The Network Layer

Design Issues

- Subnet-to-Host Interface (Network Services)
- Packet Routing
- Congestion Control
- Error Control

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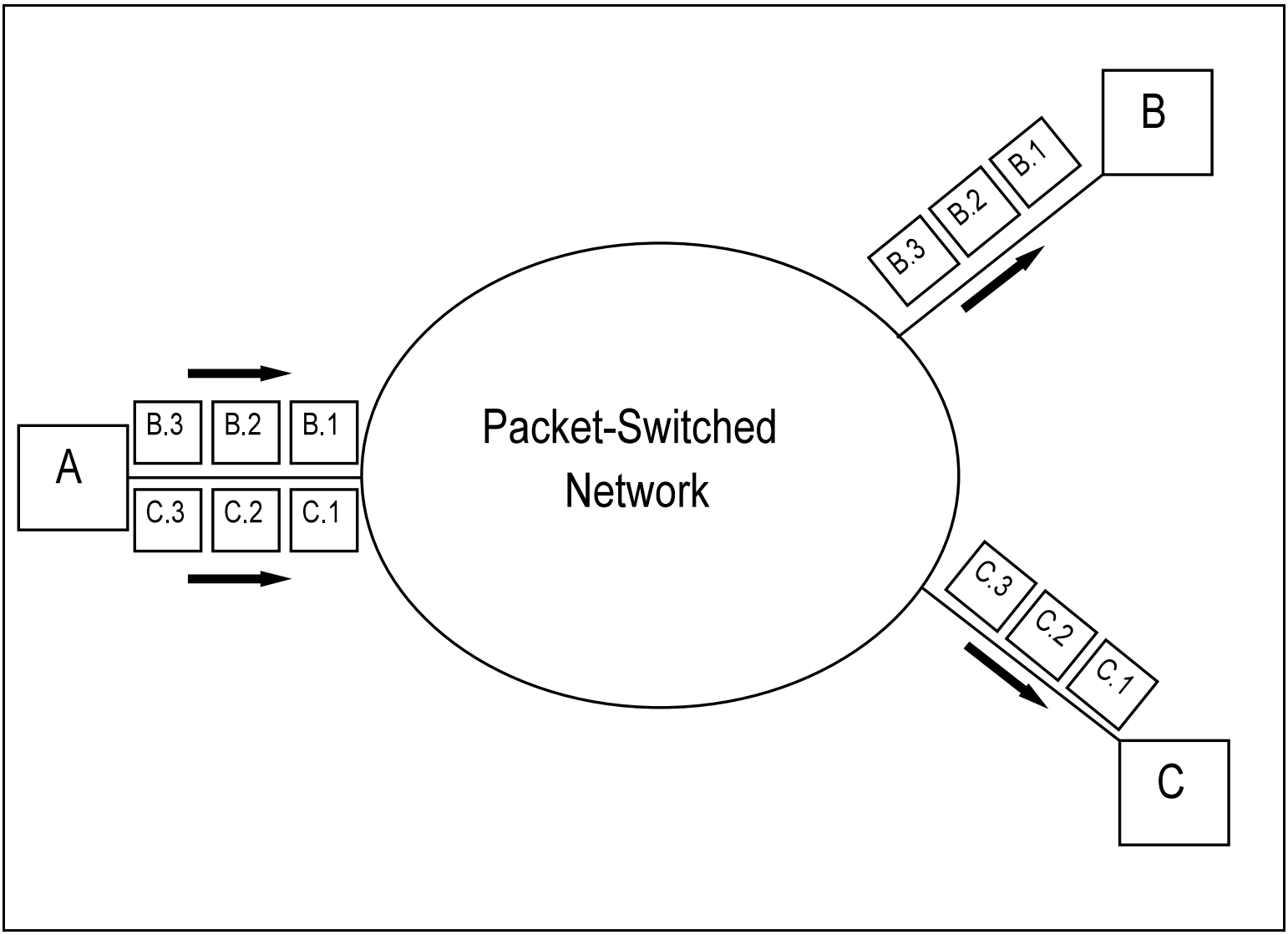
Subnet-to-Host Interface (Network Service):

! **Virtual Circuit Service:**

The network layer establishes a virtual circuit over which it exercises flow control and error control. The network attempts to deliver packets in sequence.



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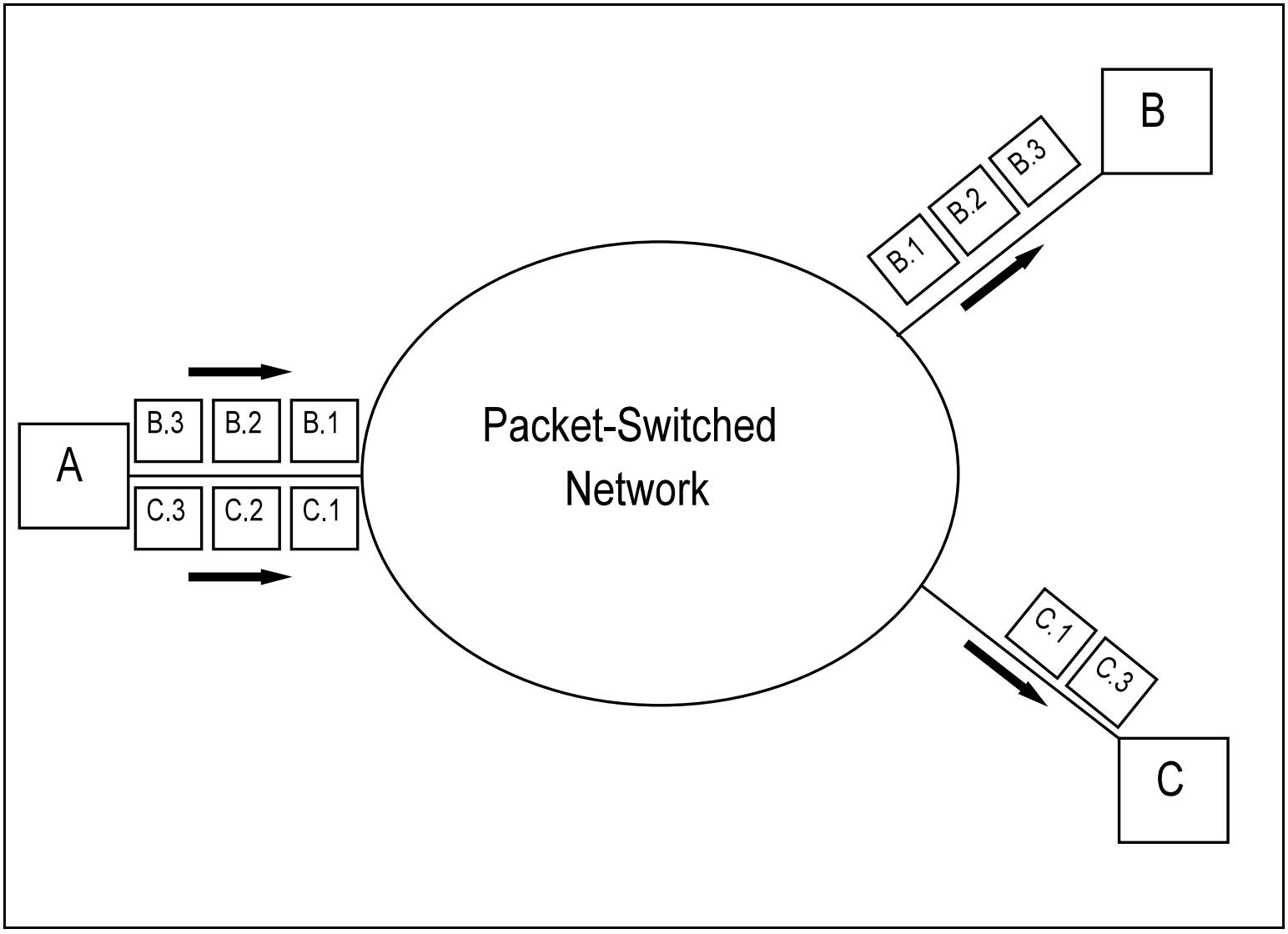
! **Datagram Service:**

