Transport Protocols

Chapter 15 in Stallings 10th Edition

Connection-Oriented Transport Mechanisms

- Two basic types of transport service:

Connection-oriented

- Establishment, maintenance and termination of a logical connection between TS users
- Has a wide variety of applications
- Most common
- Implies service is reliable

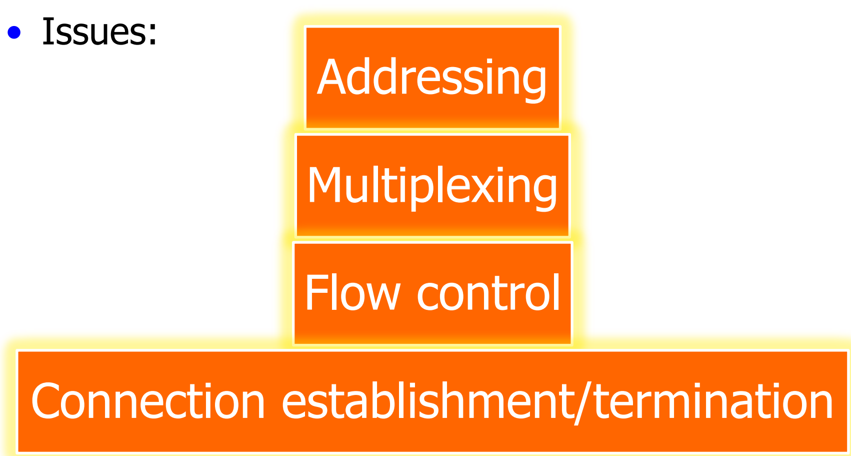
Connectionless or datagram service

Transport Protocols

- Connection Oriented Transport Protocol Mechanisms
  - —Logical connection
  - —Establishment
  - —Maintenance termination
  - —Reliable
  - —e.g. TCP

Reliable Sequencing Network Service

- Issues:

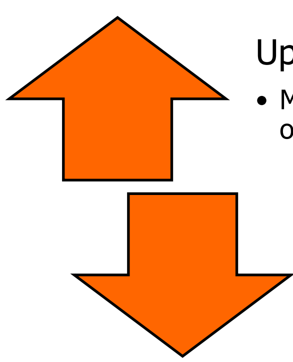


Addressing

- Target user specified by:
  - User identification
    - Usually host, port
      - Called a socket in TCP
    - Port represents a particular transport service (TS) user
  - Transport entity identification
    - Generally only one per host
    - If more than one, then usually one of each type
      - Specify transport protocol (TCP, UDP)
  - Host address
    - An attached network device
    - In an internet, a global internet address
  - Network number

Multiplexing

- Multiple users employ the same transport protocol and are distinguished by port numbers or service access points



Upward multiplexing

- Multiplexing of multiple connections on a single lower-level connection

Downward multiplexing

- Splitting of a single connection among multiple lower-level connections

Flow Control

- Longer transmission delay between transport entities compared with actual transmission time
  - —Delay in communication of flow control info
- Variable transmission delay
  - —Difficult to use timeouts
- Flow may be controlled because:
  - —The receiving user can not keep up
  - —The receiving transport entity can not keep up
- Results in buffer filling up

Alternatives to Flow Control Requirements

Receiving transport entity can:

Do nothing
- Segments that overflow the buffer are discarded
- Sending transport entity will retransmit

Refuse to accept further segments from the network service
- Relies on network service to do the work

Use a fixed sliding window protocol
- With a reliable network service this works quite well

Use a credit scheme
- A more effective scheme to use with an unreliable network service

Credit Scheme

- Greater control on reliable network
- More effective on unreliable network
- Decouples flow control from ACK
  - May ACK without granting credit and vice versa
- Each octet has sequence number
- Each transport segment has in its header:
  - sequence number,
  - acknowledge number and
  - window size

