X.25

CCITT´s Packet Switching Technology

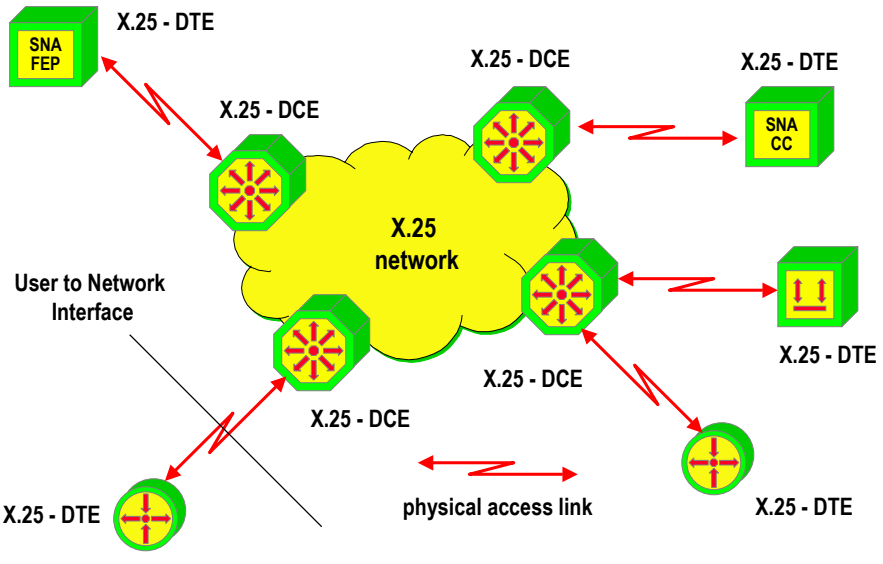
Agenda

- **Overview, Principles and Standards**
- **X.25 Data Link Layer**
- **X.25 Network Layer**
  - Services and Packet Types
  - Call Setup and Release
  - Data Transfer and Flow Control
  - Reset and Restart
- **X.25 Packet Format**
- **X.25 PAD**

What is X.25?

- **packet switching technology**
  - based on store-and-forward of packets
  - connection oriented
- **interface definition between user and network equipment**
  - X.25 - DTE (e.g. router) <–> X.25 - DCE (packet switch)
- **wide area network service**
  - based on virtual circuit technique
- **operation within X.25 network cloud**
  - switch to switch communication not standardized
  - vendor specific implementation

X.25 Topology

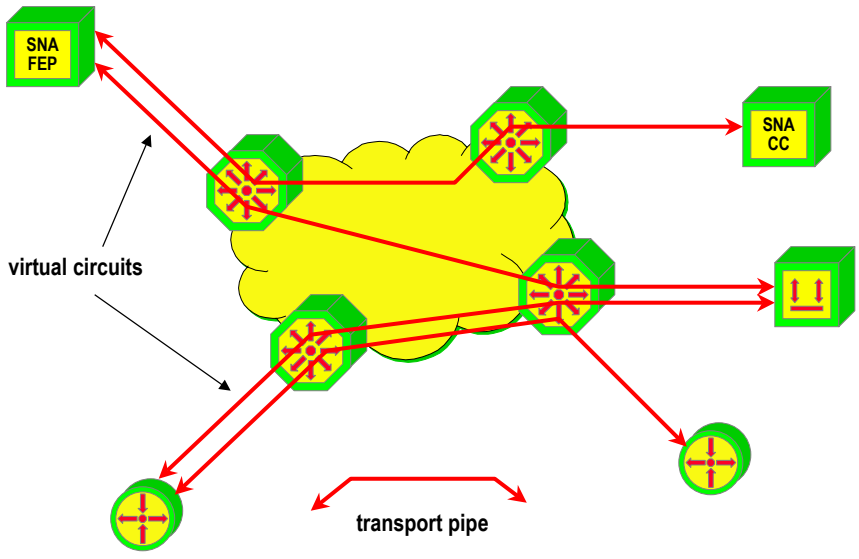


X.25 Virtual Circuits/LCN

- **virtual circuit technique**
  - for statistically multiplexing many logical data conversations over a single physical transmission link
  - end systems (X.25-DTE) use virtual circuits for delivering data to the X.25 network and vice versa
  - virtual circuits appear to end systems as transparent transport pipes (logical point-to-point connections)
- **virtual circuits (VCs) are identified using LCN numbers**
  - logical channel number (LCN)
  - LCN are of local significance only

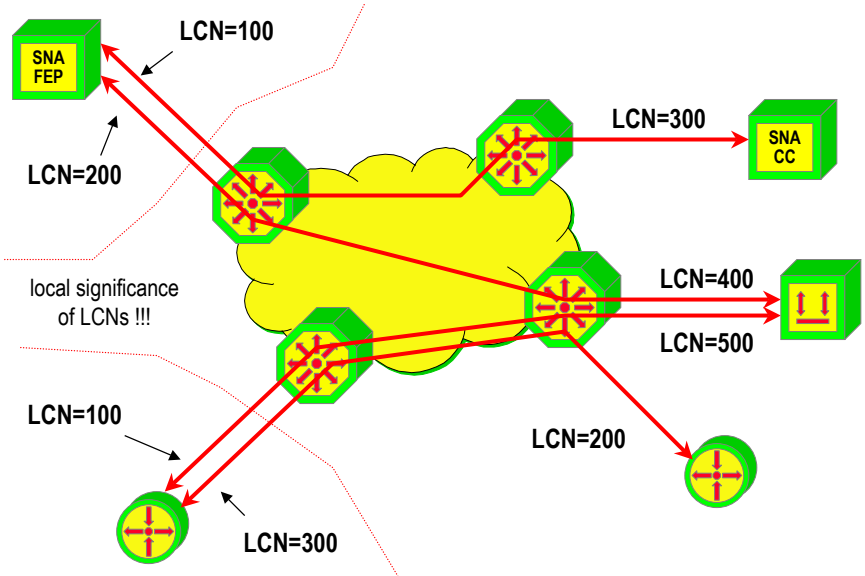
 X.25, v4.3 5

X.25 Virtual Circuits



 X.25, v4.3 6

Logical Channel Number (LCN)

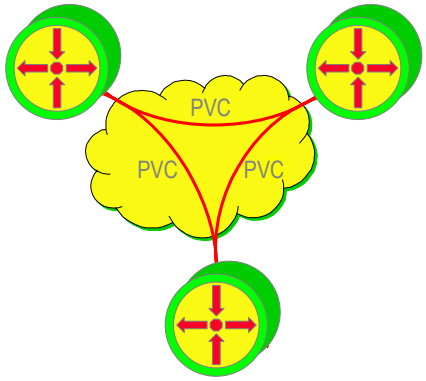


Types of Virtual Circuits

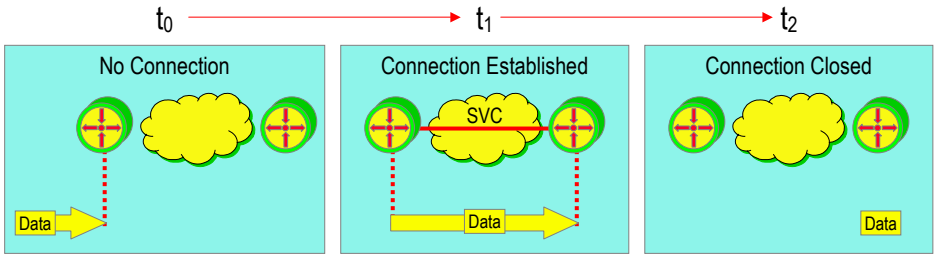
- **two kinds of virtual circuits**
  - permanent virtual circuits (PVC) established in advance by service provider
  - switched virtual circuits (SVC) established on demand by user through signaling procedure

Permanent Virtual Circuit (PVC)

- static connection between two end devices
- functionally equivalent to dedicated leased lines
- but remember
  - store and forward technology
  - variable delays



Switched Virtual Circuit (SVC)

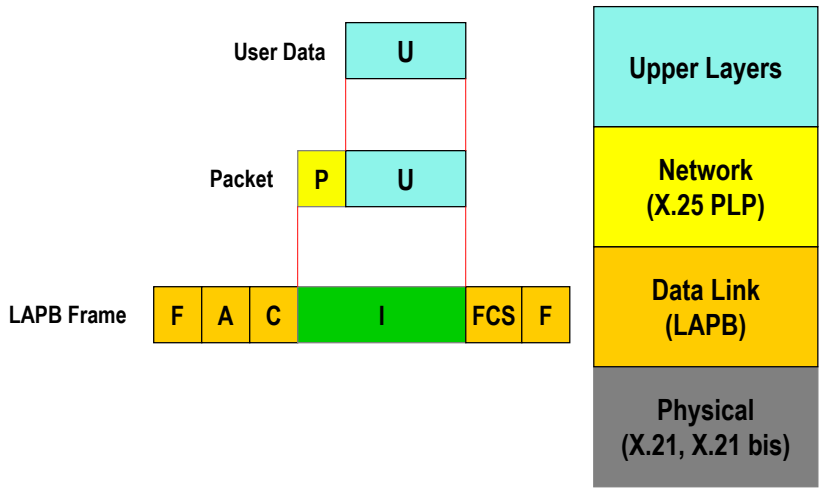


- dynamic connection setup and tear down between two end devices
- similar to dial up circuits in that they provide bandwidth on demand

