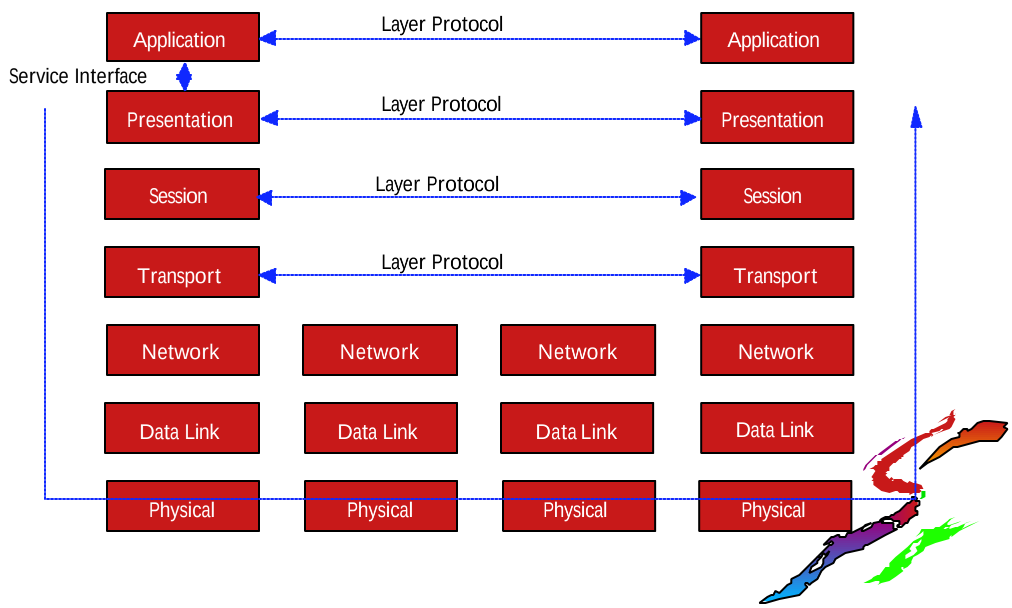
Transport Layer

Dr. G. A. Marin

OSI Reference Model



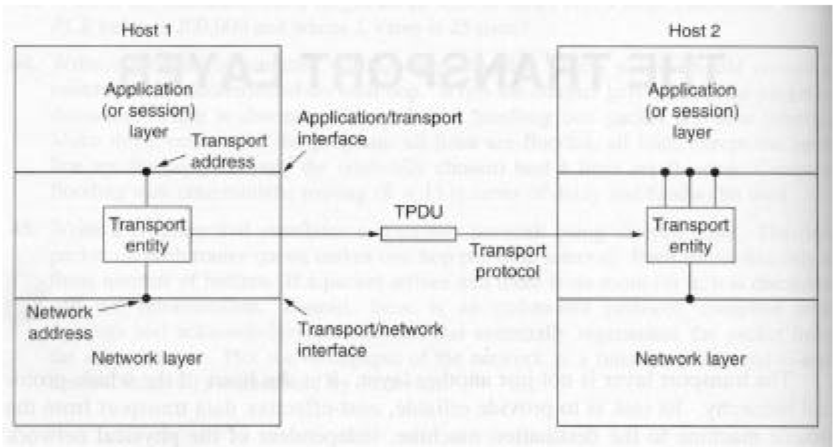
Two Types of Transport Service

- Connection-oriented
  - Sets up connection, sends data, releases connection
  - Reliable, in-sequence delivery (recovers lost or damaged data)
- Connectionless
  - Just sends/receives...
  - No guarantees
- Developers of Internet Applications (email, Web, File Transfer, phone) choose one of the above.

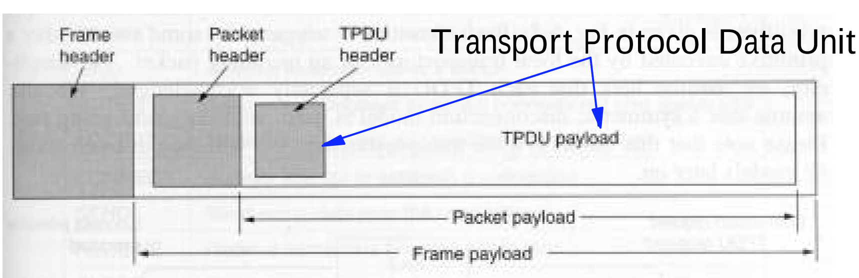
Connection-Oriented vs Connectionless at Layers 2,3,4

- Layer 2 CO may be especially useful on links with high error rates. CO at DLC means a reliable service that retransmits errored or lost frames at layer 2.
- Layer 3 CO or CL service is offerred by the network provider. Quality may differ across Internet, for example. CO at NL means setting up connections before sending data. All data follows same route, etc.
- Layer 4 CO or CL service is offerred to applications by the tranport entities that operate in the end points (hosts). Allows end-stations to deal with poor service, congestion discards, etc.

