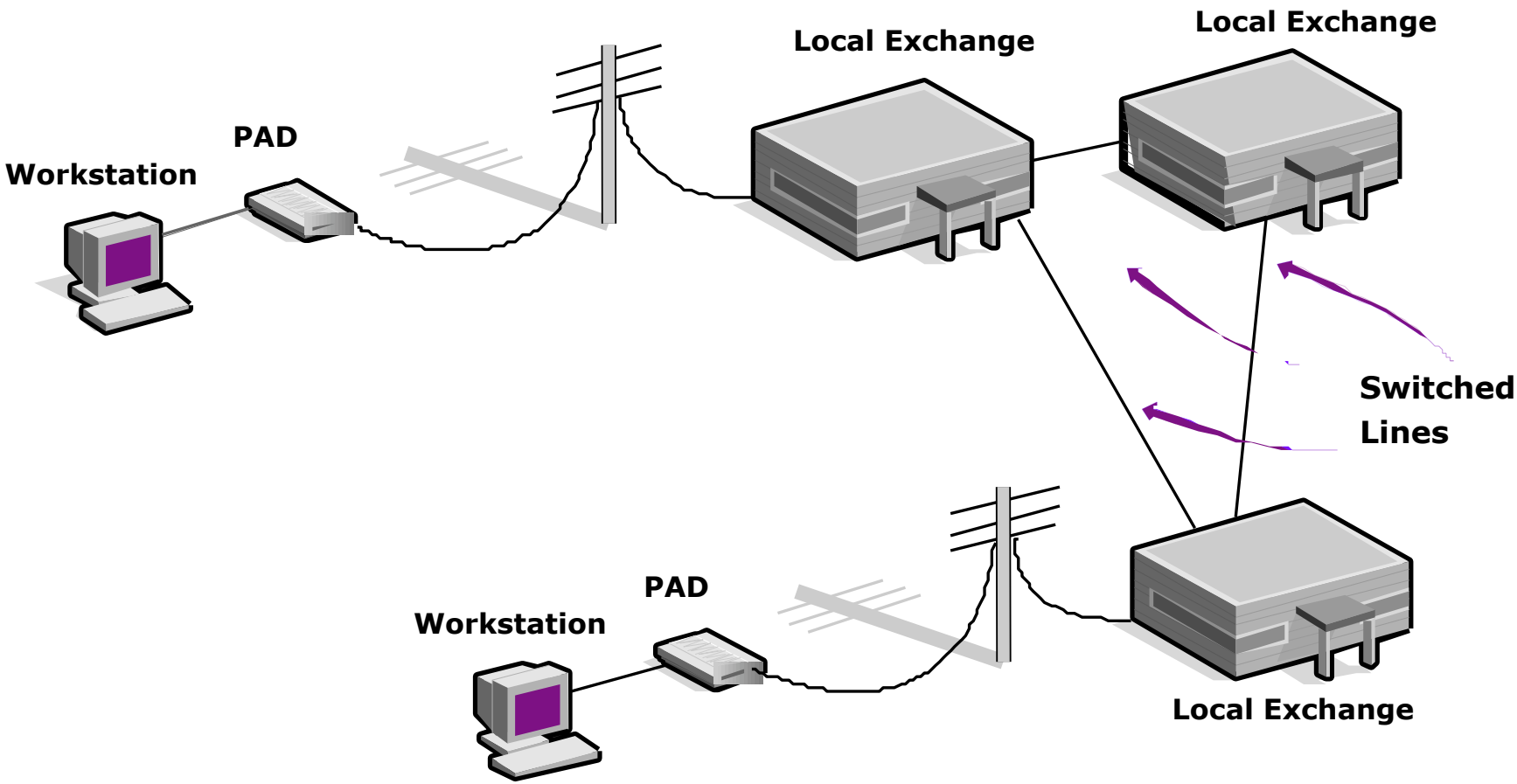
- The user end of the network is known as **Data Terminal Equipment (DTE)** and the carrier's equipment is **Data Circuit-terminating Equipment (DCE)**.
- The X.25 PLP permits a DTE user on an X.25 network to communicate with a number of remote DTEs simultaneously.


X.25 DTE
X.25 DTE
Logical Channel
Connections
X.25 Packet
Switched Network
X.25 Packet Switched
network
X.25 DTE

SVCs and PVCs

- Connections occur on logical channels of two types:
  - **Switched virtual circuits (SVCs)** - SVCs are very much like telephone calls; a connection is established, data are transferred and then the connection is released. Each DTE on the network is given a unique DTE address which can be used much like a telephone number.
  - **Permanent virtual circuits (PVCs)** - a PVC is similar to a leased line in that the connection is always present. The logical connection is established permanently by the Packet Switched Network administration. Therefore, data may always be sent, without any call setup.

Switched Lines and Dial-Up Networking



The X Series Protocols

- In the 1970s European countries worked under the auspices of ITU to develop a single standard for public data networks.
  - The result is a public data network service interface referred to as the X series protocols.
  - We will briefly look at some of the X series interface protocols.
    - The protocols are not used as much in USA as in Europe.

Packet-Switched Network Modes

- Packet-switched networks typically operate in one of two modes.
  - Virtual Circuit
  - Datagram Service