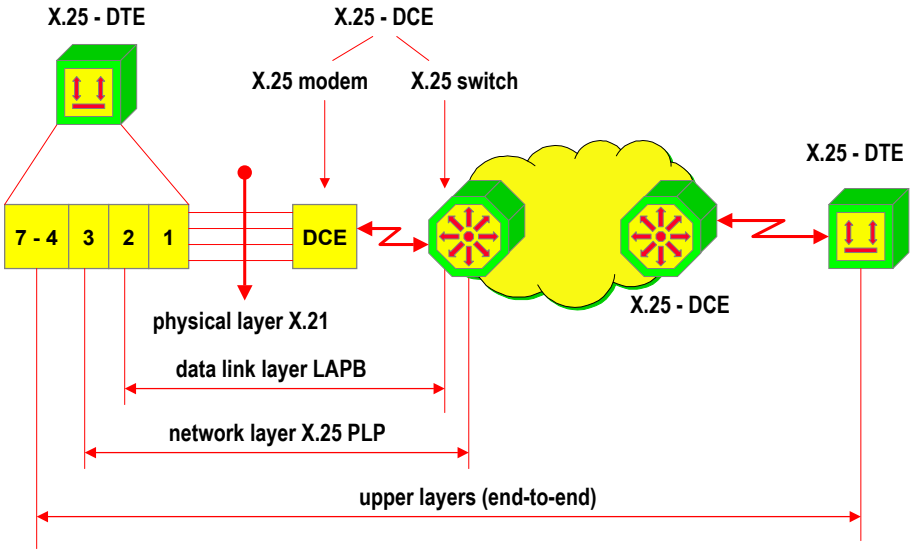
Roots of X.25

- **originally defined by CCITT**
  - as an interface between user equipment and public switched data network
  - three layers covered
    - X.21 (physical layer)
    - LAPB (data link layer)
    - X.25 (network layer)
  - different versions:
    - four years cycle
    - 1980 (yellow books), 1984 (red books), 1988 (blue book), ...
- **X.25 definitions were expanded by ISO**
  - for provisioning the Connection Mode Network Service (layer 3) in OSI based networks

X.25 Layers (CCITT)



X.25 Interface (CCITT)



 X.25, v4.3 13

X.25 and related Standards

- **X.25 specifies layer 1-3 protocol stack between**
  - X.25-DTE and X.25-DCE
  - interface specification
  - only a point-to-point protocol
  - no end-to-end protocol (DTE to DTE)
- **physical layer (1) standards**
  - CCITT X.21, X.21bis (based on V.24)
- **data link layer (2) standards**
  - ISO 7776 LAPB
  - ISO 8802-2 Logical Link Control (LANs)
  - ITU-T Q.921 LAPD (X.25 over ISDN-D Channel)

 X.25, v4.3 14

X.25 and related Standards

- **network layer (3) standards**
  - CCITT X.25 L3 (ISO 8208 Packet Level Protocol PLP)
  - CCITT X.121 X.25 Addressing
  - ISO 8348 Network Service Definition
    - Connection Mode Network Service
      OSI use of X.25, Quality of Service QoS
    - Addendum1: NSAP-address
    - Addendum2: Connectionless Mode Network Service
      (-> ISO 8473 CLNP Connectionless Network Layer Protocol)
  - ISO 8880-2 Provisioning and Support of the Connection Mode Network Service
    - ISO 8881 X.25 PLP over LANs
    - ISO 9574 X.25 PLP over ISDN

X.25 Facts

- **remember:**
  - X.25 standards defines communication between DTE and DCE only
  - operation (e.g. routing) within network not defined
  - only sequencing must be guaranteed
  - X.25 uses statistical multiplexing
- **X.25 technology was developed for low quality, low speed lines**
  - use error recovery and flow control on layer 2 to control transmission of frames over physical line
  - use flow control and optionally error recovery on layer 3 to control transmission of packets over a virtual circuit

Why X.25?

- **it is a widely used interface standard**
  - off-the-shelf hardware and software readily available
  - mature technology (long experience)
- **X.25 network services worldwide available**
- **because of error recovery**
  - X.25 can be used on low quality lines
  - X.25 provides a reliable transport pipe
- **because of flow control**
  - X.25 network can control and even stop traffic from the user (DTE) in order to prevent congestion in the network
- **provides high support of accountability**

Agenda

- **Overview, Principles and Standards**
- **X.25 Data Link Layer**
- **X.25 Network Layer**
  - Services and Packet Types
  - Call Setup and Release
  - Data Transfer and Flow Control
  - Reset and Restart
- **X.25 Packet Format**
- **X.25 PAD**

X.25 Data Link Layer

- **Link Access Procedure Balanced (LAPB)**
  - subset of HDLC
    - connection oriented service
    - ABM plus functional extensions (BA 2,8 or 2,8,10)
    - both stations are combined stations
      - can transmit commands and responses at any time
      - commands and responses can be distinguished using address field
    - specific addresses used
      - subscriber DTE must be binary 00000011
      - network node DCE must be binary 00000001
  - X.25 packets are carried within information field of LAPB I-frame
    - LAPB and X.25 use independent sequencing

LAPB and HDLC

1. for switched circuits
   XID << ADD >> XID
   RD
2. for 2-way simultaneous
   REJ << ADD >> REJ
3. for single frame retrans.
   SREJ<< ADD >>SREJ
4. for information
   UI << ADD >> UI
5. for initialization
   SIM << ADD >> RIM
6. for group polling
   UP << ADD

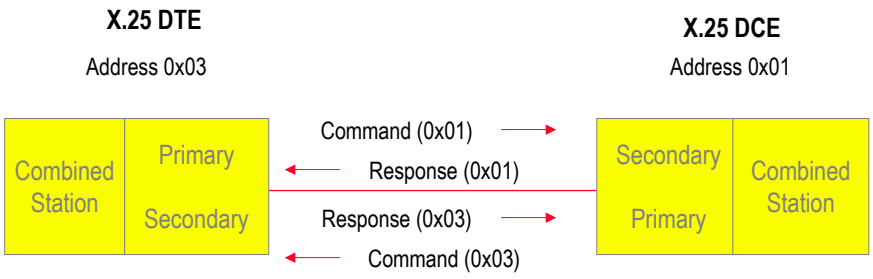
7. extended addressing
8. delete "Response" I frames
9. delete "Command" I frames
10. extended sequence numbering
11. for mode reset
    RESET << ADD
12. Data link test
    TEST << ADD >> TEST

13. request disconnect
    ADD >> RD
14. 32 bit FCS

Balanced Asynchronous (BA)

Primary	Secondary
Command	Response
I RR RNR SABM DISC	I RR RNR UA DM FRMR

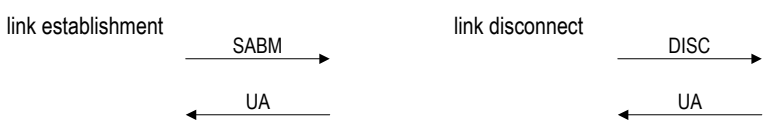
LAPB Addressing



 X.25, v4.3 21

LAPB and the Control Field

Format	Encoding								Command	Response
	1	2	3	4	5	6	7	8		
Information	0	-	N(S)	-		-	N(R)	-	I	I
Supervisory	1	0	0	0	*	-	N(R)	-	RR	RR
	1	0	0	1	*	-	N(R)	-	REJ	REJ
	1	0	1	0	*	-	N(R)	-	RNR	RNR
Unnumbered	1	1	0	0	P	0	1	0	DISC	
	1	1	0	0	F	1	1	0		UA
	1	1	1	0	F	0	0	1		FRMR
	1	1	1	1	F	0	0	0		DM
	1	1	1	1	P	1	0	0	SABM	



 X.25, v4.3 22

Usage of the P/F bit

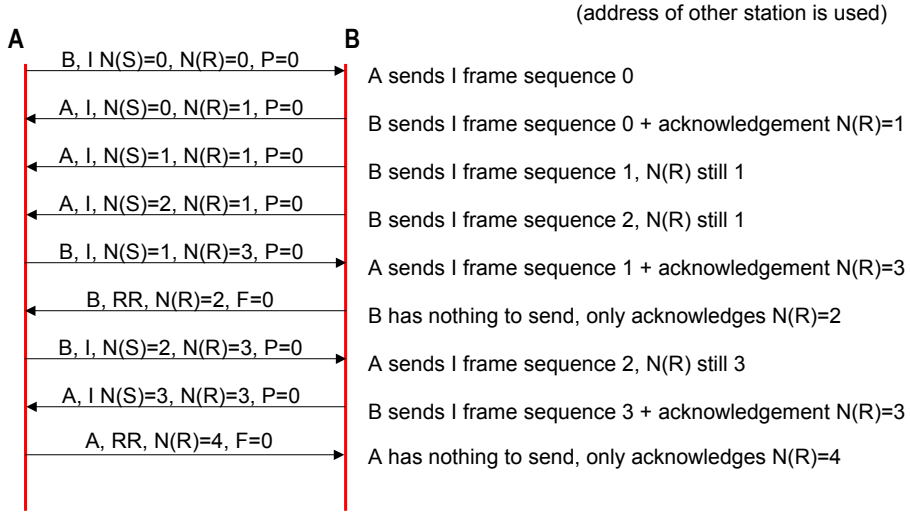
- **specific procedures with LAPB**
  - station receiving SABM/SABME, DISC, Supervisory or I frame with P set must set F in the next response
  - P = 1 is used to request a status response only
- **conventions**

command sent with P bit set:	response required with F bit set:
SABM/SABME, DISC	UA, DM
I (information transfer)	RR, REJ, RNR, FRMR
I (disconnect mode)	DM
supervisory (RR, RNR, REJ)	RR, REJ, RNR, FRMR

LAPB Example

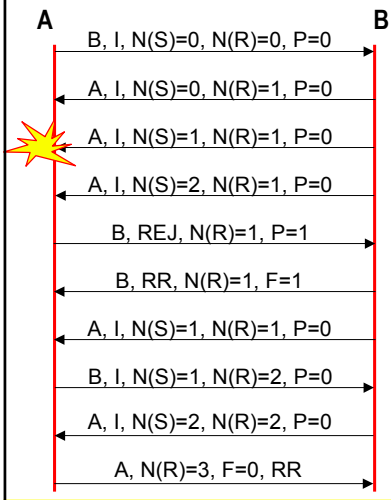
- **normal data transfer**

note: all I frames are commands
(address of other station is used)



LAPB Example

- **error recovery with reject**



A sends I frame sequence 0

B sends I frame sequence 0 + acknowledgement N(R)=1

B sends I frame sequence 1, N(R) still 1

B sends I frame sequence 2, N(R) still 1

A sends reject with N(R)=1 and P set - negative ack.