The network layer simply accepts packets from its user and attempts to deliver them as isolated units. Packets may arrive out of sequence or not at all.



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ISO CONNECTION-MODE NETWORK SERVICE PRIMITIVES

N-CONNECT.request (Called NSAP, Calling NSAP, QOS, Receipt Confirmation Selection, Expedited Data Selection, NS-User Data)
N-CONNECT.indication (Called NSAP, Calling NSAP, QOS, Receipt Confirmation Selection, Expedited Data Selection, NS-User Data)
N-CONNECT.response (Responding NSAP, QOS, Receipt Confirmation Selection, Expedited Data Selection, NS-User Data)
N-CONNECT.confirm (Responding NSAP, QOS, Receipt Confirmation Selection, Expedited Data Selection, NS-User Data)

N-DATA.request (NS-User Data)
N-DATA.indication (NS-User Data)

N-DATA-ACKNOWLEDGE.request
N-DATA-ACKNOWLEDGE.indication

N-EXPEDITED-DATA.request (NS-User Data)
N-EXPEDITED-DATA.indication (NS-User Data)

N-RESET.request (Originator, Reason)
N-RESET.indication (Originator, Reason)
N-RESET.response
N-RESET.confirm

N-DISCONNECT.request (Originator, Reason, NS-User Data, Responding Address)
N-DISCONNECT.indication (Originator, Reason, NS-User Data, Responding Address)

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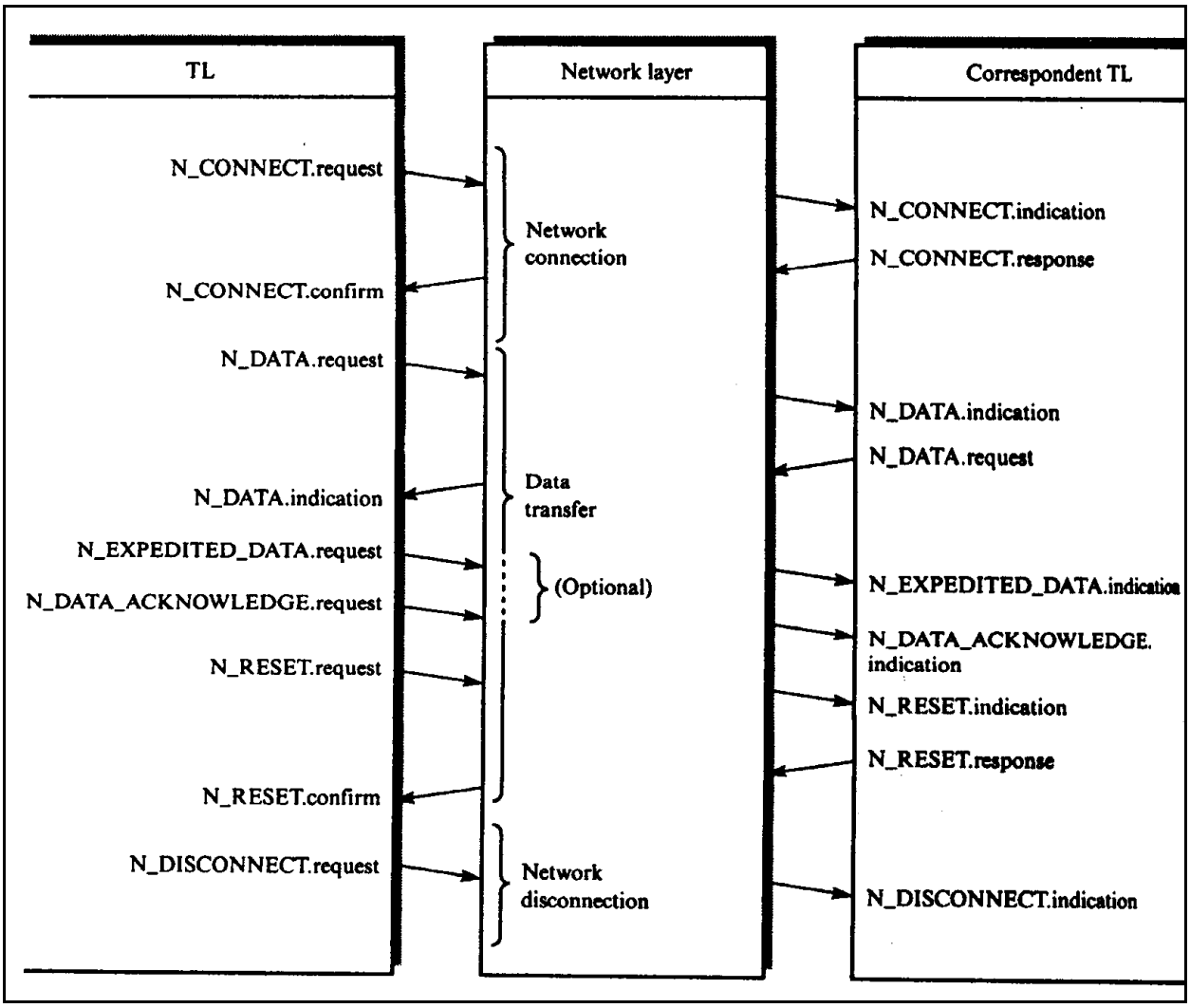
ISO Network Layer Primitives