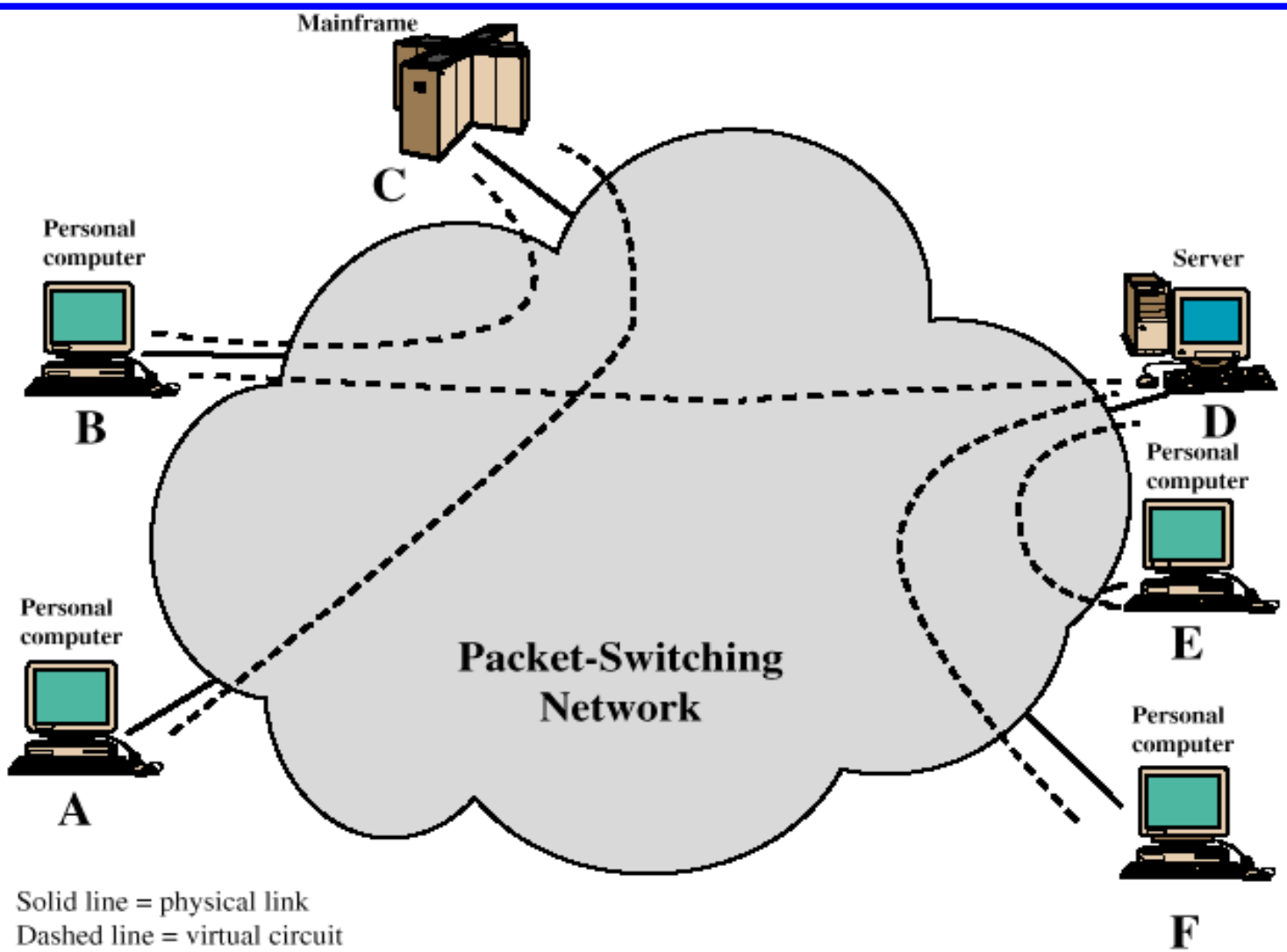
Virtual Circuits

- A device needing to establish a virtual circuit between two points requests a connection to a device somewhere else.
  - This request is routed through network nodes, establishing a path between the caller and destination.
  - All subsequent packets sent by the caller follow that same path.

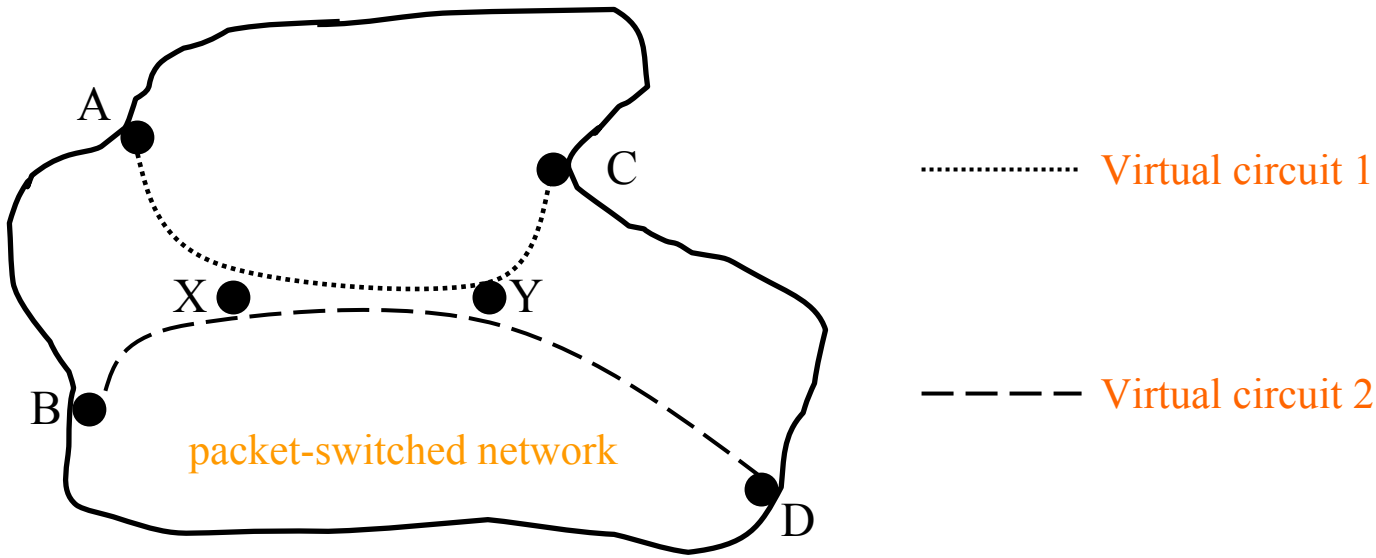
Virtual Circuit versus Circuit Switching

- Circuit switching establishes a dedicated path between two points.
- The connections between virtual circuit nodes are not dedicated.
  - Because virtual circuit paths can overlap, each node must be able to determine the virtual circuit corresponding to an incoming packet.

One Station Can Have Many Virtual Circuit Connections



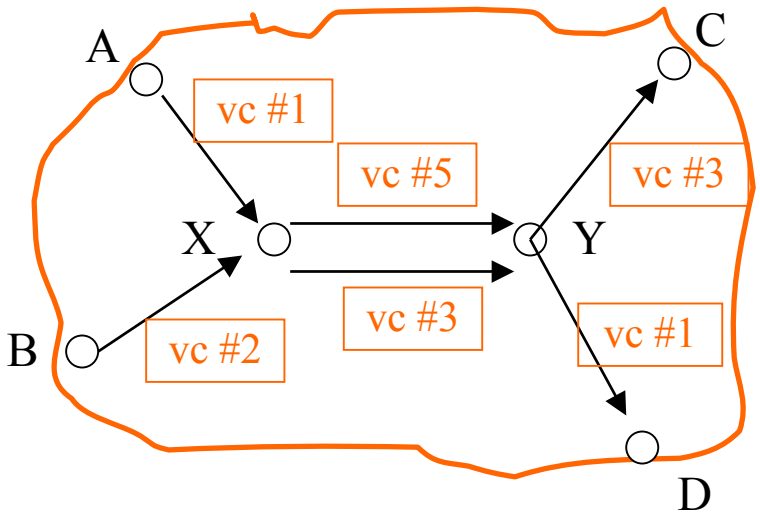
Overlapping Virtual Circuits



Assigning Virtual Circuit Numbers

- Each node assigns virtual circuit numbers independently.
  - One virtual circuit may be identified by different numbers at different nodes.
- Each node informs the circuit's preceding node of the virtual circuit number it uses for incoming packets.
  - This allows a preceding node to store the virtual circuit number for the next node in an outgoing packet.

Sending Packets along a Virtual Circuit



Routing Table for X

Incoming VC Number	Outgoing VC Number	Next Node
1	5	Y
2	3	Y

Routing Table for Y

Incoming VC Number	Outgoing VC Number	Next Node
5	3	C
3	1	D

Datagram Service

- Virtual circuits make routing decisions just once for each circuit.
  - Eliminating the need to make routing decisions for each packet.
- Datagram service puts the source and destination address in each packet.
  - Routers apply routing logic to each packet separately.
  - Each packet can take advantage of the best route available.
  - But there is no guarantee that packets will arrive in the order they were sent.