B has to clear the error condition, sending RR and F set

B retransmits sequence 1

A sends I frame 1 + acknowledgement N(R)=2

B retransmits sequence 2

A has nothing to send, acknowledges with N(R)=3

Agenda

- **Overview, Principles and Standards**
- **X.25 Data Link Layer**
- **X.25 Network Layer**
  - Services and Packet Types
  - Call Setup and Release
  - Data Transfer and Flow Control
  - Reset and Restart
- **X.25 Packet Format**
- **X.25 PAD**

X.25 Network Layer

- **X.25 offers virtual circuit services**
- **virtual circuits are identified by logical channel numbers (LCN)**
  - LCN value range: 0 - 4095 (0 reserved for diagnostics)
  - distinguish virtual circuits on one physical link
  - local between DTE and DCE
- **one physical link may contain up to 4095 logical channels**
  - permanent virtual circuit - PVC
    - predefined channel
  - switched virtual circuit
    - established using call setup procedures

X.25 Network

- **virtual circuit services are responsible for**
  - establishing and clearing of virtual circuits
    - call setup and release
    - necessary for SVC only
  - transfer of data packets
  - transfer of precedence data packets
    - interrupt data
  - flow control
  - reset of virtual circuit(s)
- **necessary protocol procedures are implemented using different types of X.25 packets**

X.25 Packet Types

Packet Type		Service	
From DCE to DTE	From DTE to DCE	SVC	PVC
	Call Setup and Clearing		
Incoming Call	Call Request	X	
Call Connected	Call Accepted	X	
Clear Indication	Clear Request	X	
DCE Clear Confirmation	DTE Clear Confirmation	X	
	Data and Interrupt		
DCE Data	DTE Data	X	X
DCE Interrupt	DTE Interrupt	X	X
DCE Interrupt Confirmation	DTE Interrupt Confirmation	X	X
	Flow Control		
DCE RR	DTE RR	X	X
DCE RNR	DTE RNR	X	X
	DTE REJ	X	X

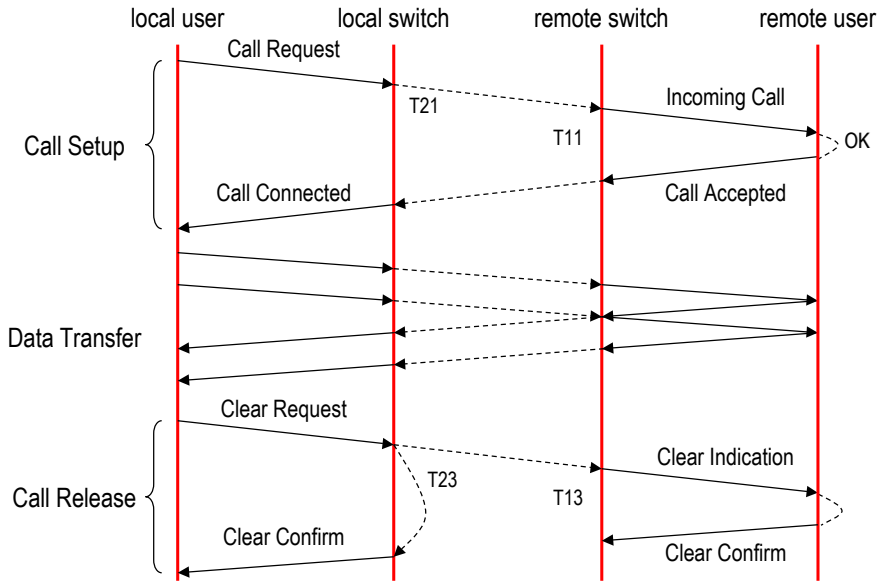
X.25 Packet Types (continued)

Packet Type		Service	
From DCE to DTE	From DTE to DCE	SVC	PVC
	Reset		
Reset Indication	Reset Request	X	X
DCE Reset Confirmation	DTE Reset Confirmation	X	X
	Restart		
Restart Indication	Restart Request	X	X
DCE Restart Confirmation	DTE Restart Confirmation	X	X
	Diagnostic		
Diagnostic		X	X
	Registration		
Registration Confirmation	Registration Request	X	X

Agenda

- **Overview, Principles and Standards**
- **X.25 Data Link Layer**
- **X.25 Network Layer**
  - Services and Packet Types
  - Call Setup and Release
  - Data Transfer and Flow Control
  - Reset and Restart
- **X.25 Packet Format**
- **X.25 PAD**

Call Setup and Call Release



Call Setup, LCN handling 1

- **local X.25-DTE**
  - selects a LCN number from the pool of free LCN numbers to identify both the call request and the virtual circuit
  - sends Call Request packet to the local switch
- **Call Request contains**
  - selected LCN number
  - address of calling/called station (remote X.25-DTE)
    - usually X.121 addresses are used
  - facilities for negotiation of network parameters
    - between user and network or user and remote user

X.25 Facilities

- **some facilities must be provided by all X.25 networks**
  - essential facilities
- **essential facilities are**
  - maximum packet size
  - window size
  - modulo 8/128
  - throughput class
    - 75, 150, 300, 600, 1200, 2400, 4800, 9600, 19200, 48000 bit/s
  - transit delay
- **essential facilities have default values**

X.25 Facilities

- **other facilities may or may not be provided by a X.25 service**
  - optional facilities
- **all facilities, if provided, have default values but can either**
  - be negotiated between user and service provider in advance or by on-line registration
  - or during call setup for individual switched circuits

X.25 Facilities

- **optional facilities**
  - incoming/outgoing calls barred
    - prevents incoming calls to be presented to DTE
    - prevents outgoing calls to be accepted by DCE
  - closed user groups
    - allows privacy in a public network service
  - reverse charging, reverse charging acceptance
  - hunt groups
    - distributes incoming calls across a designated group of DTE/DCE interfaces
  - call redirection, call redirect notification

X.25 Facilities

- **optional facilities (cont.)**
  - fast select, fast select acceptance
    - Call Request/ Incoming Call packet carries user data (up to 128 octets) to remote DTE
    - Call Accepted/Call Connected packet carries user data from remote DTE to local DTE
    - immediate clear option
    - used for short transactions
  - transit delay selection and indication
  - online facility registration
    - status of supported facilities can be checked and changed by DTE using Registration Request/Confirmation packets
  - packet retransmission
    - REJ packet support

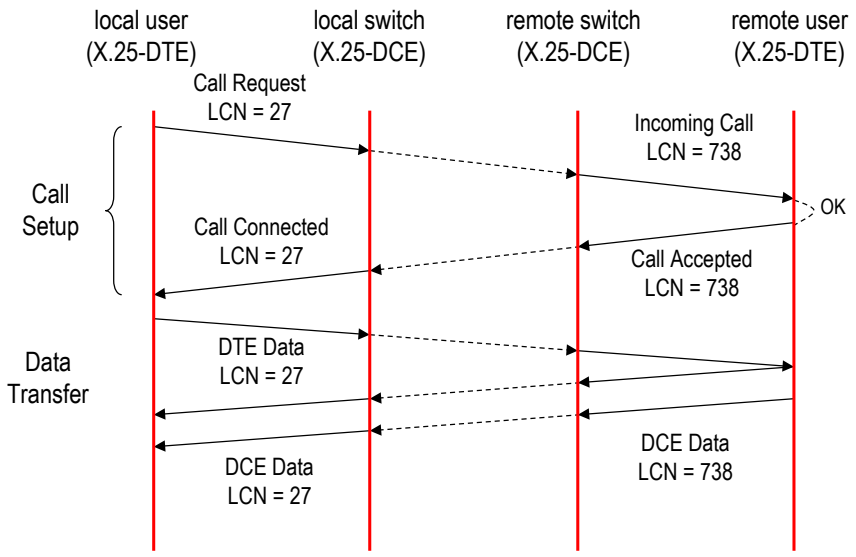
Call Setup, LCN handling 2

- **Call Request packet is delivered by network to remote switch**
  - using vendor proprietary transport method
- **remote switch**
  - again selects a LCN number from the pool of free LCN numbers to identify a call request
  - normally LCN number will be different
  - sends Incoming Call packet to remote X.25-DTE
- **remote X.25-DTE**
  - accepts incoming call
  - sends Call Accepted packet to switch