Use of Header Fields

- When sending, seq number is that of first octet in segment
- ACK includes
  - ack number $AN=i$,
  - window number $W=j$
- All octets through seq. num. $SN=i-1$ acknowledged
  - Next expected octet is i
- Permission to send additional window of $W=j$ octets
  - i.e. octets through $i+j-1$

Assume 200 octets of data in each segment, and original credit of 1400

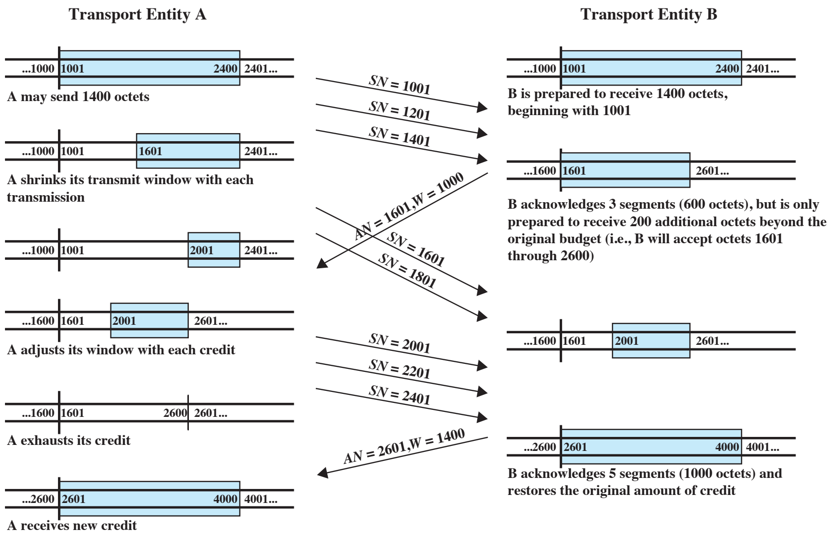


Figure 15.1 Example of TCP Credit Allocation Mechanism

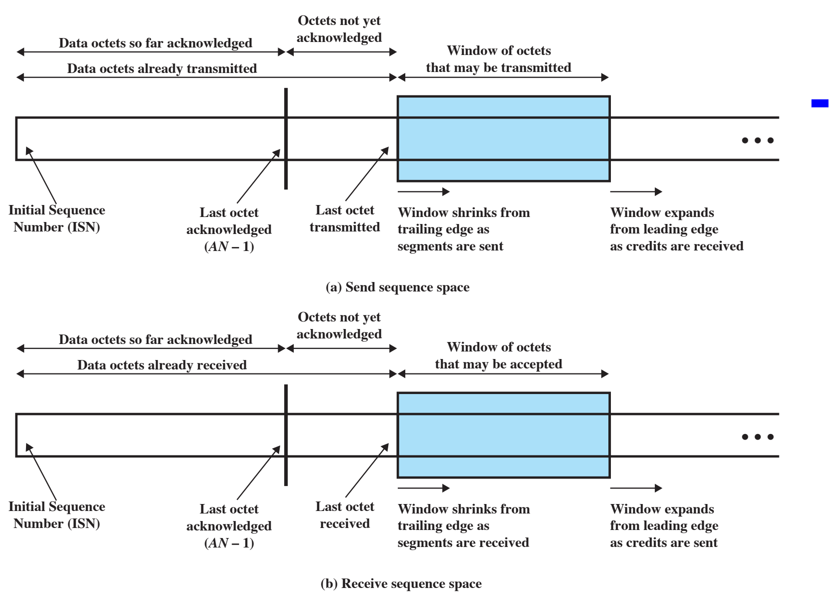


Figure 15.2 Sending and Receiving Flow Control Perspectives

Connection Establishment and Termination

- Serves three main purposes:
  - —Allows each end to assure that the other exists
  - —Allows exchange or negotiation of optional parameters
  - —Triggers allocation of transport entity resources
- Connection establishment is by mutual agreement