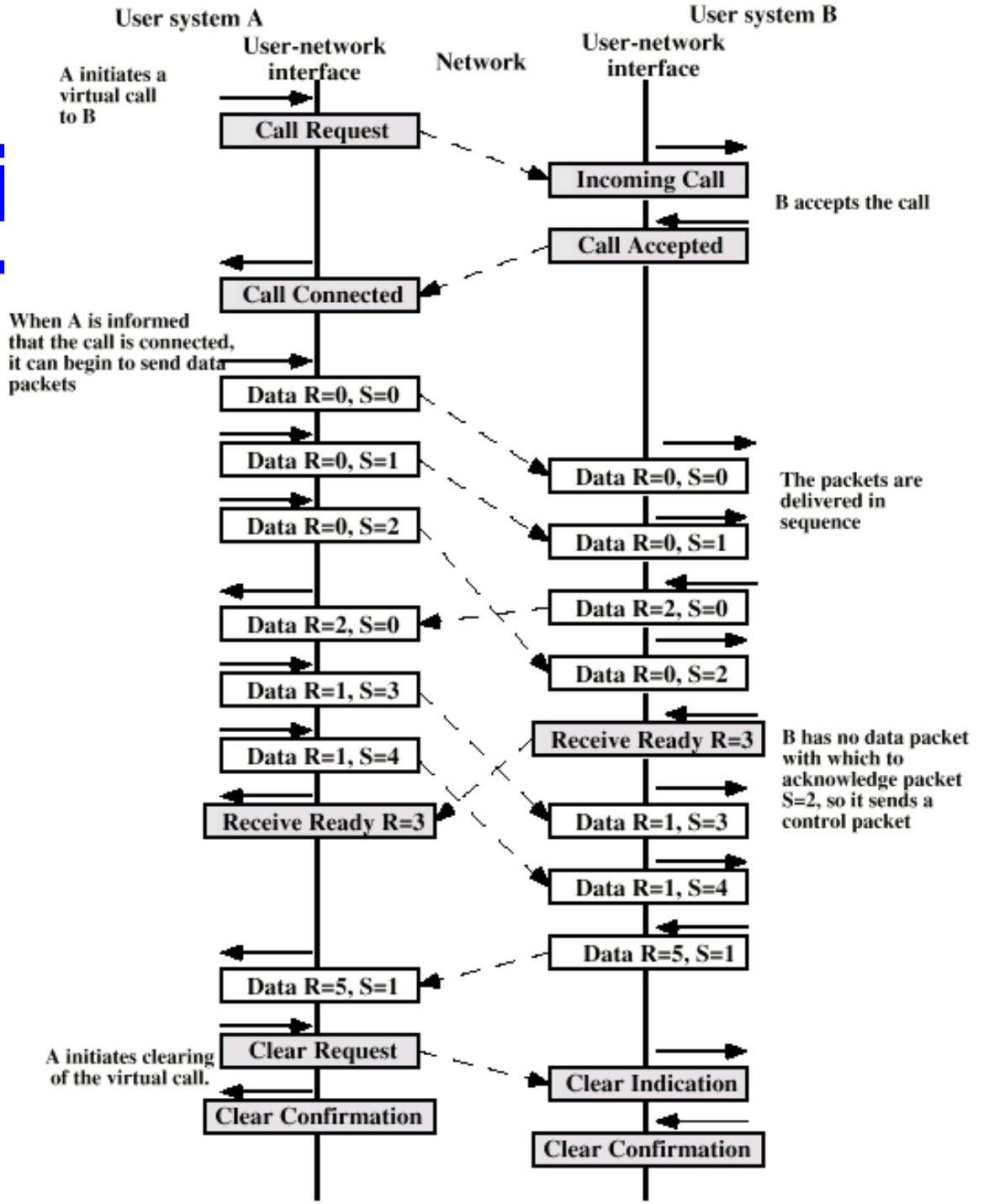
X.25 - Packet

- External virtual circuits
- Logical connections (virtual circuits) between subscribers

Virtual Circuit Service

- Virtual Call
  - Dynamically established
- Permanent virtual circuit
  - Fixed network assigned virtual circuit

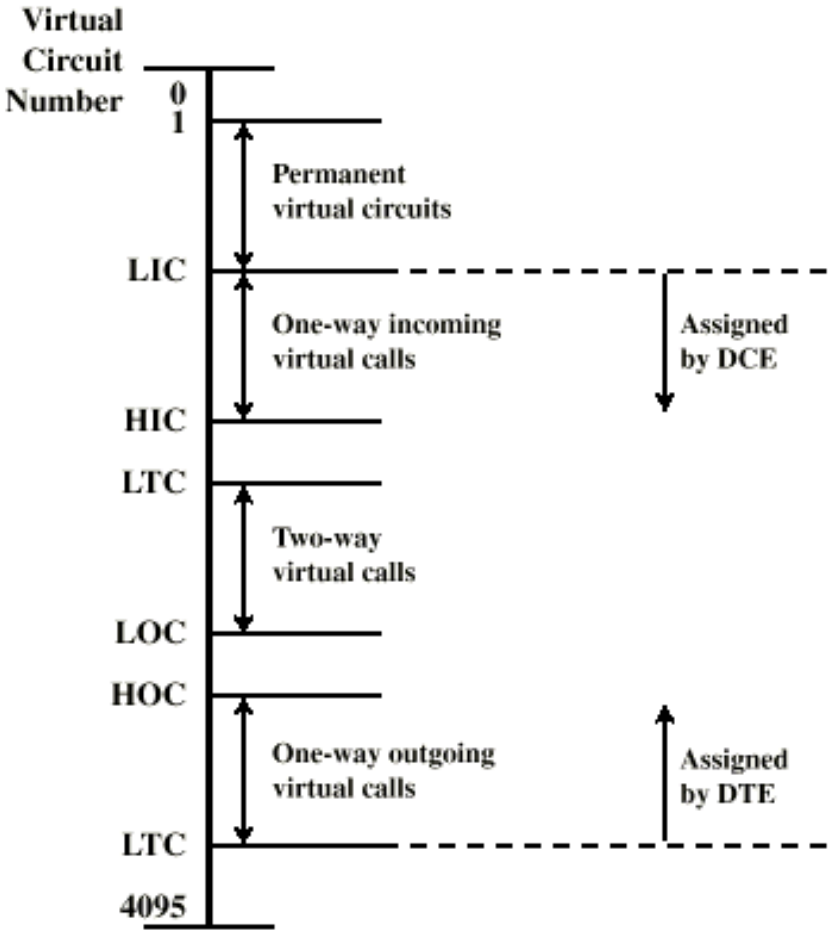
Vi


User system A
User-network interface
Network
User-network interface
User system B
A initiates a virtual call to B
Call Request
Incoming Call
B accepts the call
Call Accepted
Call Connected
When A is informed that the call is connected, it can begin to send data packets
Data R=0, S=0
Data R=0, S=1
Data R=0, S=2
Data R=2, S=0
Data R=1, S=3
Data R=1, S=4
Receive Ready R=3
Data R=5, S=1
A initiates clearing of the virtual call.
Clear Request
Clear Confirmation
Data R=0, S=0
Data R=0, S=1
Data R=2, S=0
Data R=0, S=2
Receive Ready R=3
Data R=1, S=3
Data R=1, S=4
Data R=5, S=1
Clear Indication
Clear Confirmation
The packets are delivered in sequence
B has no data packet with which to acknowledge packet S=2, so it sends a control packet

Multiplexing

- DTE can establish 4095 simultaneous virtual circuits with other DTEs over a single DTC-DCE link
- Packets contain 12 bit virtual circuit number

Virtual Circuit Numbering



LIC = Lowest incoming channel
HIC = Highest incoming channel
LTC = Lowest two-way channel

HTC = Highest two-way channel
LOC = Lowest outgoing channel
HOC = Highest outgoing channel

Virtual circuit number =
logical group number and
logical channel number

Packet Sequences

- Complete packet sequences
- Allows longer blocks of data across network with smaller packet size without loss of block integrity
- A packets
  - M bit 1, D bit 0
- B packets
  - The rest
- Zero or more A followed by B

Reset and Restart

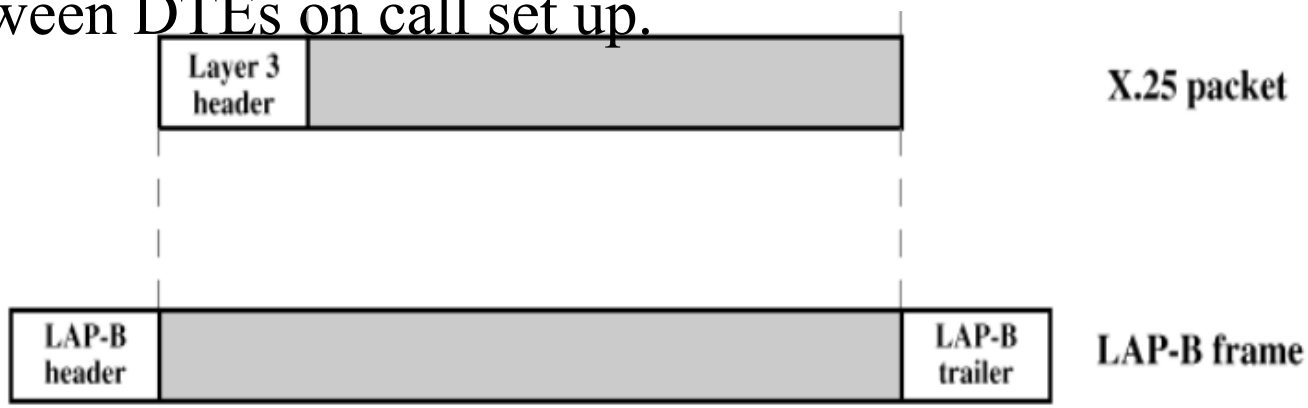
- Reset
  - Reinitialize virtual circuit
  - Sequence numbers set to zero
  - Packets in transit lost
  - Up to higher level protocol to recover lost packets
  - Triggered by loss of packet, sequence number error, congestion, loss of network internal virtual circuit
- Restart
  - Equivalent to a clear request on all virtual circuits
  - E.g. temporary loss of network access