Network Layer Primitives - Sequence of Usage

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QOS Parameters for the ISO Network Service	
NC Establishment Delay	**Maximum acceptable delay between an N-CONNECT.request and the corresponding N-CONNECT.confirm.**
NC Establishment Failure Probability	**Proportion of connection establishment attempts that fail as a result of NS provider behavior, such as, misconnection, NC refusal, or excessive delay. Connection failures die to NS user behavior are excluded from the calculation.**
Throughput	**Rate of NSDU transfer that can be sustained by the NS provider. Desired and minimum acceptable values are specified.**
Transit Delay	**Average elapsed time between an N-DATA.request and the corresponding N-DATA.indication, using a nominal NSDU size of 128 octets. Desired and maximum acceptable values are specified.**
Residual Error Rate	**Equal to (N(e)+N(l)+N(x))/N, where N(e)=incorrect NSDUs; N(l)=lost NSDUs; N(x)=duplicate NSDUs; and N=total NSDUs transferred.**
Transfer Failure Probability	**Applies to Throughput, Transit Delay, and Residual Error Rate. For each of these parameters, the transfer probability is the observed proportion of time that the NS provider fails to provide the minimum acceptable service.**
NC Resilience	**Two parameters: Probability of an NS-provider-invoked NC release, and the probability of an NS-provider-invoked reset.**
NC Release Delay	**Maximum acceptable delay between an NS-user-invoked N-DISCONNECT.request and the successful release of the NC at the peer NS user.**
NC Release Failure Probability	**Proportion of release requests that are not satisfied within the maximum acceptable delay.**
NC Protection	**A set of four features that may be provided in any combination: (1) Prevention of unauthorized monitoring; (2) Detection of modification, deletion, replay, or insertion of data; (3) Peer entity authentication to prevent masquerading; and (4) Authentication of NSDU origin.**
NC Priority	**Specifies the relative priority of NCs with respect to (1) the order in which the connections have their QOS downgraded, if necessary, and (2) the order in which NCs are broken to recover resources, if necessary.**
Maximum Acceptable Cost	**Maximum acceptable cost for an NC, composed of communications and end-system resource costs.**

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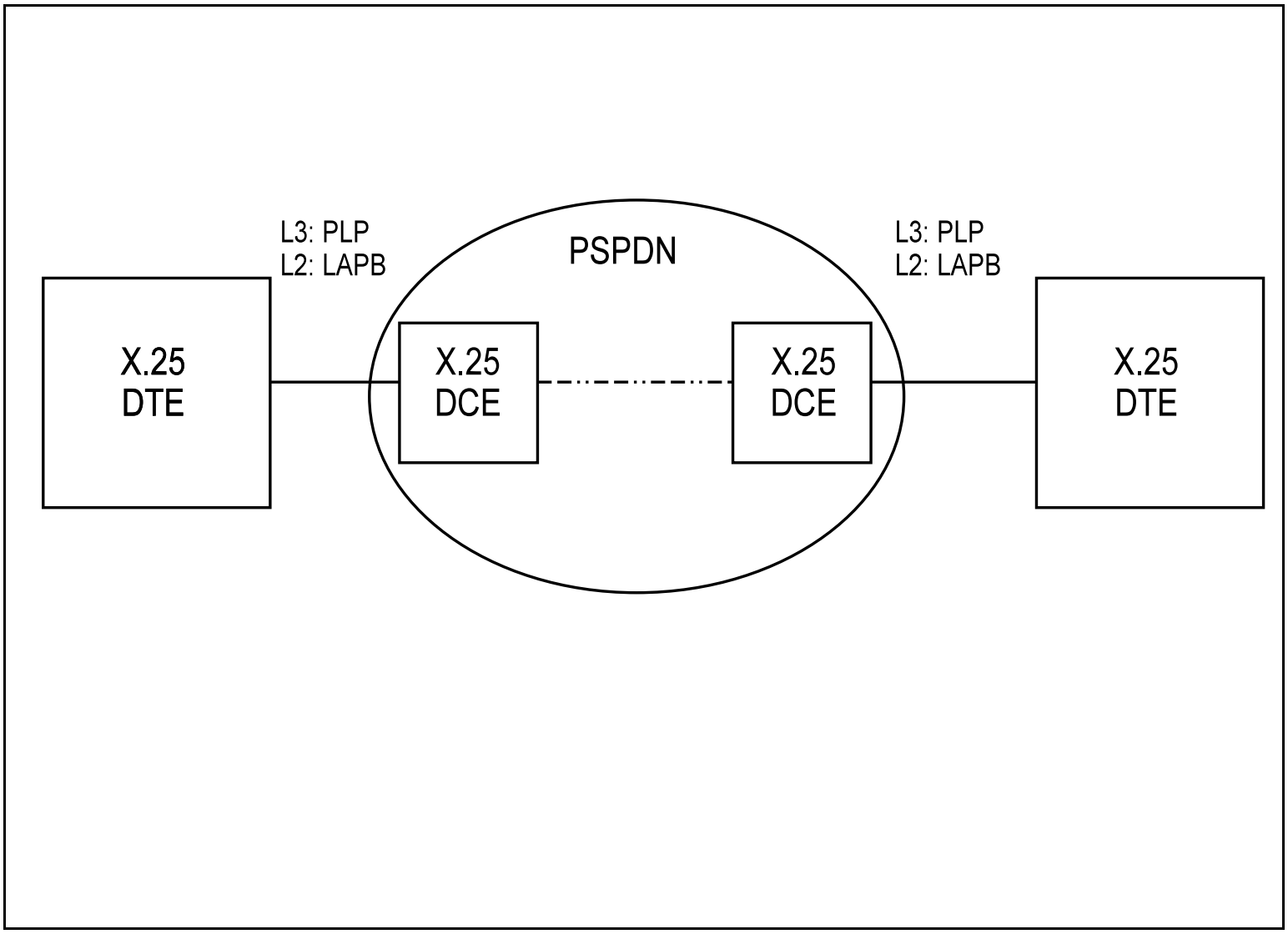
X.25 Data Transfer



Note:

DTE - Data Terminal Equipment
DCE - Data Circuit Terminating Equipment

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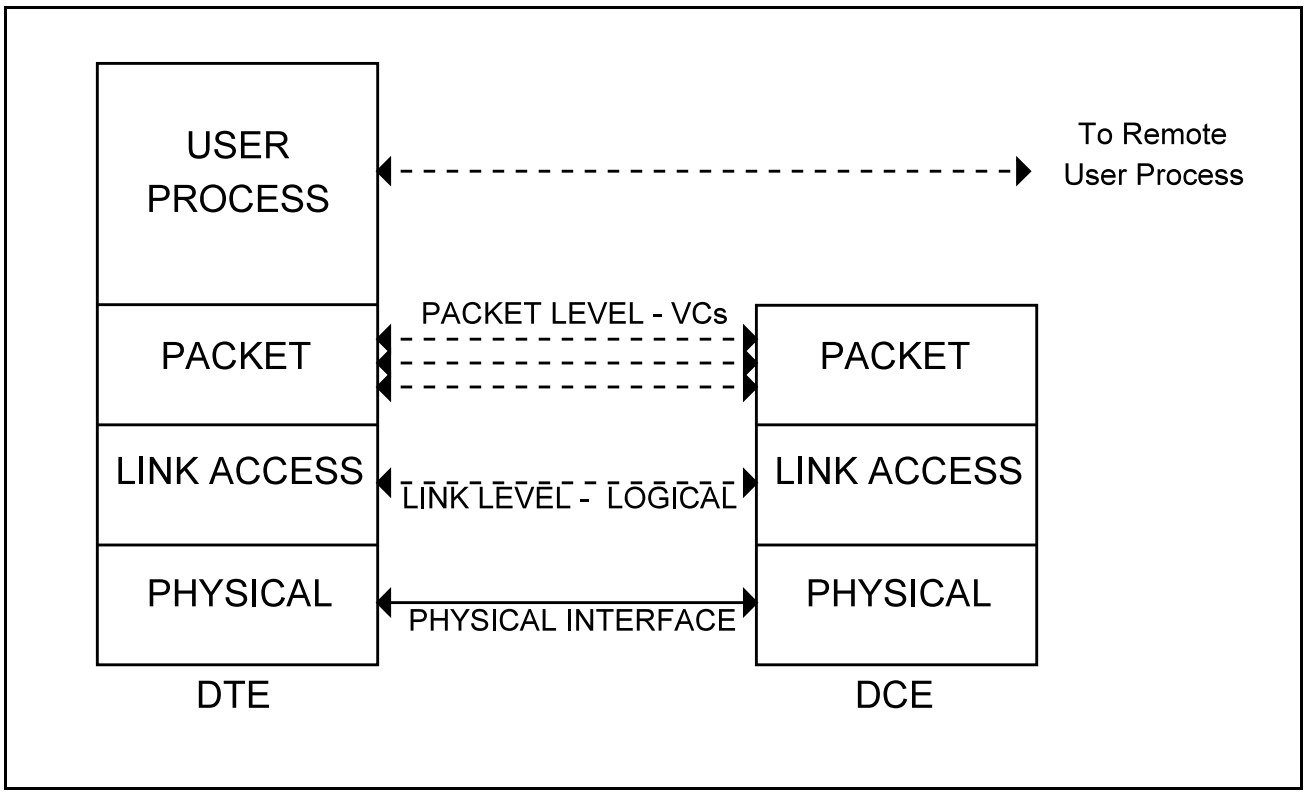
X.25 Standard

! Specifies a three level DTE < ---> DCE interface:
  1. Physical Level:
     - X.21
     - X.21 bis (similar to EIA-232-D)
  2. Link Access Level:
     - Single Link Procedure (SLP):
       LAP-B (a subset of the ABM mode of HDLC)
     - Multilink Procedure (MLP):
  3. Packet Level: (PLP - Packet Layer Protocol)
     - X.25 (Virtual Circuit Service)
       ! Virtual Call : dynamically established
       ! Permanent Virtual Circuit : network assigned



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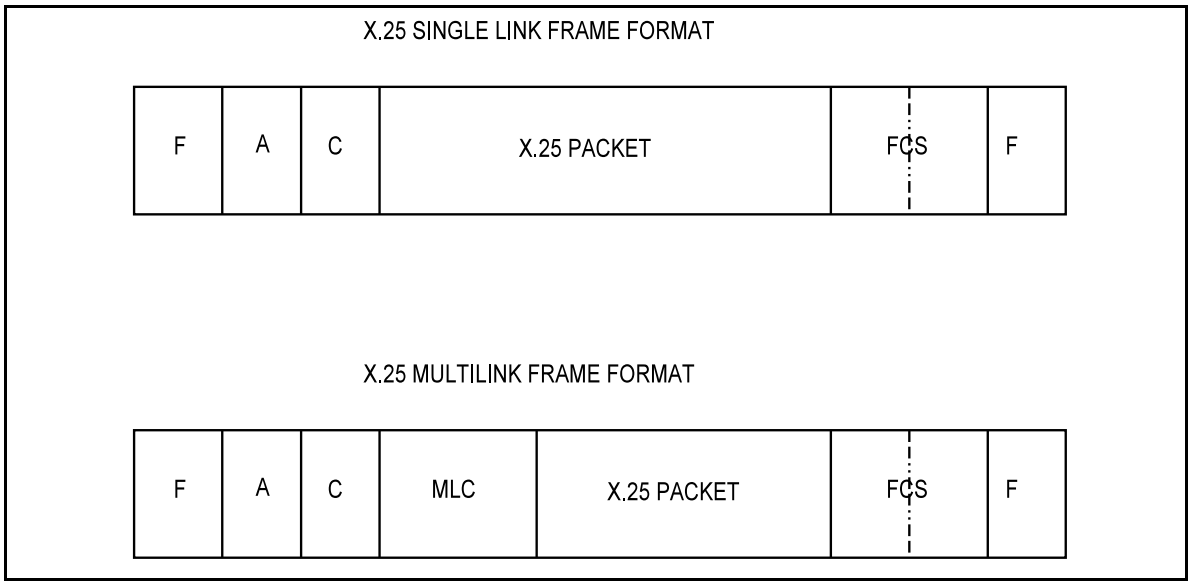
X.25 Link Level

1. Single Link Procedure (SLP):
   - ! LAP-B
2. Multilink Procedure (MLP):
   - ! Allows for multi-line DTE-DCE connections.
   - ! Each link is governed by the SLP LAP-B.