Transport Service Model



Construction of a Frame



Server/Clients Basic Primitives

- Server executes LISTEN (and blocks)
- Any ready client executes a CONNECT
  - blocks caller process and sends Conn Req to server transport process
- Server transport entity checks that server is on LISTEN, unblocks server, sends Conn Accepted back to client.
- When Conn Accepted TPDU received at client, client unblocked and connection is established.
- Data exchanged using SEND and RECEIVE.
- Transport user sees only primitives LISTEN, CONNECT, SEND, RECEIVE, DISCONNECT.

Basic Connection Steps

- Client application issues a CONNECT
- Client transport entity sends Connection Request (CR) in TPDU
- Server transport entity checks to see Server is blocked on LISTEN
  - then it unblocks server
  - then it sends Connection Accepted (CA) to Client transport entity
- Use SEND and RECEIVE primitives to exchange data.
- Use DISCONNECT to end connection.

Disconnecting

- Asymmetric Disconnect
  - Either transport user may issue the DISCONNECT primitive which results in a DISCONNECT TPDU being sent to the remote transport entity.
  - When TPDU arrives, connection released.
- Symmetric Disconnect
  - One side issues DISCONNECT to indicate no more data to send.
  - Connection not released until both sides issue DISCONNECT primitive.

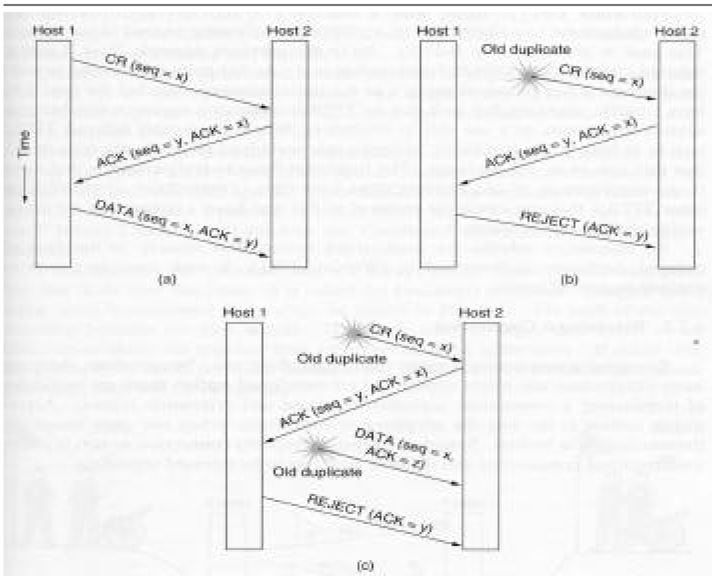
Transport Service Addresses

- When process issues CONNECT primitive, it must specify "to what?"
- Answer is the access point of the service: Transport Service Access Point or TSAP.
  - In Internet these are IP address, port.
- These addresses either "well-known" or are generally available from a name server whose address is well-known.
  - Example: FTP port 21; TELNET port 23

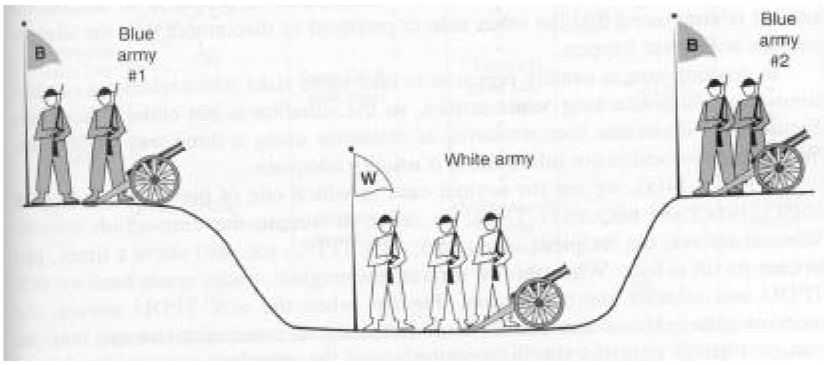
Establishing a Connection

- Complicated because network can lose, store or duplicate packets.
  - Nightmare: packets pop out of network twice - each time requesting transfer of a large sum of money to an account.
- Dealing with delayed duplicates:
  - Change transport address with each request.
  - Number connections with an ID so you know if one is being recreated. (But machines crash...)
  - Better: Kill off aged packets inside the network.
- With bounded packet lifetimes, possible to establish connections safely.

Three-way Handshake



Difficult to Tell if Connect/Disconnect REALLY Happened



Flow Control at Transport Layer

- Why is it needed?
  - network may be unreliable (connectionless)
  - Data Link Flow Control NOT end-to-end (only to receiving network layer)
  - Receiving transport layer may be out of buffers
- Sender buffers: when receiving transport layer cannot guarantee buffer availability. Receiver free to use shared (dynamic) buffering schemes.
- Receiver buffers: when it can guarantee buffer available. Usually dedicated space per connection (max TPDUxwindow size).
  - May be extremely wasteful (single char min).