X.25 Call Setup

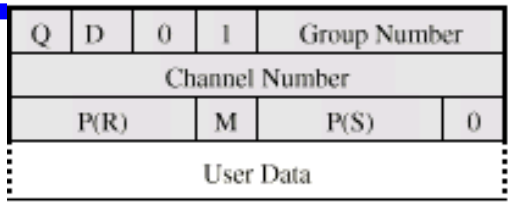
- To establish a connection on an SVC, the calling DTE sends a **Call Request** Packet, which includes the address of the remote DTE to be contacted.
- The destination DTE decides whether or not to accept the call (the Call Request packet includes the sender's DTE address, as well as other information that the called DTE can use to decide 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. When either DTE wishes to terminate the call, a **Clear Request** packet is sent to the remote DTE, which responds with a **Clear Confirmation** packet.
- The destination for each packet is identified by means of the **Logical Channel Identifier (LCI)** or **Logical Channel Number (LCN)**. This allows the PSN to route the each packet to its intended DTE.

X.25 Packet Size

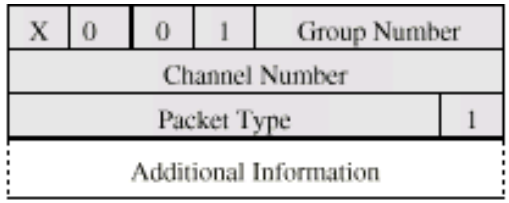
- X.25 relies on the underlying robustness of HDLC LAPB to get data from node to node through the X.25 network.
- An X.25 packet makes up the data field of an HDLC frame. Additional flow control and windowing are provided for each Logical Channel at the X.25 level.
- Maximum packet sizes vary from 64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



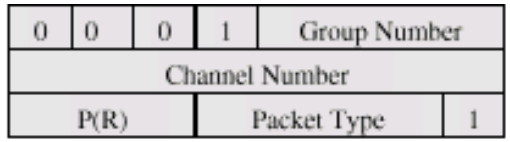
X.25 Packet Formats



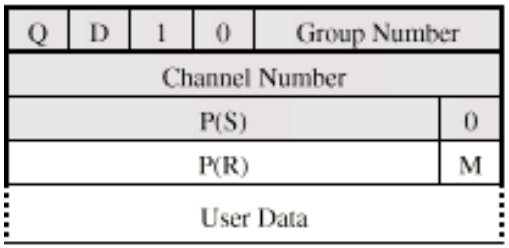
(a) Data packet with 3-bit sequence numbers



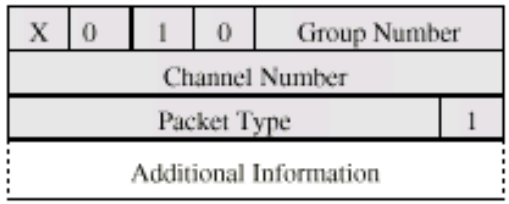
(b) Control packet for virtual calls with 3-bit sequence numbers



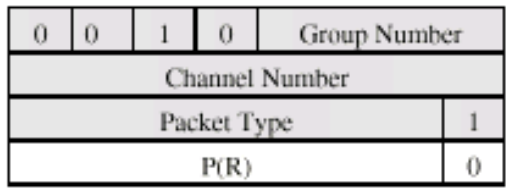
(c) RR, RNR, and REJ packets with 3-bit sequence numbers



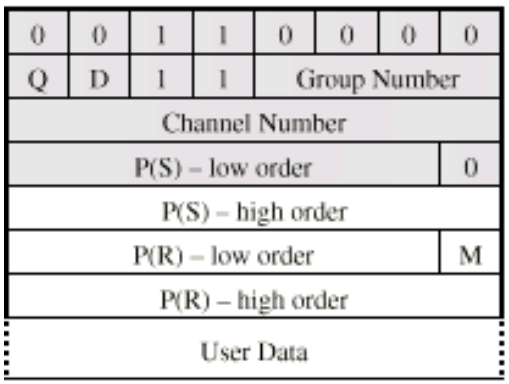
(d) Data packet with 7-bit sequence numbers



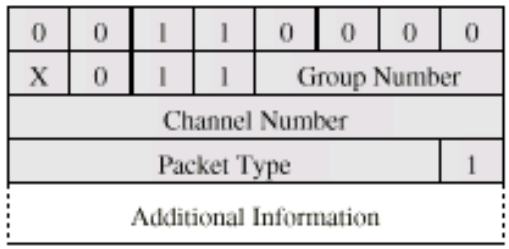
(e) Control packet for virtual calls with 7-bit sequence numbers



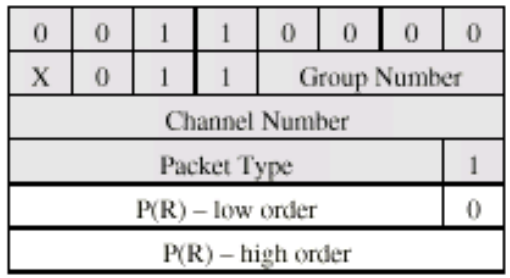
(f) RR, RNR, and REJ packets with 7-bit sequence numbers