Call Setup, LCN handling 3

- **Call Accepted packet is delivered by network to local switch**
- **local switch**
  - sends Call Connected packet with local LCN to local X.25-DTE
- **now local and remote X.25-DTE**
  - are ready to use virtual circuit for data transfer
- **local LCN numbers on both sides are used for data packets**
  - mapping is done by X.25 network

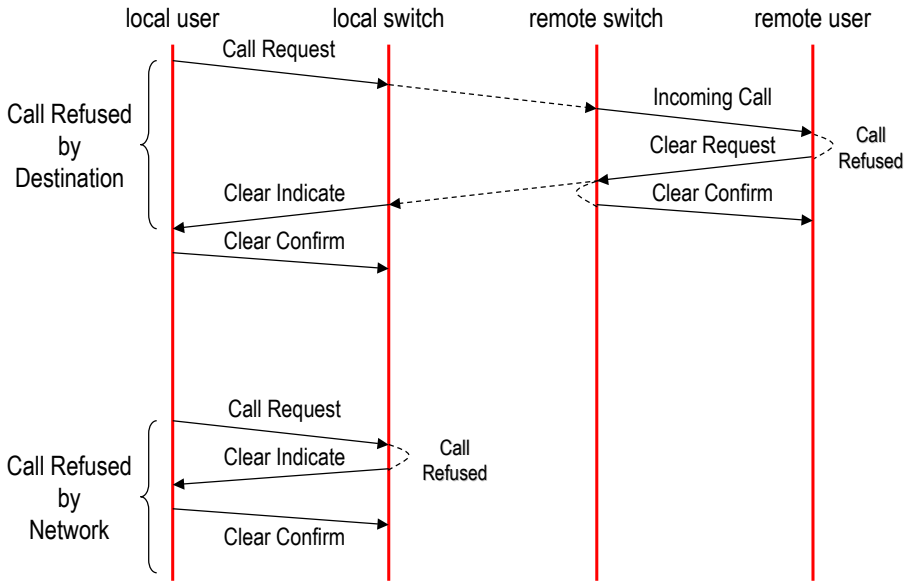
LCN Handling



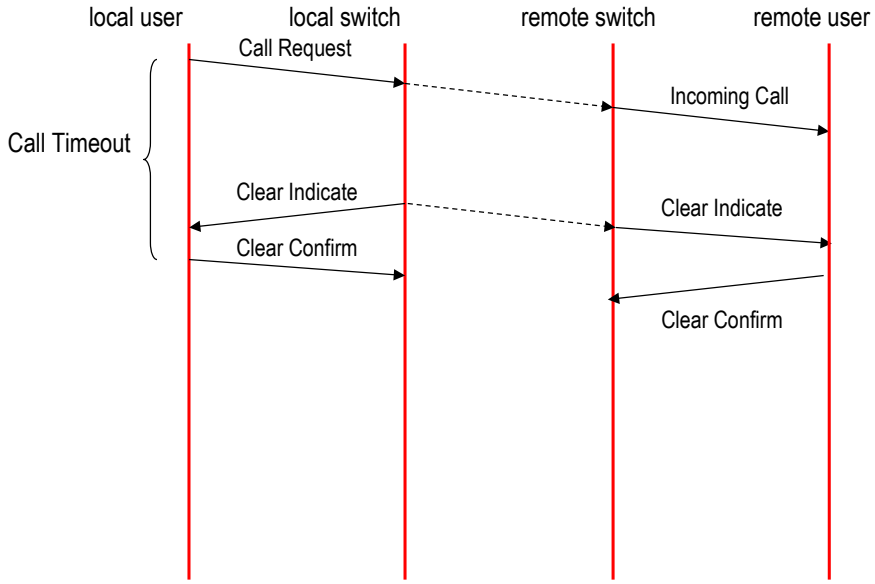
Call Refusal and Release

- **calls could be denied**
  - by remote X.25-DTE (Clear Request packet is sent)
  - by network itself (Clear Indication packet is sent)
- **Clear Indication packet**
  - contains always reason for clearing
    - e.g. clearing done by remote station or network, non available facilities, network error, access closed, etc.
- **both sides can tear down a virtual circuit**
  - using Clear Request packets
  - other side is informed by Clear Indication packet
- **Call Release finished**
  - when Clear Confirmation packets are received

Call Refusal



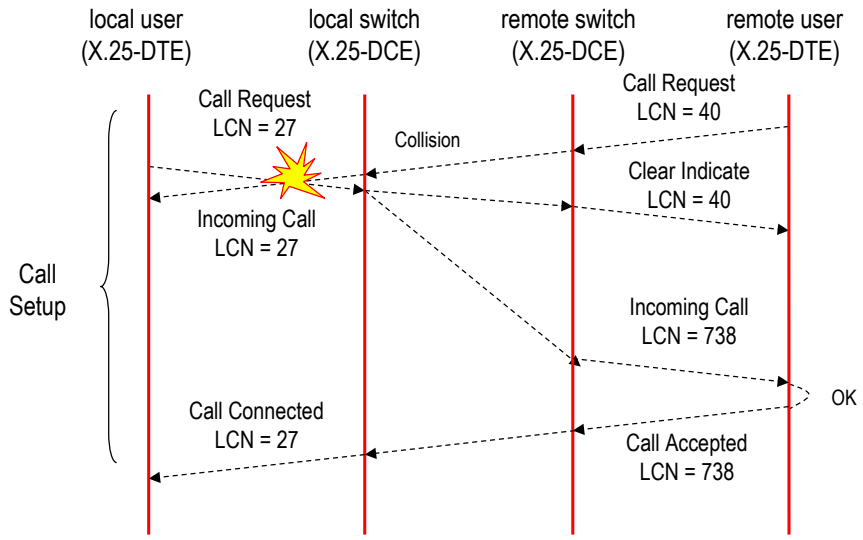
Call Timeout



Call Collision

- **Call Request packet contains**
  - LCN number selected by originating X.25-DTE
- **Incoming Call packet contains**
  - LCN number selected by destination X.25-DCE
- **if call setup is interleaved with incoming call**
  - collision of LCN numbers is possible
- **collision solved**
  - call of originating X.25-DTE will be continued
  - incoming call will be refused by Clear Indication on the other side

Call Collision



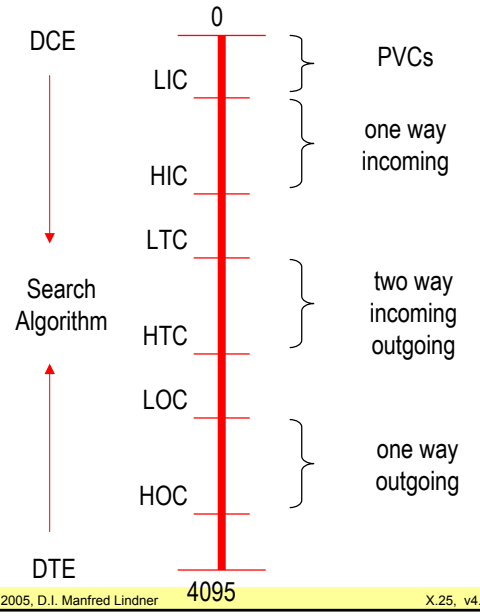
 X.25, v4.3 45

LCN Ranges to avoid Call Collision

- **in order to minimize collision**
  - incoming calls use low LCN number
  - outgoing calls use high LCN Number
- **LCN values can be divided into four ranges**
  - PVCs
  - one way incoming (LIC – HOC)
  - one way outgoing (LOC – HOC)
  - two way (LTC – HTC)
- **LCN = 0 reserved**
  - diagnostics
  - restart

 X.25, v4.3 46

LCN Ranges to avoid Call Collision



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

Agenda

- **Overview, Principles and Standards**
- **X.25 Data Link Layer**
- **X.25 Network Layer**
  - Services and Packet Types
  - Call Setup and Release
  - Data Transfer and Flow Control
  - Reset and Restart
- **X.25 Packet Format**
- **X.25 PAD**

Data Transfer

- **Data Packets**
  - ContinousRQ method with sequencing and piggyback acknowledgement
  - very similar to HDLC
    - P(S) and P(R) instead of N(S) and N(R)
  - range of sequence numbers
    - 0-7 or 0-127 (extended)
  - sequence numbers and windowing are used mainly for flow control reasons and not for error recovery
  - remember:
    - X.25 packets are transmitted in LAPB I-frames
    - a loss of an I-frame and hence loss of X.25 packet will be already covered by error recovery method of LAPB

Flow Control

- **X.25 flow control**
  - is based on windowing and RR, RNR
    - delay of of acknowledgement (piggybacked or with RR) is used to close the send window at the transmitter side
    - RNR is used to stop the transmitter when send window is open
    - RR, RNR do not cause retransmission of packets
  - is done for individual virtual circuits
    - note: LAPB can handle flow control on physical link only
- **optional error recovery**
  - optional GoBackN with DTE REJ Control Packet
    - usage of REJ can be negotiated during facility exchange
    - makes sense in case end-to-end acknowledgement is used (D-bit = 1; will be covered later)