! MLP Frame Format:
   a) Multilink Control Field (MLC) (2 octets)
      i) 12 bit sequence number across all links (needed because frames sent out over different links may arrive out of order).
      ii) The destination reorders the packets according to the MLP sequence numbers.
   b) The X.25 Packet

! SLP Frame Format:
   a) A LAP-B frame.
   b) Sequence numbers are on a per link basis.



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X.25 Packet Types			
Packet Type		Service	
DCE → DTE	DTE → DCE	VC	PVC
Call Set-up and Clearing			
Incoming Call	Call Request	X	
Call Connected	Call Accepted	X	
Clear Indication	Clear Request	X	
Clear Confirmation	Clear Confirmation	X	
Data and Interrupt			
Data	Data	X	X
Interrupt	Interrupt	X	X
Interrupt Confirmation	Interrupt Confirmation	X	X
Flow Control and Reset			
RR	RR	X	X
RNR	RNR	X	X
	REJ	X	X
Reset Indication	Reset Request	X	X
Reset Confirmation	Reset Confirmation	X	X
Restart			
Restart Indication	Restart Request	X	X
Restart Confirmation	Restart Confirmation	X	X
Diagnostic			
Diagnostic		X	X
Registration			
Registration Confirmation	Registration Request	X	X

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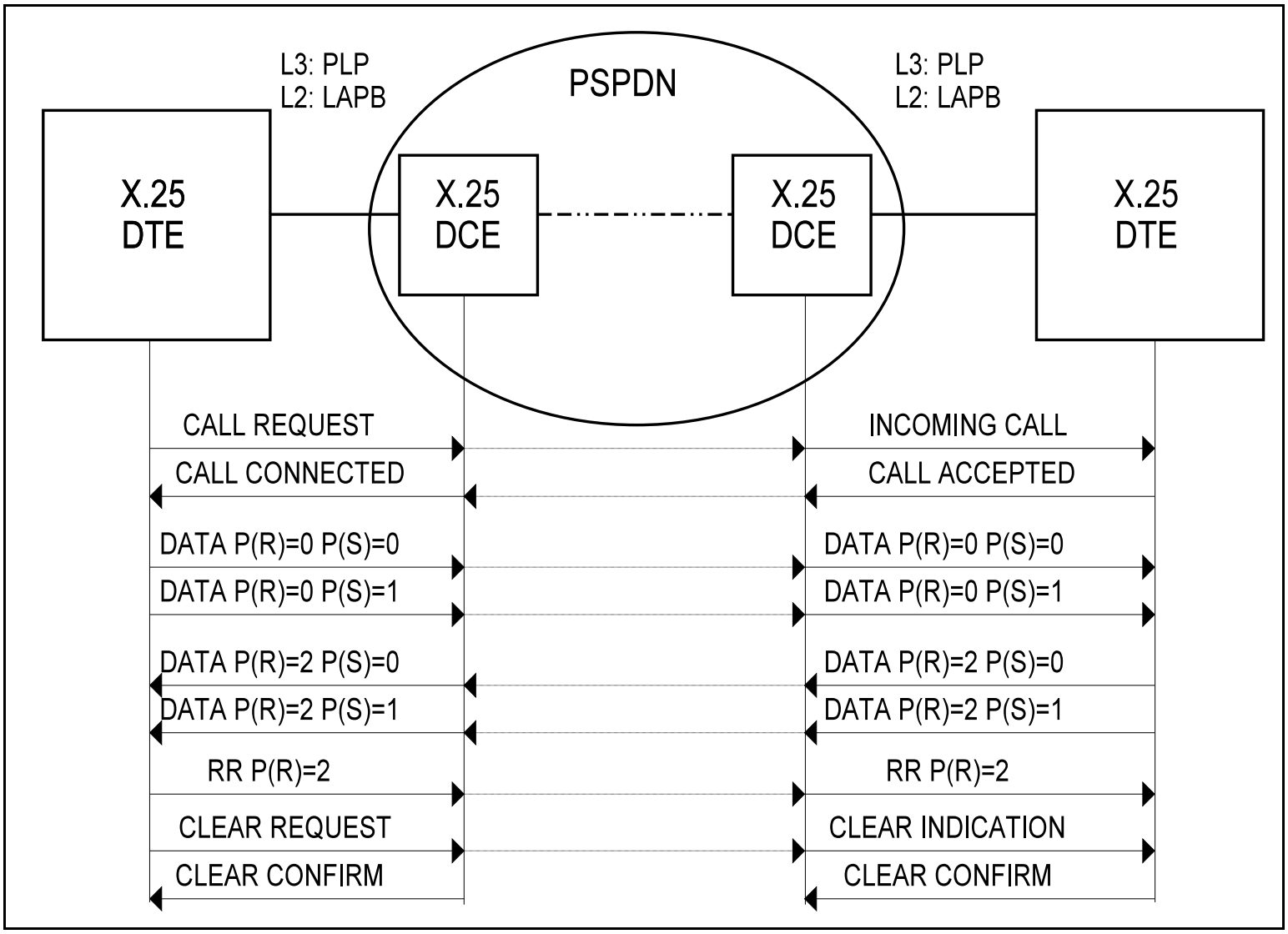

X.25 Data Transfer - Example

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Call Request / Incoming Call Packet							
A	D	0/1	1/0	Logical Channel Group Number			
Logical Channel Number							
0	0	0	0	1	0	1	1
Calling DTE Address Length				Called DTE Address Length			
Called DTE Address							
Calling DTE Address							
0	0	User Facility Length (≤ 109 octets)					
User Facilities							
User Data							
(≤ 16 octets - Normal; ≤ 128 octets - Fast Select)							

Call Accepted / Call Connected Packet							
0	0	0/1	1/0	Logical Channel Group Number			
Logical Channel Number							
0	0	0	0	1	1	1	1
Optional Additional Information							