(g) Data packet with 15-bit sequence numbers

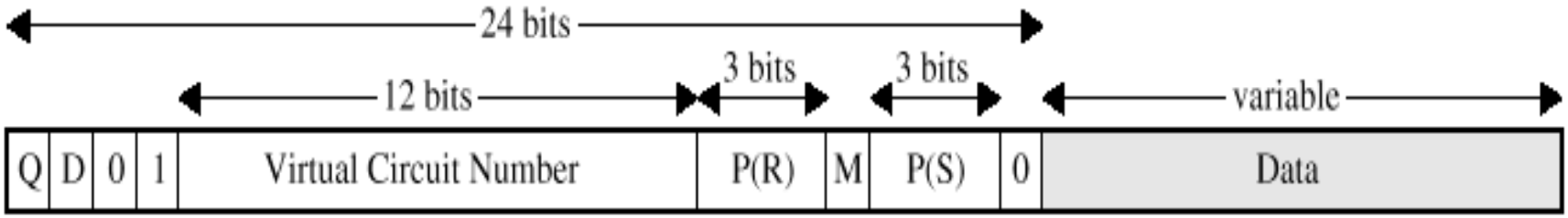


(h) Control packet for virtual calls with 15-bit sequence numbers

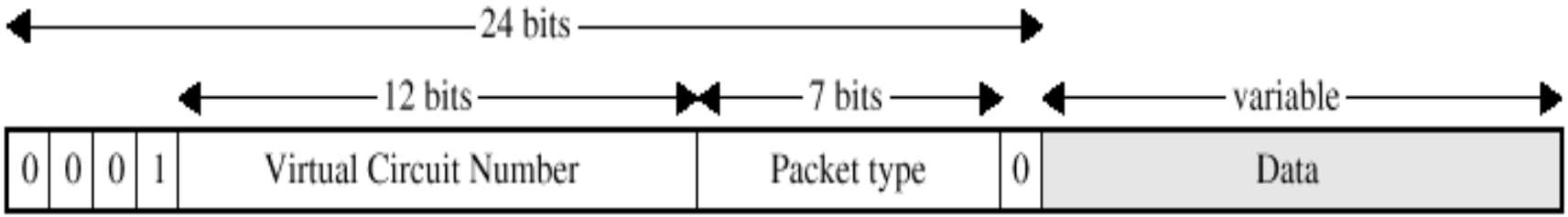


(i) RR, RNR, and REJ packets with 15-bit sequence numbers

X.25 Packet Formats



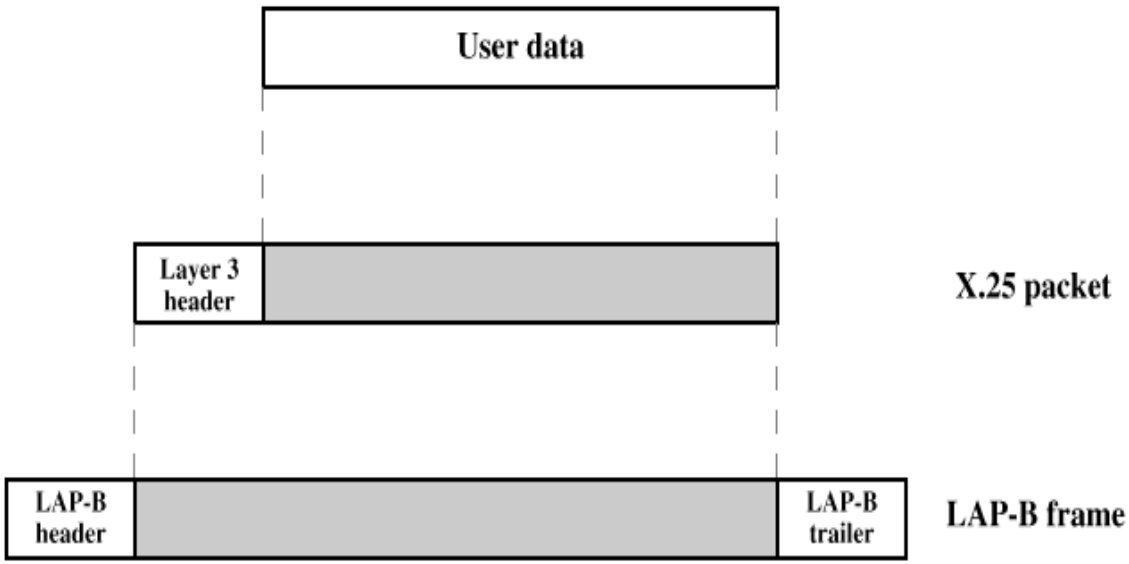
(a) Data Packet



(b) Control Packet

X.25 and Higher Layers

- X.25 is a data pump: there has to be some higher level that is making sense of the bits. There are standards for allowing certain applications to make use of X.25.



X.25 PAD

- For long-distance network links, a different type of equipment is frequently used, which is based on a standard named X.25. Many so-called Public Data Networks, like Tymnet in the U.S., or Datex-P in Germany, offer this service.
- X.25 requires special hardware, namely a Packet Assembler/Disassembler or *PAD*. X.25 defines a set of networking protocols of its own right, but is nevertheless frequently used to connect networks running TCP/IP and other protocols. Since IP packets cannot simply be mapped onto X.25 (and vice versa), they are simply encapsulated in X.25 packets and sent over the network.
- Frequently, radio amateurs use their equipment to network their computers; this is called *packet radio* or *ham radio*. The protocol used by ham radios is called AX.25, which was derived from X.25.

X.25 PAD

- Now, because most terminals do not speak X.25, a set of standards has been defined to specify the way a dumb terminal communicates with the public Network. These standards are known collectively as the Triple X - that is , standards X.3, X.29, and X.28. The terminal is connected to a PAD (Packet Assembler - Disassembler), the function of which is defined by X.3. The link between the terminal and the PAD is defined by X.28, and the link between the PAD and the network is defined by X.29.

Triple-X Standard for Non-X.25 Devices

- One disadvantage of X.25 is that it requires a computer or other intelligent device capable of creating and interpreting X.25 packets.
  - This leaves out dumb terminals or character-oriented devices still in use.
- A solution is a set of protocols defined by the ITU.
  - The X.3 packet assemble/disassembler (PAD)
  - The X.28 PAD-Terminal Interface
  - The X.29 PAD-Host Interface

The X.3 PAD Protocol

- The PAD replaces the DCE as a network interface.
  - It accepts characters from character-oriented devices and assembles them into packets before sending them onto the network.
  - Similarly, it can receive packets from the network, disassemble them, and transmit the data as a character stream to the terminal.

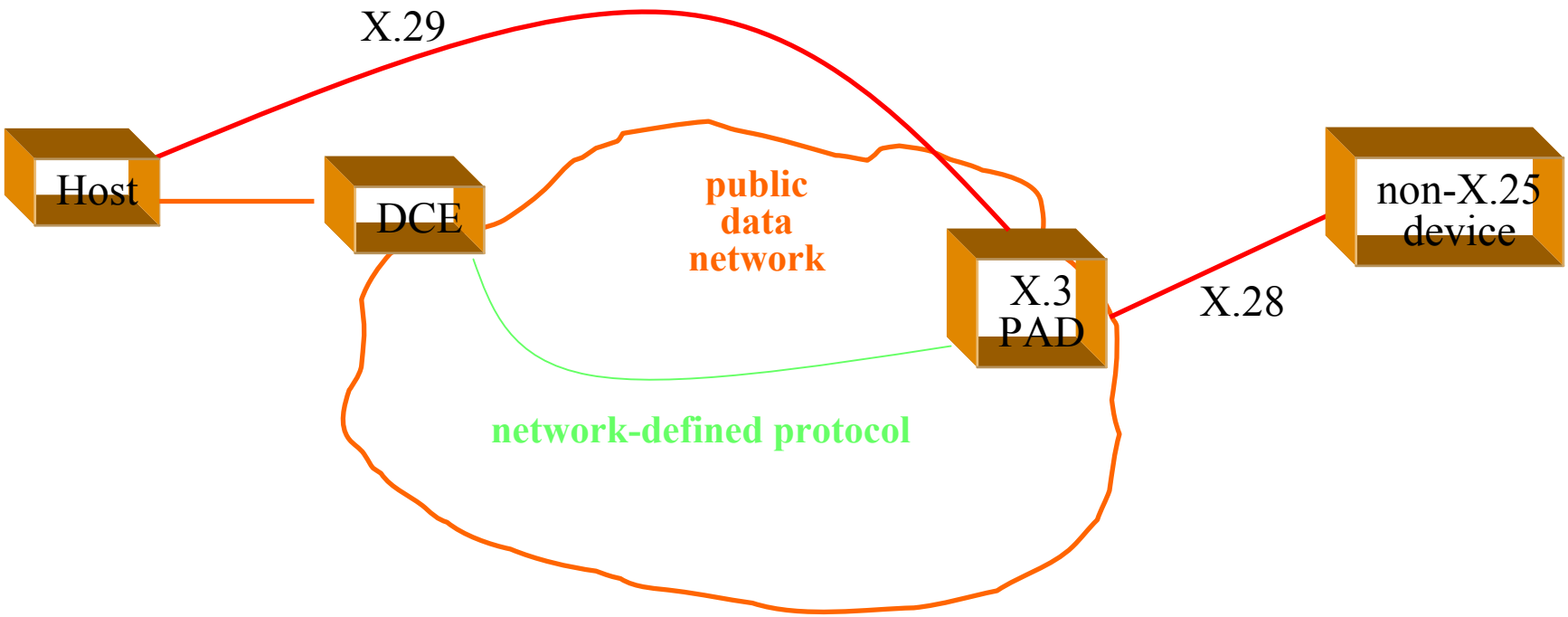
The X.28 Protocol

- The X.28 protocol defines the communication between the PAD and the character-oriented device.
  - e.g., a user can enter a command to request a virtual call to a remote host.
  - The command goes to the PAD, which must create an X.25 call request packet and send it over the network.
  - When the call accepted packet returns, the PAD returns an acknowledgment to the user.