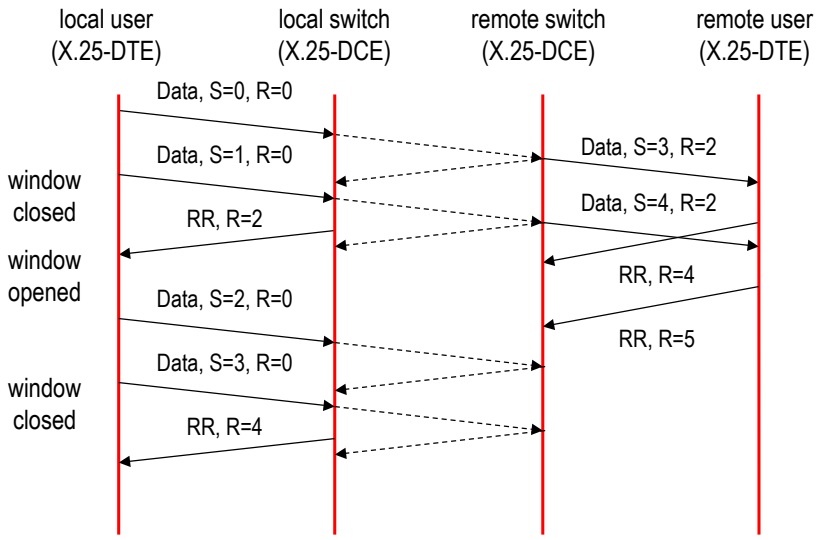
Window Size

- **window size defines maximum number of unacknowledged packets**
- **window sizes and maximum packet sizes**
  - either are agreed in advance between user and network provider or could be negotiated during call setup for individual SVCs
  - maximum window size depends on modulo used for sequencing
    - modulo 8 - 3 bit sequence number
    - maximum send window size = 7
    - modulo 128 - 7 bit sequence number
    - maximum send window size = 127
  - standard window size of 2

Data Transfer with D (Delivery) - Bit

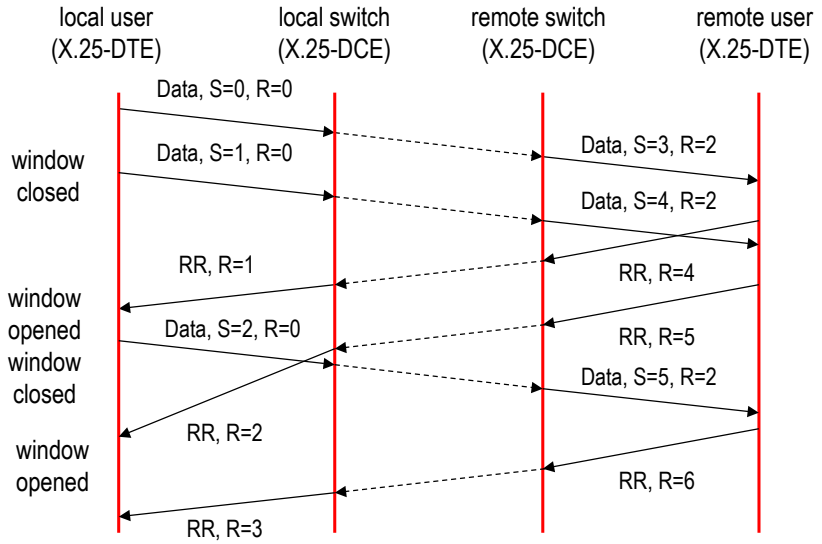
- **Data packet without D-bit indicator**
  - D = 0
  - acknowledgement number P(R) has only local meaning
  - handling of acknowledgement by switch
    - vendor specific
  - flow control and acknowledgement between switches
    - vendor specific
- **Data packet with D-bit indicator**
  - D = 1
  - can force acknowledgement number P(R) to be end-to-end
  - must be negotiated during call setup

Windowing (w = 2) without D-bit



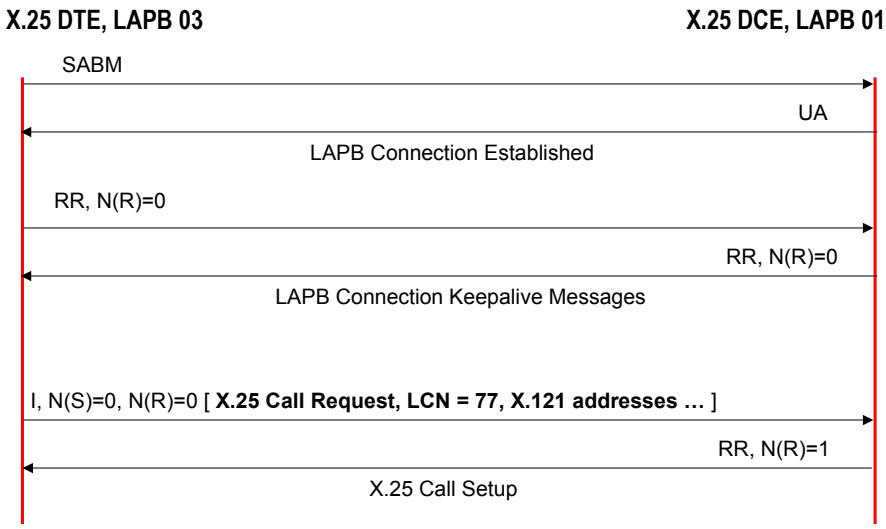
 X.25, v4.3 53

Windowing (w = 2) with D-bit



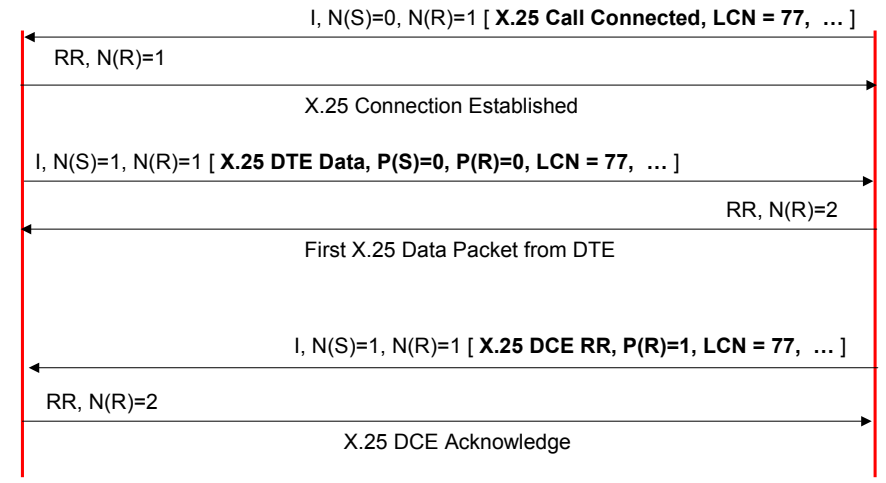
 X.25, v4.3 54

LAPB - X.25 Example 1 of 2



 X.25, v4.3 55

LAPB - X.25 Example 2 of 2



 X.25, v4.3 56

Data Transfer with Q (Qualifier) - Bit

- **Q - bit can be used by higher layers to distinguish two types of data**
  - for example
    - Q = 0 ... user data
    - Q = 1 ... control data
  - usage not defined in X.25
- **some Q - bit usage examples**
  - X.29 control information
    - for PAD equipment
  - QLLC header indication
    - for SNA over X.25

Data Transfer with M (More) - Bit

- **default maximum data field size in X.25**
  - 128 byte
  - other sizes could be negotiated (64, 256, 512, 1024, 2048, 4096)
  - sizes could be different on local and remote side
- **if remote DTE requests smaller packets then local DTE**
  - remote or local switch can segment packets using M-bit
    - M = 1 first or middle packet (packet completely filled with data)
    - M = 0 single or last packet
- **if remote DTE allows larger packets then local DTE**
  - remote or local switch can combine packets

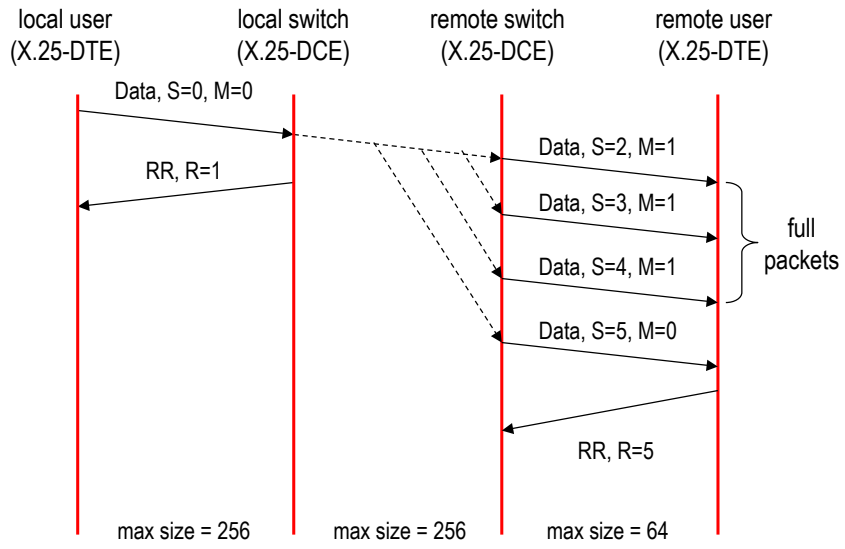
Categories of Data Packets

- **combined use of M and D bit allows to define two categories of packets (A and B)**
  - A packets are packets within a sequence of packets
    - M bit is set to 1
    - D bit is set to 0
  - B packets are standalone packets or packets at the end of a sequence
    - M bit is set to 0
    - can have D=1 to request end-to-end acknowledgement
- **a complete packet sequence consists of zero or more A packets followed by an B packet**