Buffer Management

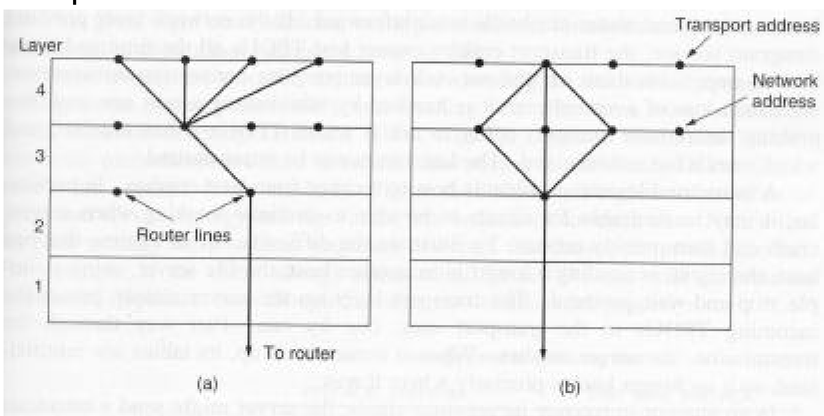
- May vary by traffic type
  - low bandwidth/bursty traffic best handled by dynamic buffer allocation with sender buffering.
  - high-bandwidth traffic may best be handled by dedicated buffers at receiver.
- Sending host generally requests buffers at receiver (collectively or per connection)
- Receiver grants what it can afford and sender keeps track of number of unacknowledged TPDUs vs number of granted buffers.

Dynamic Buffer Allocation

	A	Message	B	Comments
1	→	< request 8 buffers>	→	A wants 8 buffers
2	←	<ack = 15, buf = 4>	←	B grants messages 0-3 only
3	→	<seq = 0, data = m0>	→	A has 3 buffers left now
4	→	<seq = 1, data = m1>	→	A has 2 buffers left now
5	→	<seq = 2, data = m2>	• • •	Message lost but A thinks it has 1 left
6	←	<ack = 1, buf = 3>	←	B acknowledges 0 and 1, permits 2-4
7	→	<seq = 3, data = m3>	→	A has buffer left
8	→	<seq = 4, data = m4>	→	A has 0 buffers left, and must stop
9	→	<seq = 2, data = m2>	→	A times out and retransmits
10	←	<ack = 4, buf = 0>	←	Everything acknowledged, but A still blocked
11	←	<ack = 4, buf = 1>	←	A may now send 5
12	←	<ack = 4, buf = 2>	←	B found a new buffer somewhere
13	→	<seq = 5, data = m5>	→	A has 1 buffer left
14	→	<seq = 6, data = m6>	→	A is now blocked again
15	←	<ack = 6, buf = 0>	←	A is still blocked
16	• • •	<ack = 6, buf = 4>	←	Potential deadlock

Transport Layer Multiplexing

Upward Downward



Recovering from Crashes

- If transport entity is within host (usual), it can easily recover from network/router crashes.
- If host crashes, counters will be reinitialized and host will not know where to begin.
- Suppose host asks client: "What state are you in?" Client says: "Waiting for the ack to TPDU 6." Host thinks it must have received TPDU 5 ok (because it ACKed 5) and asks for 6 again.
- BUT host may have already received TPDU 6 and passed it up to application (written to ap) before sending ACK 6. Just after writing and before ack, it crashed. In this case host would get a DUP of 6.

TCP Service

- Sender and receiver create end points (sockets).
  - Socket numbers consist of host IP address plus 16-bit port number.
  - To obtain TCP service, connection must be established between sockets on each end.
- Port numbers below 256 are called "well-known ports." (RFC 1700)
- All TCP connections are full-duplex, pt-to-pt.
- TCP connection is a byte stream (does not preserve application-level boundaries).

TCP Segments

- Sending and receiving TCP entities exchange data in segments.
  - Segment has a fixed 20-byte header (plus optional data) followed by data bytes.
  - Each segment must fit into the 65,535 byte IP payload max.
  - Each network also supports a maximum transfer unit (MTU).
  - If segment too large for a network, router may divide it into multiple segments (repeats the IP and segment header overhead).

Transport Layer May Support QoS Parameters

- Conection establishment delay
- Connection establishment failure probability
- Throughput
- Transit delay
- Residual error ratio
- Protection
- Priority
- Resilience

Problems

- Chapter 1: 5,7,14,16,18,26,27
- Chapter 3: 1,3,6,12,22,24,28
- Chapter 4: 3,4,19,20,28,40
- Chapter 5: 8,16,19,20,26,28,34,38
- Chapter 6: 1,2,3,6,7,14,22,23,31 through 37 (due Monday, 23rd)