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Essential Optional Packet Switched User facilities (X.2)	
Assigned for an Agreed Contractual Basis	
Flow Control Parameter Negotiation	**Permits negotiation on a per call basis of the window size and maximum user data field length to be used on that call in each direction.**
Throughput Class Negotiation	**Permits negotiation on a per call basis on the throughput of data that can be transferred on a virtual circuit. The range of values is 75bps to 48kbps.**
Closed User Group	**Enables the DTE to belong to one or more closed user groups. A closed user group per,its the DTEs belonging to the group to communicate with each other but precludes communication with all other DTEs.**
Fast Select Acceptance	**Authorizes the DCE to transmit to the DTE incoming fast select calls.**
Incoming Calls Barred	**Prevents incoming calls from being presented to the DTE.**
Outgoing Calls Barred	**Prevents the DCE from accepting outgoing virtual calls.**
One-Way Logical Channel Outgoing	**Sets the Lowest Outgoing Channel boundary. A subscriber reserves a number of logical channels in this fashion to match an expected or desired pattern of calls.**
Requested on a Per-Virtual Call Basis	
Flow Control Parameter Negotiation	**When a DTE has subscribed to this facility, it may, in a CALL REQUEST packet, separately request user data field and window sizes. The DCE indicates its acceptance or modification of these values in the CALL CONNECTED packet. The DCE may modify window size requests in the direction of W=2, and may modify user data field size requests in the direction of 128 octets.**
Throughput Class Negotiation	**Operates in a manner similar to Flow Control Parameter Negotiation. The DCE may revise the proposed values in either direction to values smaller than those requested.**
Closed User Group Selection	**When a DTE has subscribed to this facility, it may, in a CALL REQUEST packet, indicate the closed user group applicable to this call. Similarly, the DCE can indicate the closed user group applicable to an incoming call in an INCOMING CALL packet.**
Fast Select	**The DTE may employ the fast select facility.**
Transit Delay Selection and Identification	**The DTE may request a particular transit delay that the network will attempt to meet.**

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Data Packet - 3 bit sequence numbering				
Q	D	0	1	Logical Channel Group Number
Logical Channel Number				
P(R)		M	P(S)	0
Data				

Data Packet - 7 bit sequence numbering				
Q	D	1	0	Logical Channel Group Number
Logical Channel Number				
P(S)				0
P(R)				M
Data				

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RR,RNR,REJ - 3 bit sequence numbering						
0	0	0	1	Logical Channel Group Number		
Logical Channel Number						
P(R)			0	Type	0	1

RR,RNR,REJ - 7 bit sequence numbering						
0	0	1	0	Logical Channel Group Number		
Logical Channel Number						
0	0	0	0	Type	0	1
P(R)						0

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Clear Request / Clear Indication Packet							
0	0	0/1	1/0	Logical Channel Group Number			
Logical Channel Number							
0	0	0	1	0	0	1	1
Clearing Cause							
Diagnostic Code							

Clear Confirmation Packet							
0	0	0/1	1/0	Logical Channel Group Number			
Logical Channel Number							
0	0	0	1	0	1	1	1

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X.25 Details

- The network must support a maximum user field length of at least 128 octets.
- The network may allow selection of other maximum lengths in the range 16 to 4096 octets.
- The length may differ for the two ends of the virtual circuit.
- The DTE constructs control packets and encapsulates data into data packets.
- The packets are sent to the DCE using LAP-B.
- The DCE strips the layer-2 header and encapsulates the packet according to some internal network protocol.

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! Multiplexing:

A DTE is allowed to have establish up to 4095 simultaneous virtual circuits (permanent + virtual calls)

Each packet contains a 12-bit virtual circuit number (Number 0 is reserved for restart and diagnostic packets)

! Flow Control:

A sliding window protocol is used

Default window size is 2 (max is 7 or 127)

! Acknowledgements:

May have either local or end-to-end significance:

- When D= 0, the ack is between the DTE and the network
- When D= 1, the ack is from the remote DTE

! Error Recovery:

a) Reset Packet
Re-initialize a virtual circuit

b) Restart Packet
Resets all active virtual circuits

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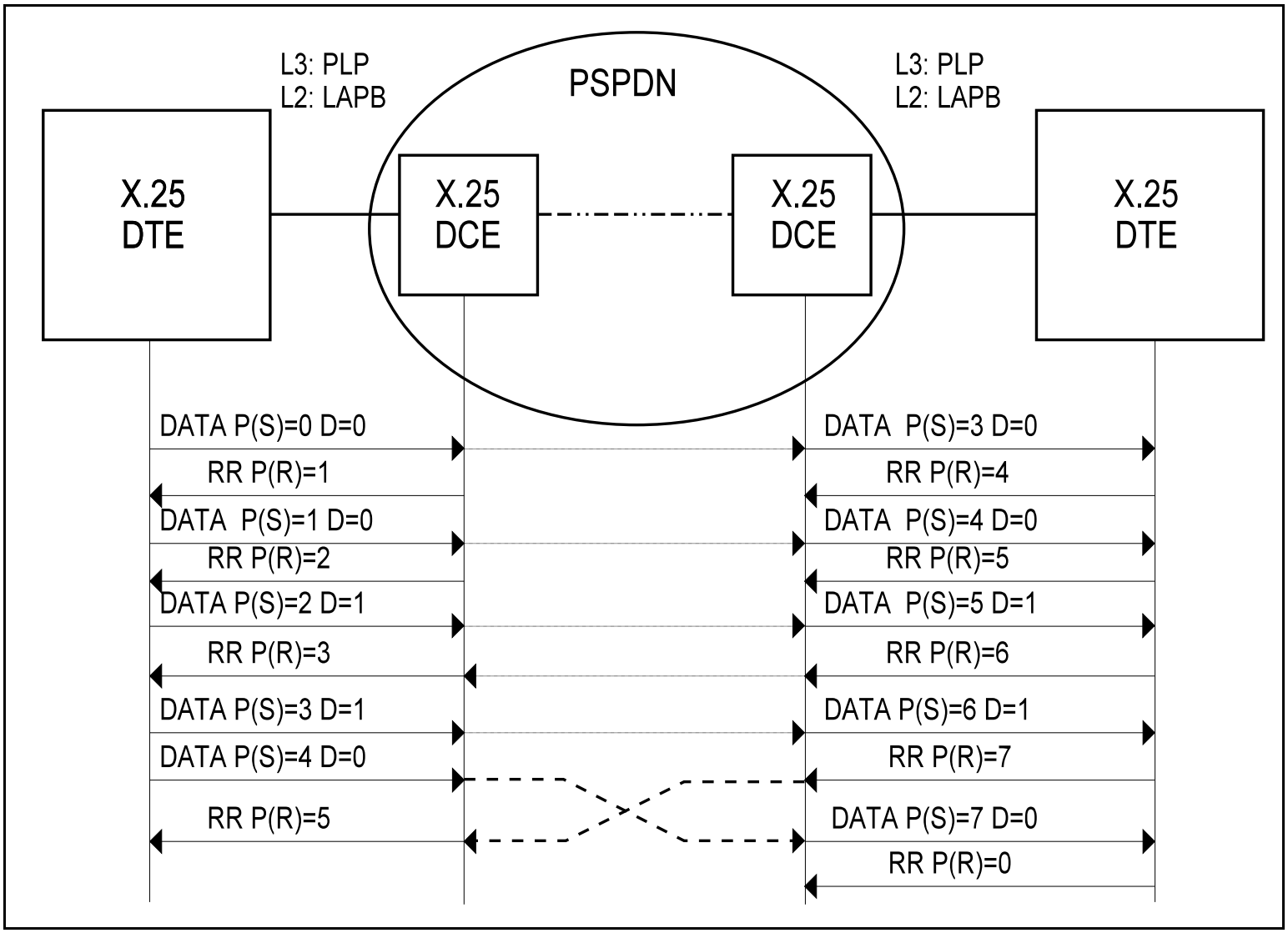
X.25 Flow Control - Example



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Fast Select Facility

Designed to handle transaction oriented applications.