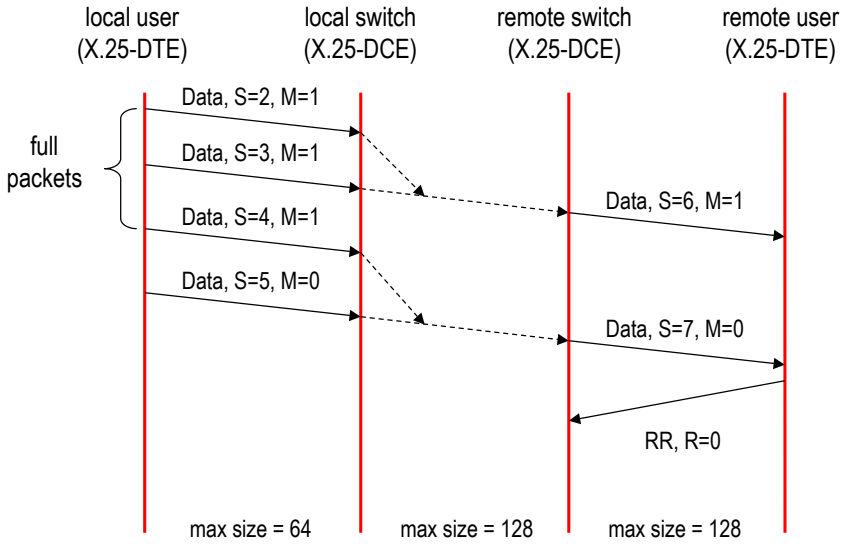
Combining and Segmenting

- **the network may combine a sequence of one or more A packets followed by a B packet to make one or more larger packets**
  - complete packet sequence information still remains at the receiver side
- **the network may also segment (fragment) a B packet into a sequence of smaller A and B packets**
  - receiver side is informed about fragmentation by recognizing a complete packet sequence

Fragmenting with M-bit



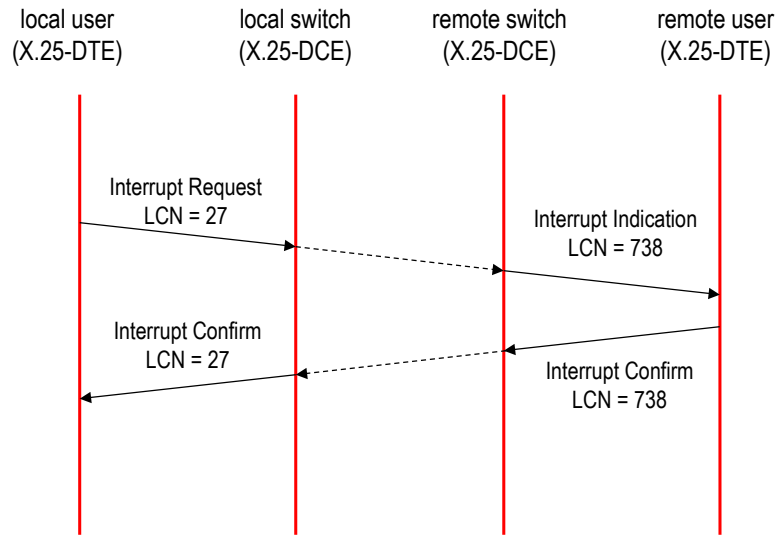
Combining with M-bit



Precedence Data

- **Interrupt Packets**
  - can be used to send precedence data without taking care of normal sequence
  - IdleRQ method
    - Interrupt packet must be acknowledged by Interrupt Confirmation packet before next Interrupt packet can be sent
    - Stop and Wait
  - only 32 octets of data can be sent using Interrupt packet

Precedence Data Transfer



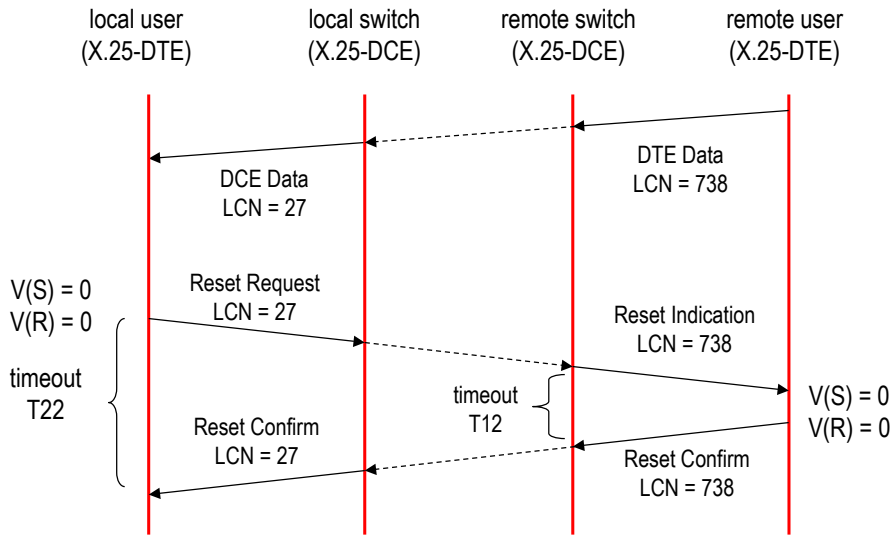
Agenda

- **Overview, Principles and Standards**
- **X.25 Data Link Layer**
- **X.25 Network Layer**
  - Services and Packet Types
  - Call Setup and Release
  - Data Transfer and Flow Control
  - Reset and Restart
- **X.25 Packet Format**
- **X.25 PAD**

Reset / Restart

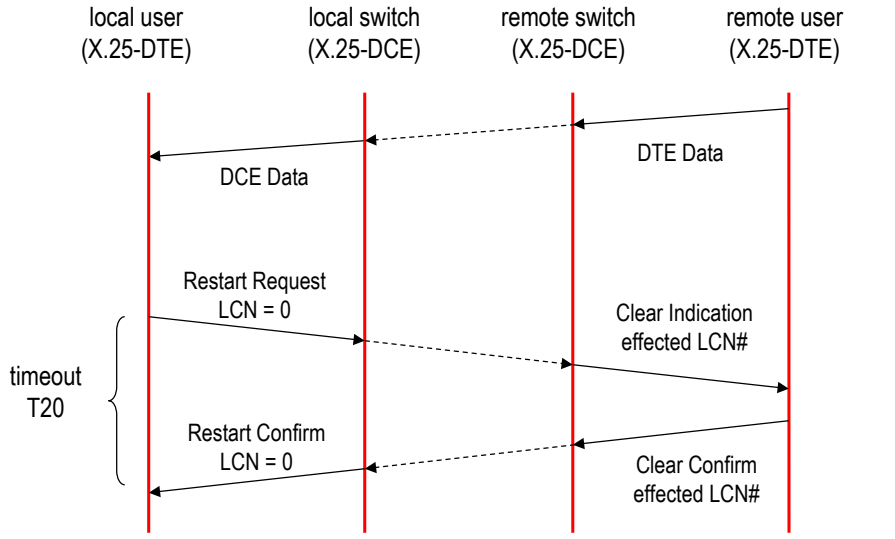
- **main error recovery mechanisms associated with packet layer**
- **reset procedure reinitializes a virtual circuit in case of protocol errors**
  - done by DTE (Reset Request) or DCE (Reset Indication)
  - data packets already transmitted are discarded
  - sequence number registers are set to zero
  - but virtual circuit is still available
- **restart procedure clears all virtual circuits**
  - done by DTE (Restart Request) or DCE (Restart Indication)
  - virtual circuits are not available any longer

Reset by DTE



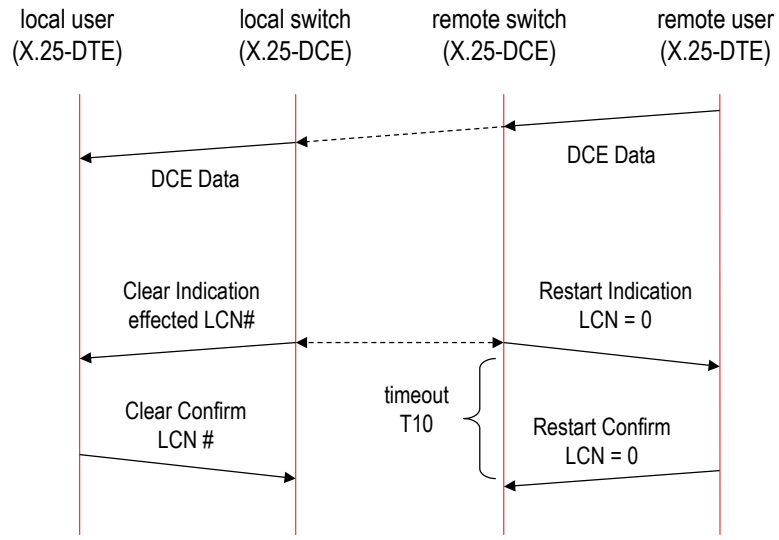
 X.25, v4.3 67

Restart by DTE



 X.25, v4.3 68

Restart by DCE



DTE Timeouts

- **DTE timers**
  - T20 … 180 seconds
    - started when DTE issues a Restart Request
  - T21 … 200 seconds
    - started when DTE issues a Call Request
  - T22 … 180 seconds
    - started when DTE issues a Reset Request
  - T23 … 180 seconds
    - started when DTE issues a Clear Request
  - T28 … 300 seconds
    - started when DTE issues a Registration Request