The X.29 Protocol

- The X.29 protocol defines how the PAD and a remote host communicate and specifies allowable commands and acknowledgments.
  - Using X.29, the remote host can change PAD parameters.

Triple-X Protocols



X.25 Usage Fee Structure

- X.25 gives you a **virtual high quality digital network** at low cost. It is economical for the same reason that it is usually cheaper to use the mail than to run your own postal service: there are tremendous savings to be made if multiple parties share the same infrastructure.
- In most parts of the world, X.25 is paid for by a monthly connect fee plus packet charges. There is usually no holding charge, making X.25 ideal for organizations that need to be on line all the time. Another useful feature is speed matching: because of the store-and-forward nature of Packet Switching, plus excellent flow control, DTEs do not have to use the same line speed. So you can have, for instance, a host connected at 56kbps communicating with numerous remote sites connected with cheaper 19.2kbps lines.
- X.25 has been around since the mid 1970's and so is pretty well **debugged and stable**. There are literally no data errors on modern X.25 networks.

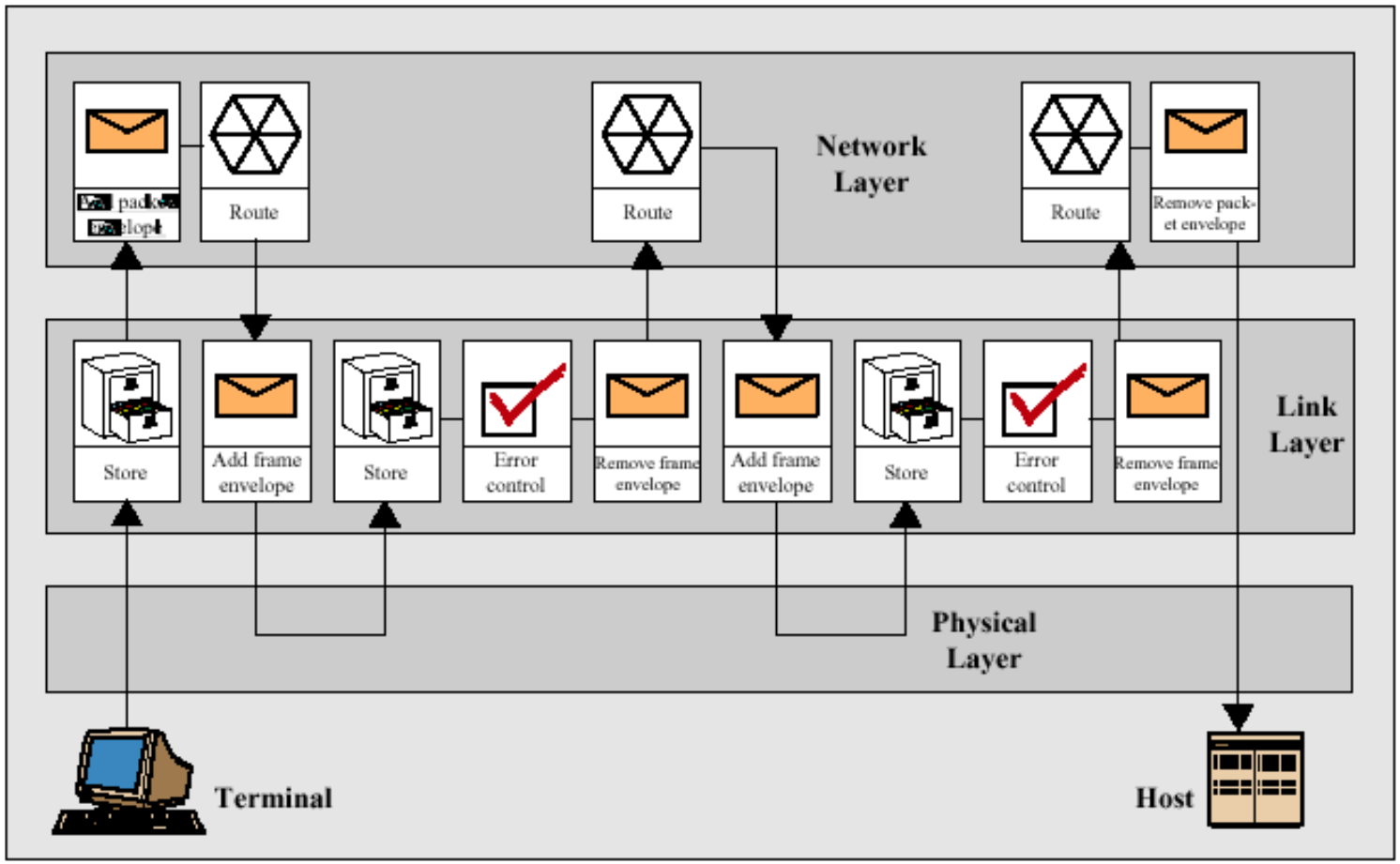
X.25 Drawbacks - 1

- X.25 does have some drawbacks. There is an inherent delay caused by the store-and-forward mechanism. On most single networks the turn-around delay is about 0.6 seconds. This has no effect on large block transfers, but in flip-flop types of transmissions the delay can be very noticeable.
- Frame Relay (also called Fast Packet Switching) does not store and forward, but simply switches to the destination part way through the frame, reducing the transmission delay considerably.

X.25 Drawbacks - 2

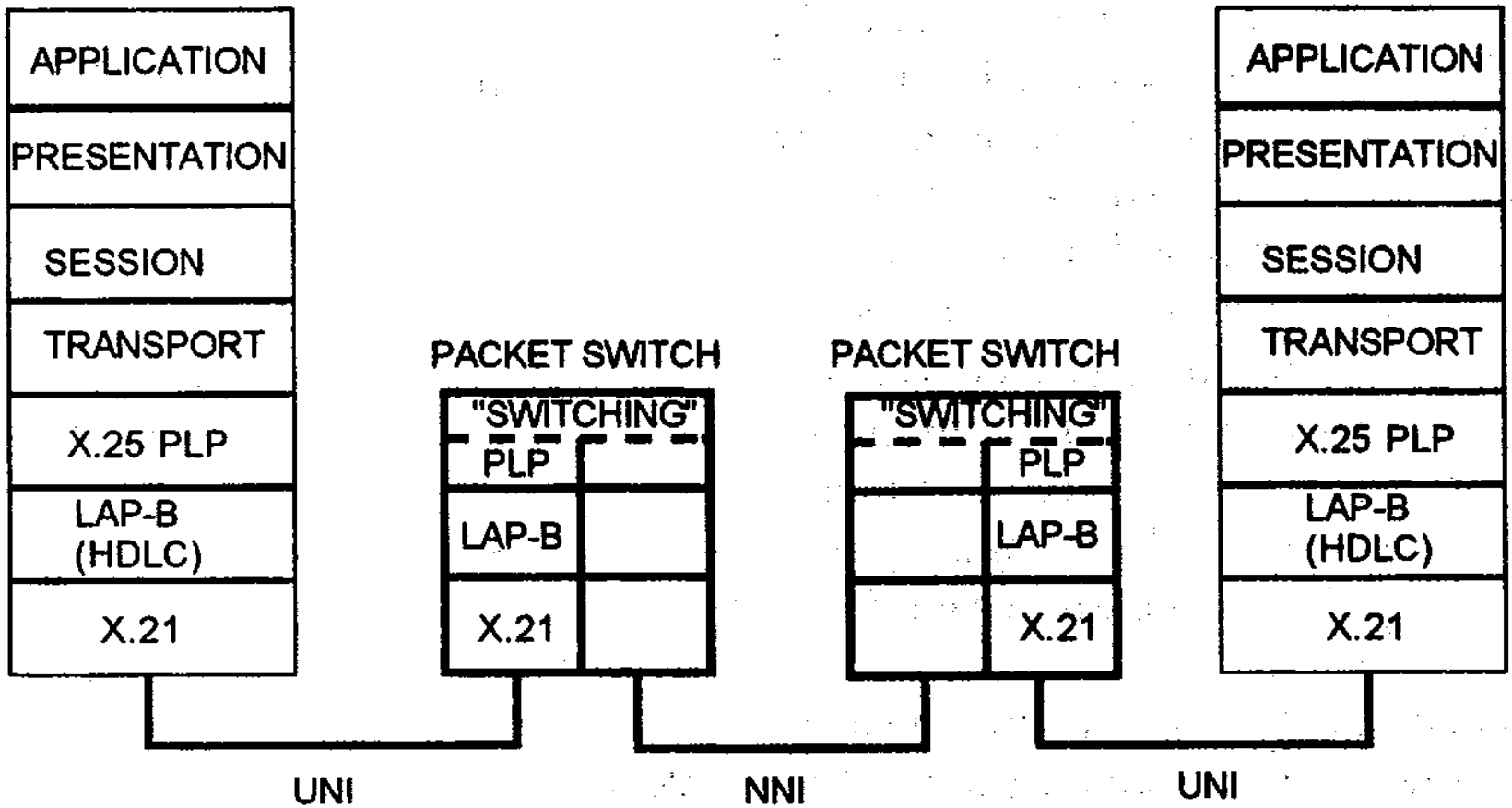
- Another problem for the networks is a large requirement for buffering to support the store-and-forward data transfer. One of the reasons that Frame Relay is so cost effective is that storage requirements are minimal.