- DTE request Fast Select in the facilities field of Call Request packet.
- 128 bytes of user data are now allowed.
- DTE must specify unrestricted or restricted response:
  - Restricted Option:
    Remote DTE must respond with Clear Request which may also contain 128 octets of data.
  - Unrestricted Option:
    Remote DTE may respond with a Call Accepted (with 128 octets of data) after which a virtual circuit would have been established.

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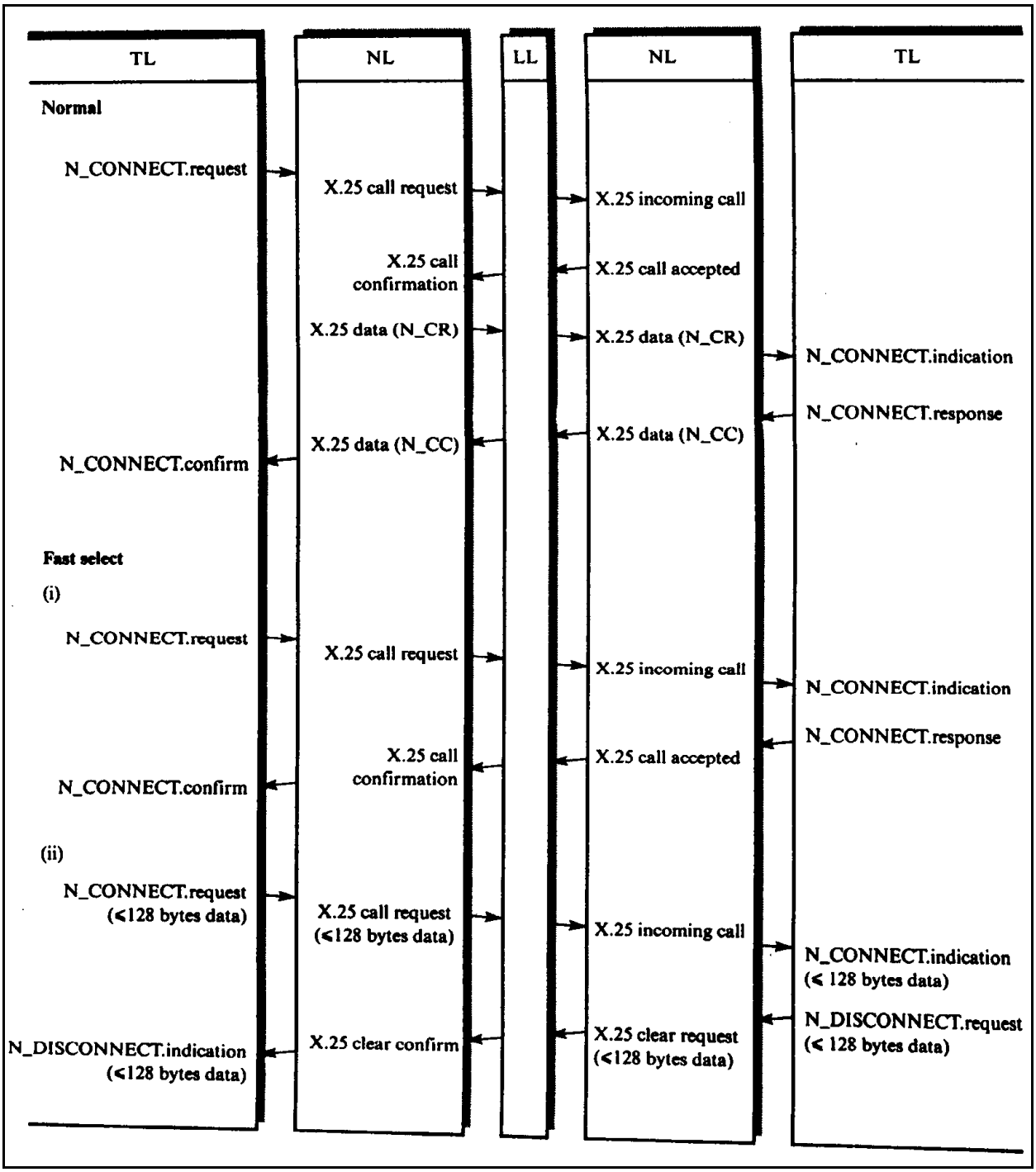
Mapping Network Layer Primitives to X.25 Packets