DCE Timeouts

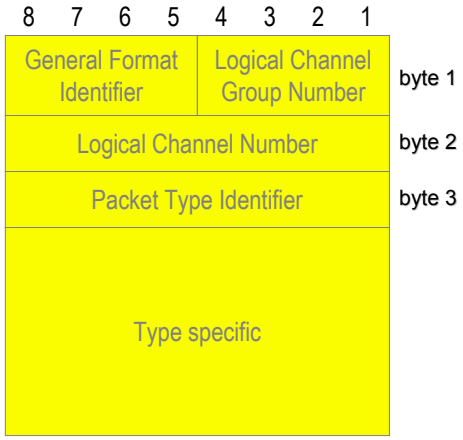
- **DCE timers**
  - T10 60 seconds
    - started when DCE issues a Restart Indication
  - T11 180 seconds
    - started when DCE issues an Incoming Call
  - T12 60 seconds
    - started when DCE issues a Reset Indication
  - T13 60 seconds
    - started when DCE issues a Clear Indication

Agenda

- **Overview, Principles and Standards**
- **X.25 Data Link Layer**
- **X.25 Network Layer**
  - Services and Packet Types
  - Call Setup and Release
  - Data Transfer and Flow Control
  - Reset and Restart
- **X.25 Packet Format**
- **X.25 PAD**

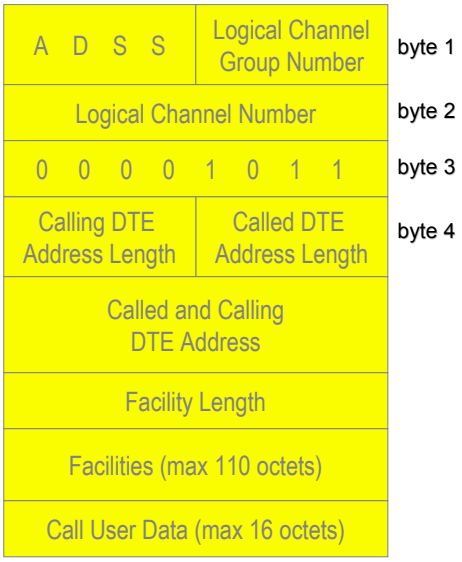
General Packet Format

- **every packet contains at least three bytes**
- **third byte is used either**
  - packet type identifier for non data packets
  - sequencing byte for data packets
    - first bit set to 0 to indicate data packet
- **logical channel group number together**
  - with LCN number allows up to 4096 virtual channels



Packet Format Call Setup

- **Call Request and Incoming Call**
  - packet type (byte 3) = 0x 0B
  - SS = 01 (mod 8)
  - SS = 10 (mod 128)
  - D = 1 D-bit mechanism supported
  - D = 0 D-bit mechanism not supported
  - A = 1 escape from conventional X.25 addresses (1988)

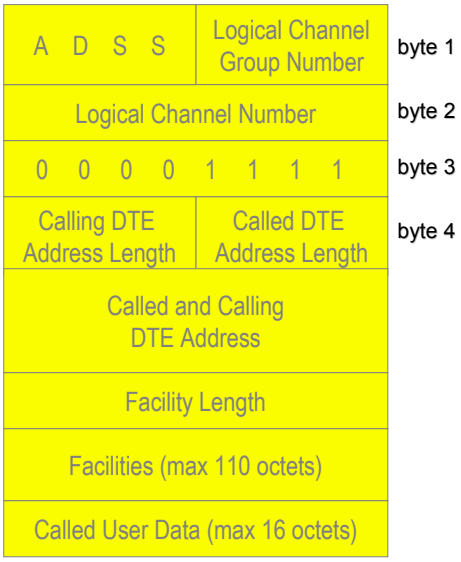


Call Setup

- **additional fields**
  - DTE address and address length
    - for call establishment packets, usually X.121 addresses are used
  - facilities and facilities length
    - used to negotiate or declare several optional functions of X.25
  - call user data may contain data associated with facility
  - some examples
    - flow control parameter negotiation
    - closed user group
    - reverse charging, reverse charging acceptance
    - network user identification
    - call redirection

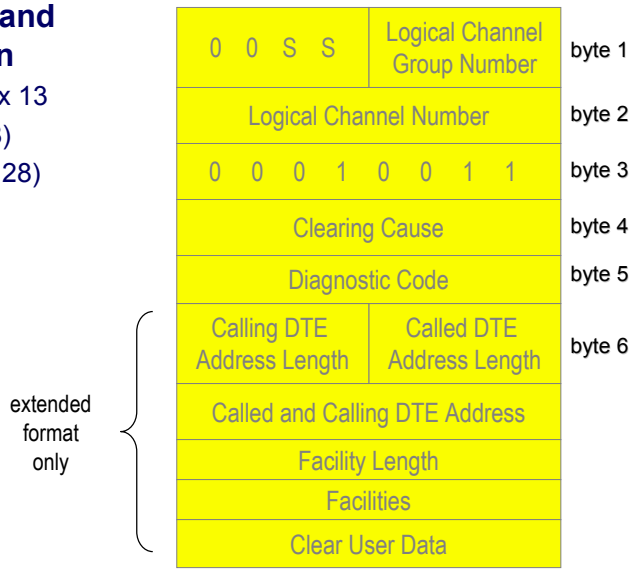
Packet Format Call Setup

- **Call Accepted and Call Connected**
  - packet type (byte 3) = 0x 0F
  - SS = 01 (mod 8)
  - SS = 10 (mod 128)



Packet Format Call Release

- **Clear Request and Clear Indication**
  - packet type = 0x 13
  - SS = 01 (mod 8)
  - SS = 10 (mod 128)

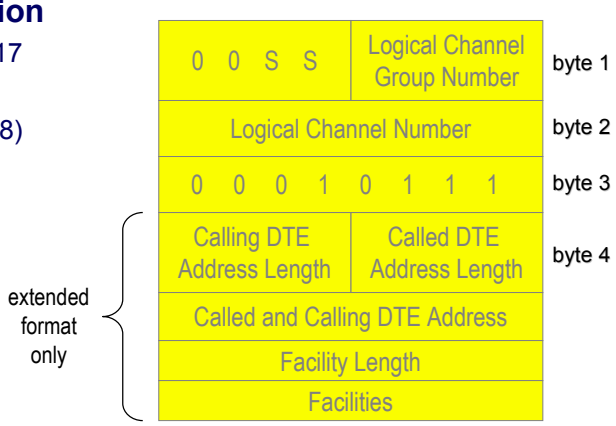


Clearing Cause (Call Release)

- **0x00** normal disconnect request from DTE
- **0x01** remote DTE busy
- **0x09** remote DTE failure
- **0x11** remote DTE protocol failure
- **0x19** no reverse charging accepted
- **0x29** no fast select accepted
- **0x03** invalid facility request
- **0x0B** access denied
- **0x13** local failure
- **0x05** network congested
- **0x0D** destination unreachable
- **0x15** network failure

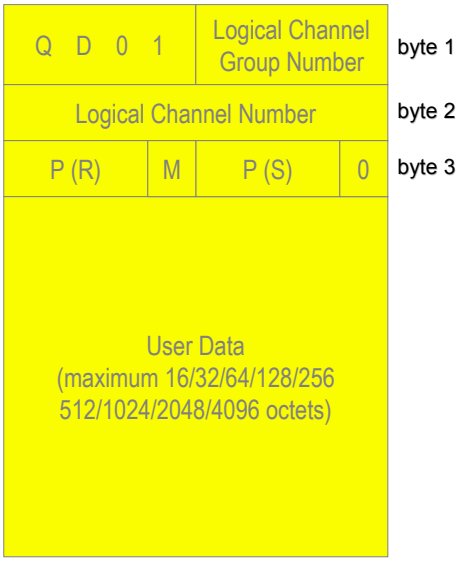
Packet Format Call Release

- **Clear Confirmation**
  - packet type = 0x17
  - SS = 01 (mod 8)
  - SS = 10 (mod 128)



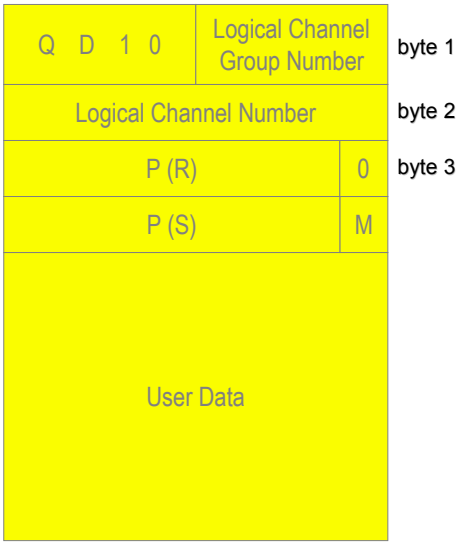
Packet Format Data Transfer

- **Data modulo 8**
  - packet type -> last bit zero
  - D = 1 end-to-end ack. required
  - D = 0 only local ack. required
  - Q = 1 user data
  - Q = 0 control data



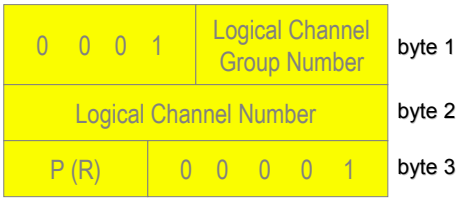
Packet Format Data Transfer

- **Data modulo 128**
  - packet type -> last bit zero
  - D = 1 end-to-end ack. required
  - D = 0 only local ack. required
  - Q = 1 user data
  - Q = 0 control data