X.25 Data Flow

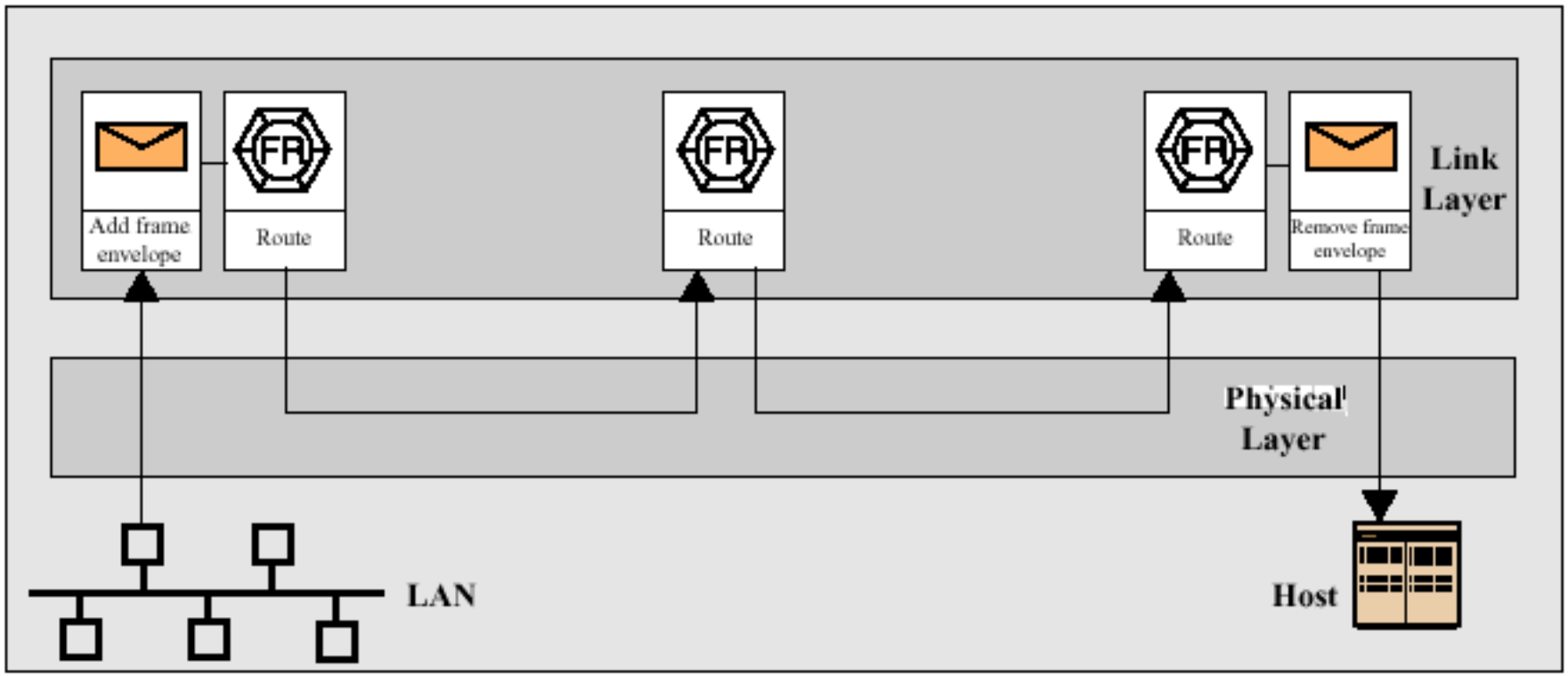


(a) Packet switching

X.25 Packet-Switched Network

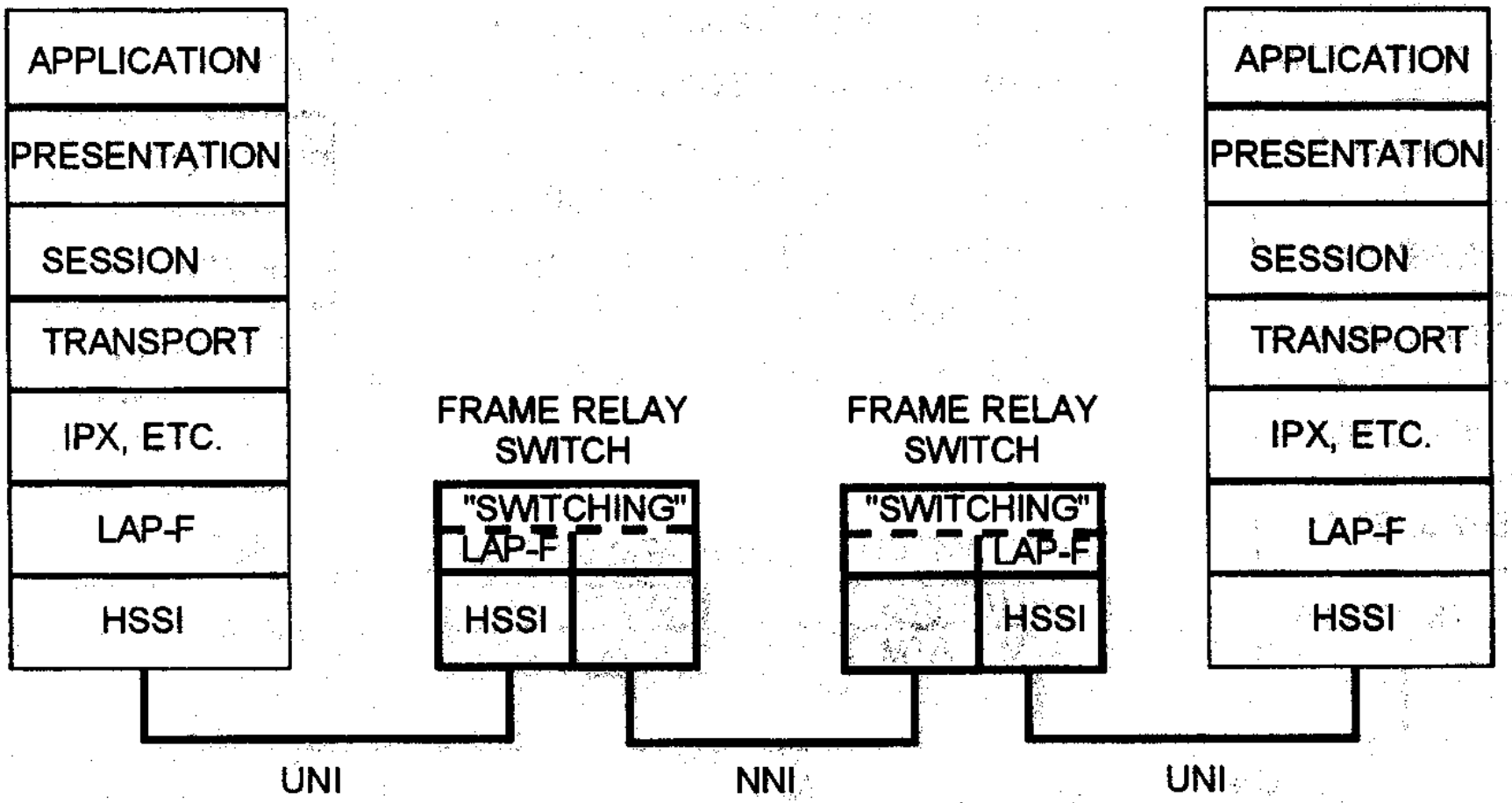


Frame Relay Data Flow



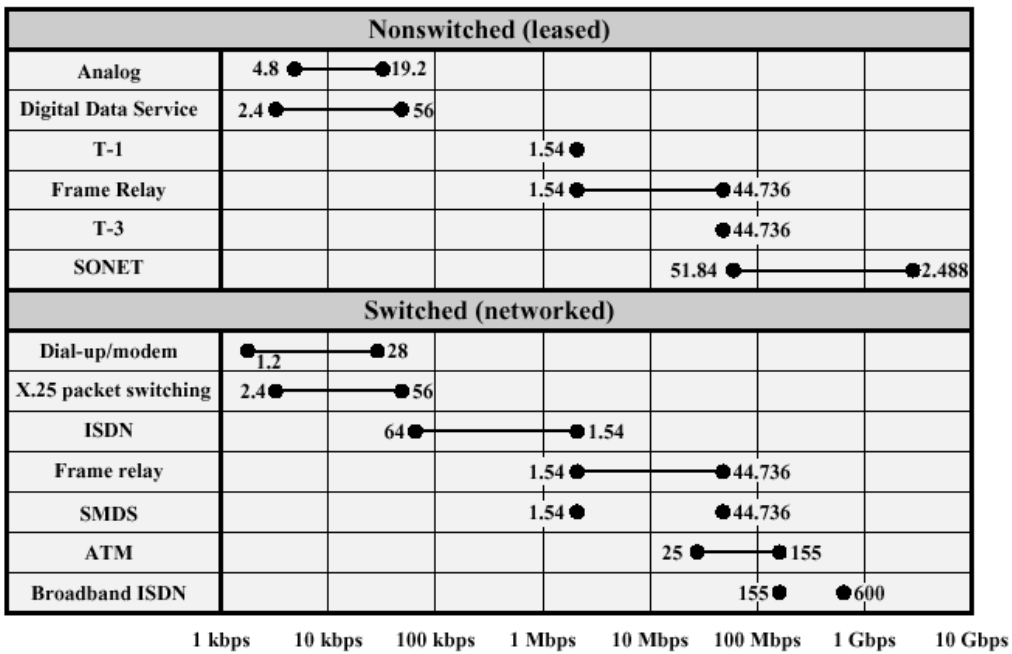
(b) Frame relay

Frame Relay Network



X.25 vs. Others

Service	Link Speed	Equipment Needs