Mapping Network Layer Primitives to X.25 Packets

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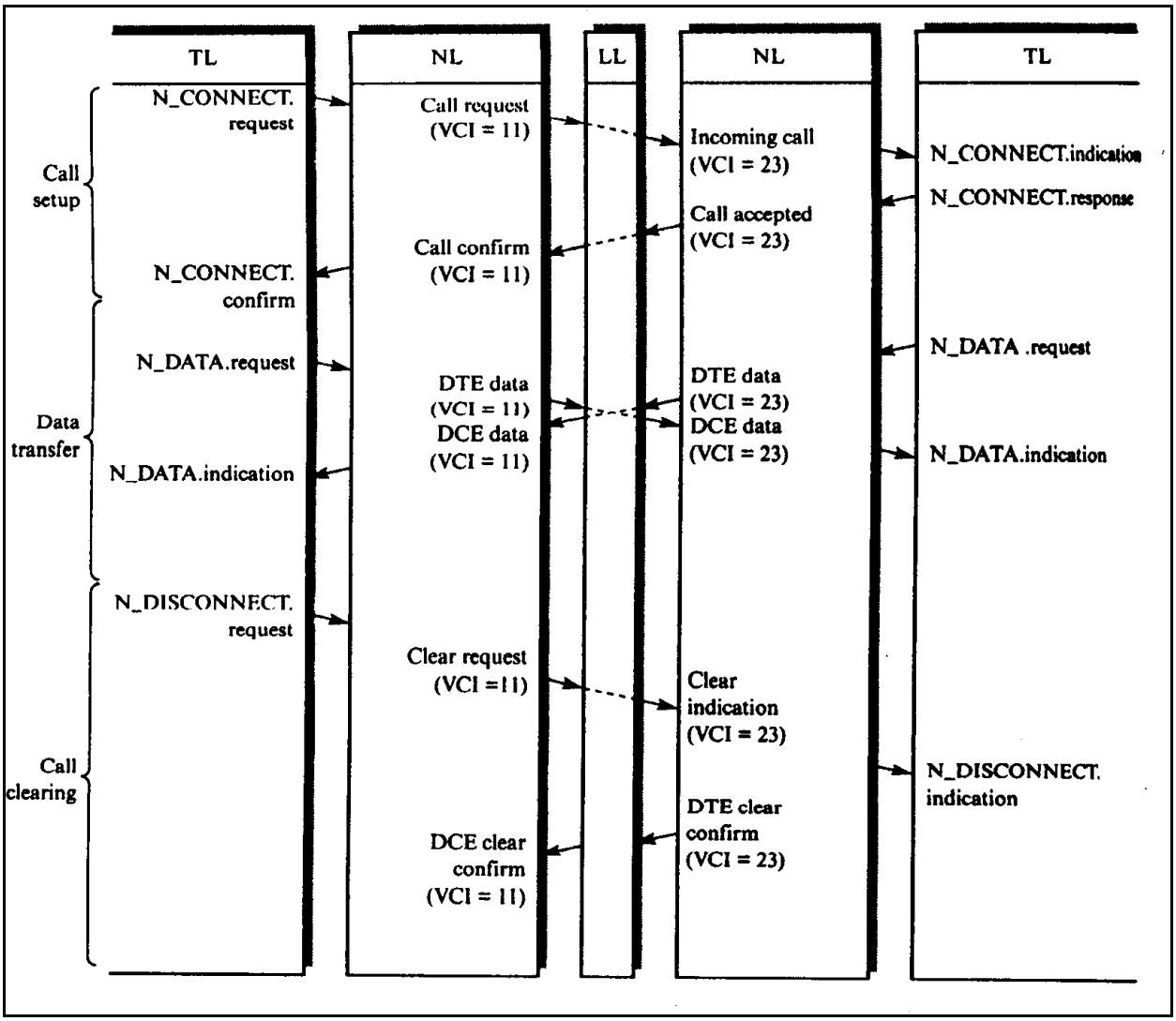
Mapping N.L. Primitives to X.25 Packets cont.



Mapping Primitives to X.25 Packets cont.

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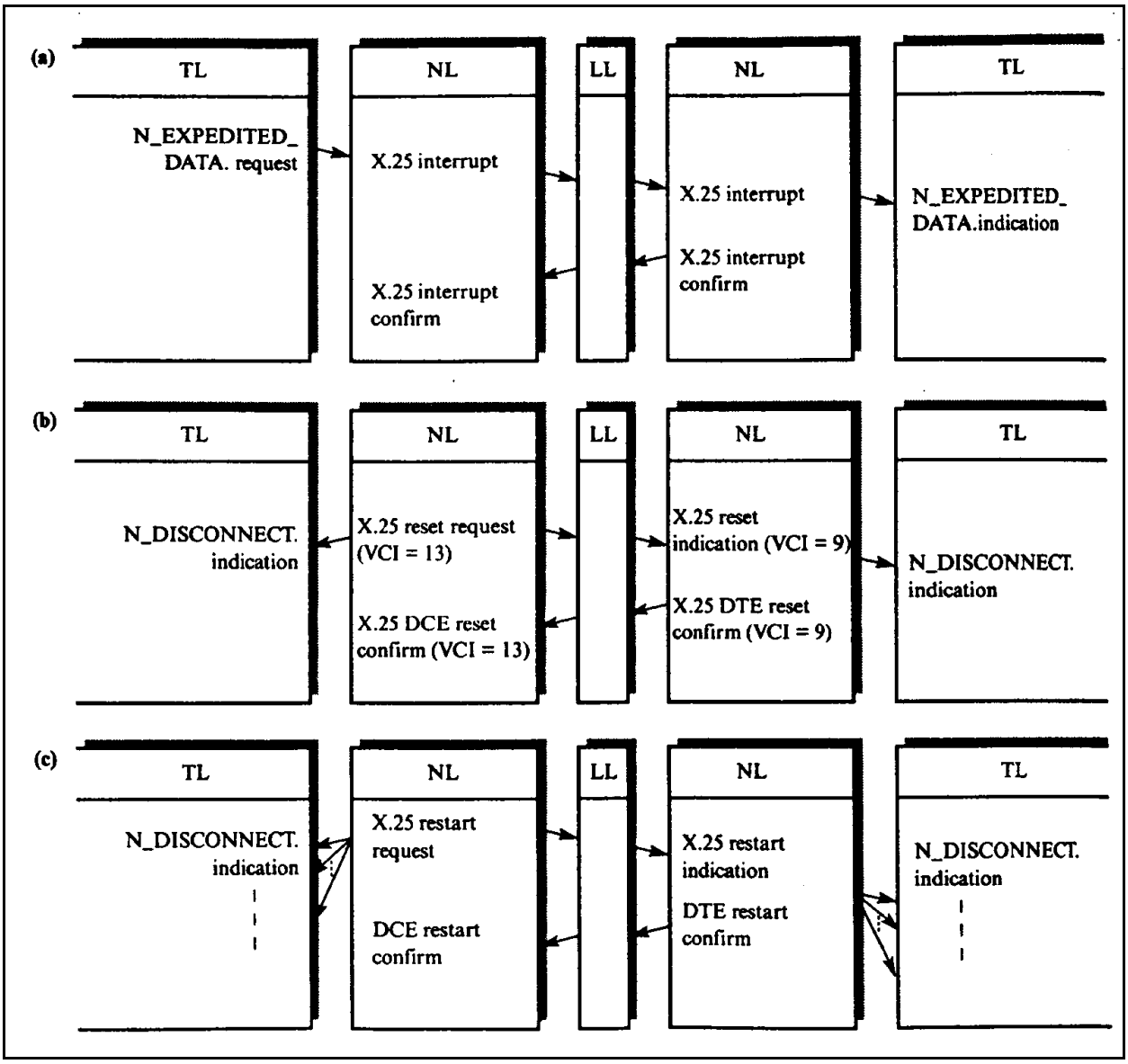
Expedited Data, Reset, & Restart



a) Expedited Data b) Reset c) Restart

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