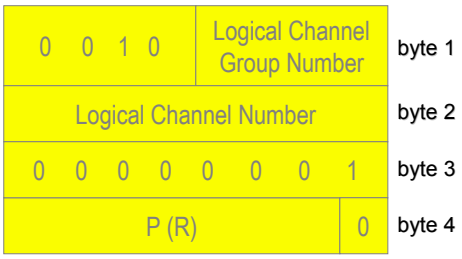


Packet Format RR

- **modulo 8**
  - packet type = XXX 00001 (X ... don´t care)

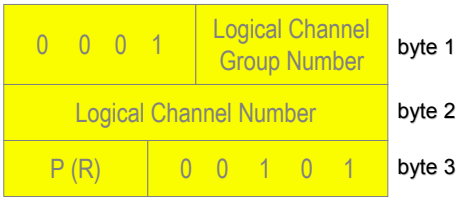


- **modulo 128**
  - packet type = 0x 01

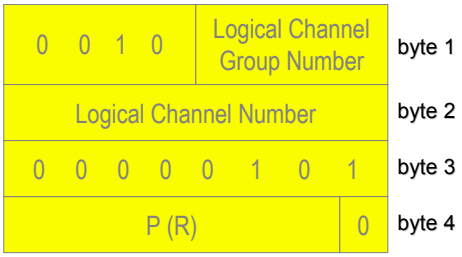


Packet Format RNR

- **modulo 8**
  - packet type = XXX 0101

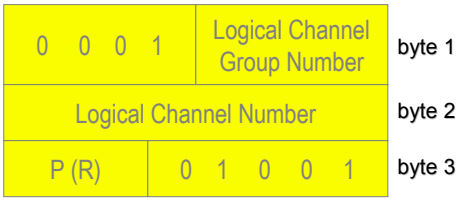


- **modulo 128**
  - packet type = 0x 05

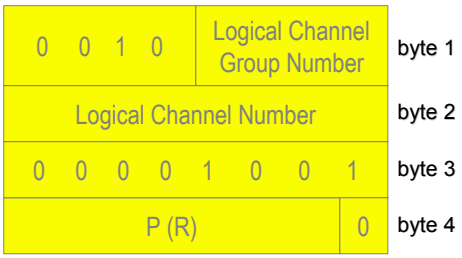


Packet Format REJ

- **modulo 8**
  - packet type = XXX 1001

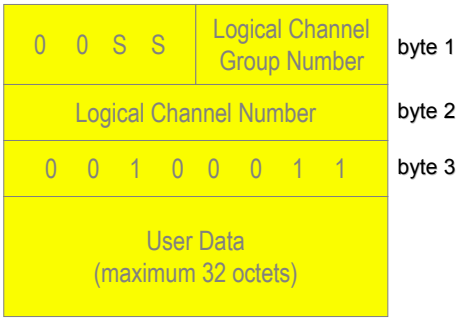


- **modulo 128**
  - packet type = 0x 09

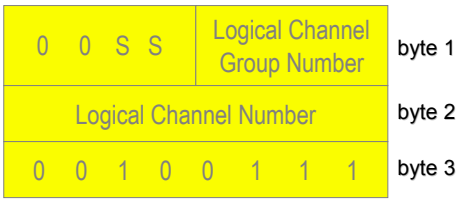


Packet Format Interrupt

- **Interrupt Request and Interrupt Indication**
  - packet type = 0x 23
  - SS = 01 (mod 8)
  - SS = 10 (mod 128)

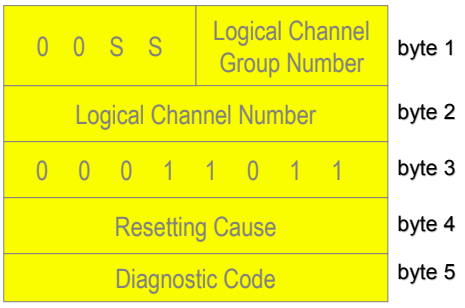


- **Interrupt Confirmation**
  - packet type = 0x 27
  - SS = 01 (mod 8)
  - SS = 10 (mod 128)

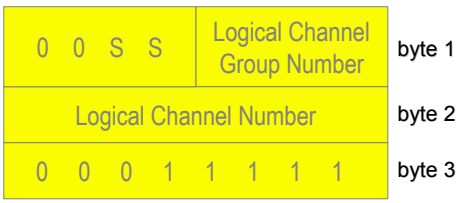


Packet Format Reset

- **Reset Request and Reset Indication**
  - packet type = 0x 1B
  - SS = 01 (mod 8)
  - SS = 10 (mod 128)



- **Reset Confirmation**
  - packet type = 0x 1F
  - SS = 01 (mod 8)
  - SS = 10 (mod 128)



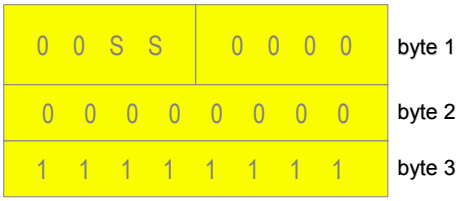
Clearing Cause (Reset)

- 0x00 reset request from DTE
- 0x01 remote DTE failure (PVC only)
- 0x03 remote DTE protocol failure
- 0x05 local failure
- 0x07 network congested
- 0x09 remote DTE available (PVC only)
- 0x0F network available (PVC only)
- 0x11 remote DTE incompatible

Packet Format Restart

- **Restart Request and Restart Indication**
  - packet type = 0x 1B
  - SS = 01 (mod 8)
  - SS = 10 (mod 128)

- **Restart Confirmation**
  - packet type = 0x FF
  - SS = 01 (mod 8)
  - SS = 10 (mod 128)



Clearing Cause (Restart)

- **0x00** **restart request from DTE**
- **0x01** **local failure**
- **0x03** **network congested**
- **0x05** **network available**

Packet Format Diagnostics

- **Diagnostics**
  - packet type = 0x F
  - SS = 01 (mod 8)
  - SS = 10 (mod 128)

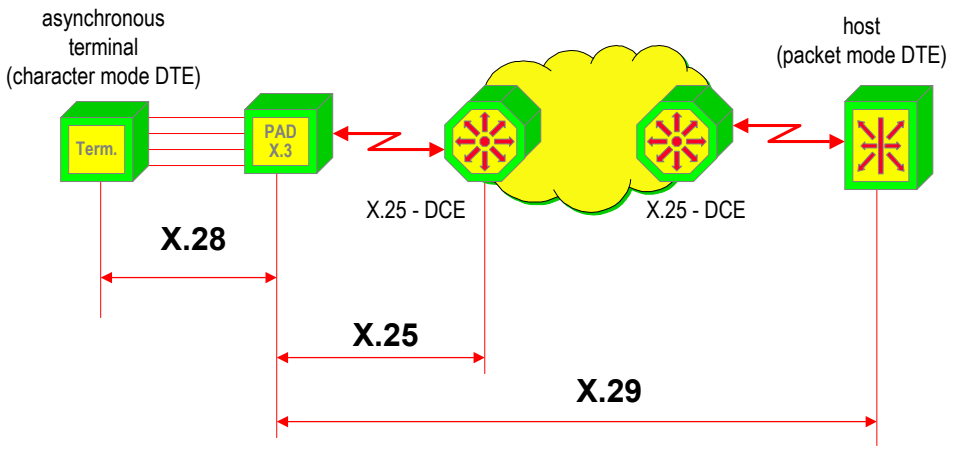
Agenda

- **Overview, Principles and Standards**
- **X.25 Data Link Layer**
- **X.25 Network Layer**
  - Services and Packet Types
  - Call Setup and Release
  - Data Transfer and Flow Control
  - Reset and Restart
- **X.25 Packet Format**
- **X.25 PAD**

X.25 PAD

- **provides protocol conversion and packet assembly/disassembly functionality for dumb asynchronous terminals**
- **defined by companion standards X.3, X.28, X.29**

Packet Assembler / Dissassembler



X.25 PAD

- **X.3**
  - specifies functionality of PAD
  - provides parameters to service different terminal types
    - escape from data transfer
    - data forwarding signal
    - terminal speed, flow control, linefeed handling, echo
    - forward only full packets
    - forward a packet upon carriage return
    - send service signals to user
    - send interrupt packet upon receipt of a BREAK
    - etc.
  - determines how the PAD communicates with the user DTE

X.25 PAD

- **X.28**
  - defines the procedures to control the data flow between non-packet DTEs and the PAD
  - non-packet DTE user sends X.28 command to the PAD
  - PAD returns a response value
  - examples
    - setup a call
    - initialize a service
    - exchange data
    - exchange control information
    - configuring PAD parameter
    - read PAD parameter

X.25 PAD

- **X.29**
  - defines how a PAD and a remote packet station may exchange control information
  - remote station can be a PAD or a remote DTE
  - uses packet header Q bit
    - Q=1, packet contains PAD control information
  - allows for example to change the configuration of a remote PAD

Summary

- connection oriented network, using virtual circuits
- three layers defined
  - physical layer
  - data link layer
  - network layer
- uses HDLC subset at data link layer (LAPB)
- supports PVCs and SVCs
  - call setup sequence required for SVCs
- supports windowing and flow control
- supports several options called facilities
- PAD functions for non-packet DTEs defined