X.25	300 bps to 56 Kbps	Interface Card
Frame Relay	56 Kbps to 1.544 Mbps	Interface Card CSU/DSU
ISDN	128 Kbps to 1.544 Mbps	Modem/Router
ATM	100 to 2.48 Gbps	Interface Card CSU/DSU



X.25 is a Traditional Low Speed WAN Technology

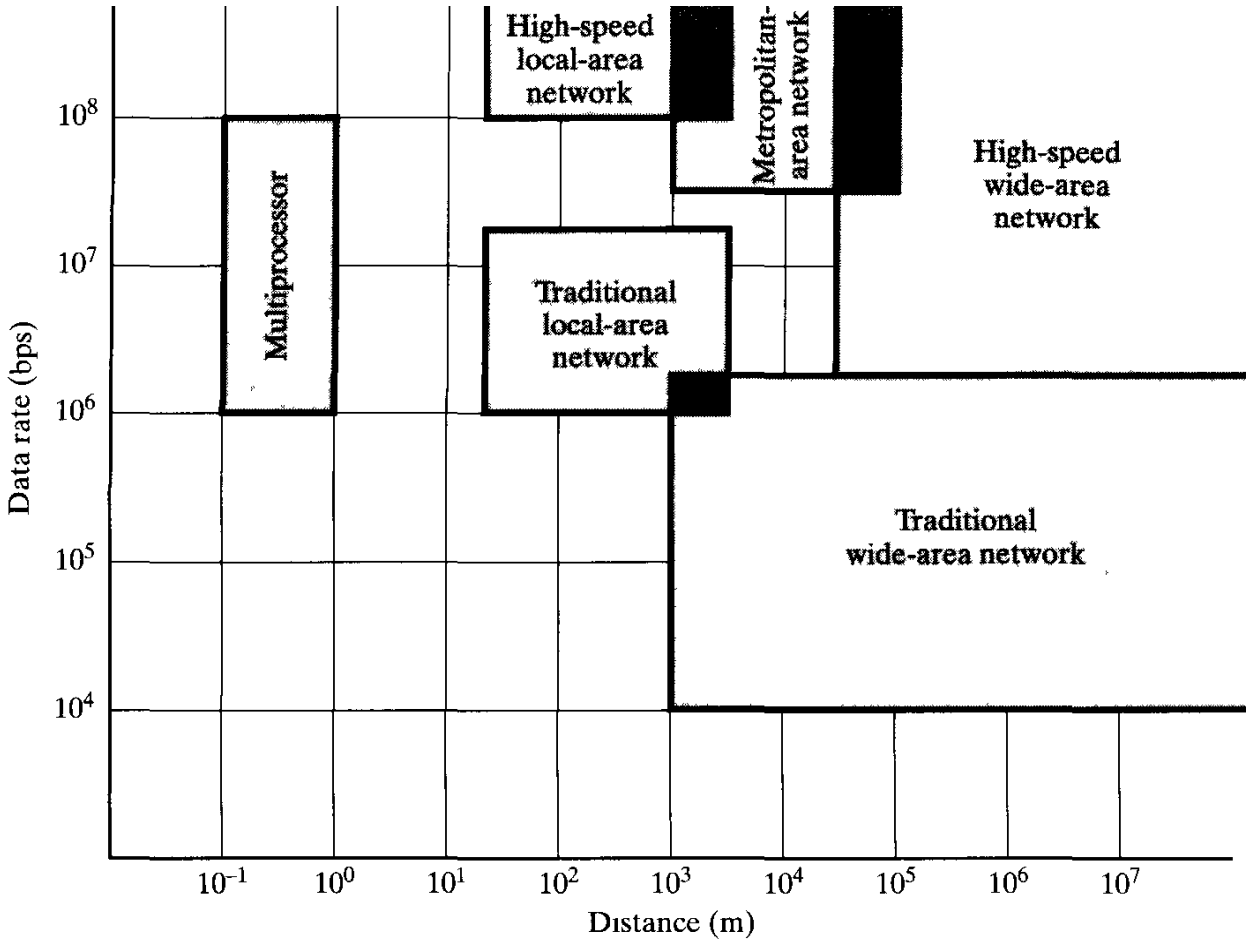


FIGURE 7.1 Comparison of Multiprocessor Systems, LANs, MANs, and WANs