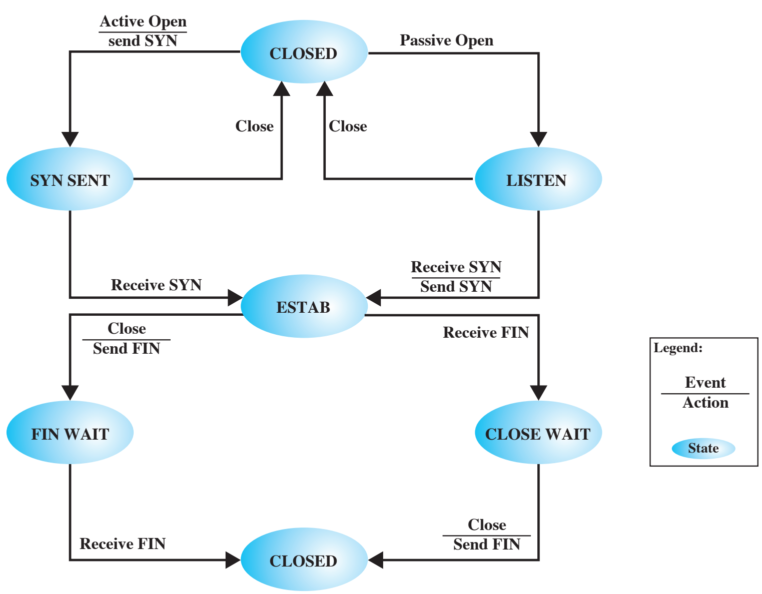


Figure 15.3 Simple Connection State Diagram

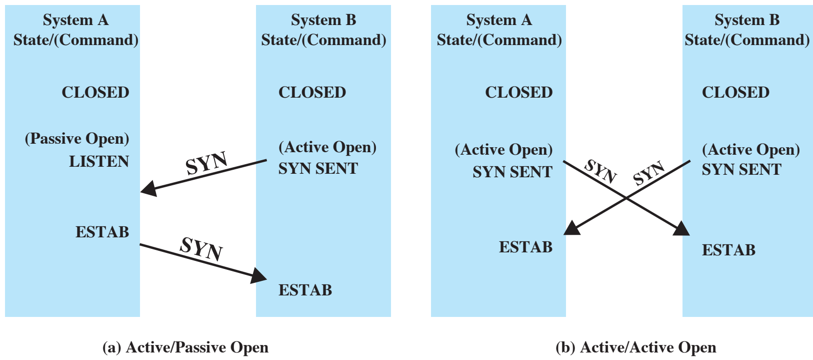


Figure 15.4 Connection Establishment Scenarios

What to do if TS is Not Listening

- Three things can happen
  - —Reject with RST (Reset)
  - —Queue request until matching open issued
  - —Signal **transport service (TS)** user to notify of pending request
    - May replace passive open with accept

Termination

- Either or both sides
- By mutual agreement
- Abrupt termination
- Or graceful termination
  - Close wait state must accept incoming data until FIN received

Unreliable Network Service

Examples:

- Internetwork using IP
- Frame relay network using only the LAPF core protocol
- IEEE 802.3 LAN using the unacknowledged connectionless LLC service

➢ Segments are occasionally lost and may arrive out of sequence due to variable transit delays

Problems

- Ordered Delivery
- Retransmission strategy
- Duplication detection
- Flow control
- Connection establishment
- Connection termination
- Crash recovery

Ordered Delivery

- With an unreliable network service it is possible that segments may arrive out of order
- Solution to this problem is to number segments sequentially
  - —TCP uses scheme where each data octet is implicitly numbered

Retransmission Strategy

- Events necessitating retransmission:

  - Segment may be damaged in transit but still arrives at its destination
  - Segment fails to arrive

- Sending transport does not know transmission was unsuccessful
- Receiver acknowledges successful receipt by returning a segment containing an acknowledgment number

Cont.

Retransmission Strategy (cont.)

- No acknowledgment will be issued if a segment does not arrive successfully
  - Resulting in a retransmit
- A timer needs to be associated with each segment as it is sent
- If timer expires before acknowledgment is received, sender must retransmit

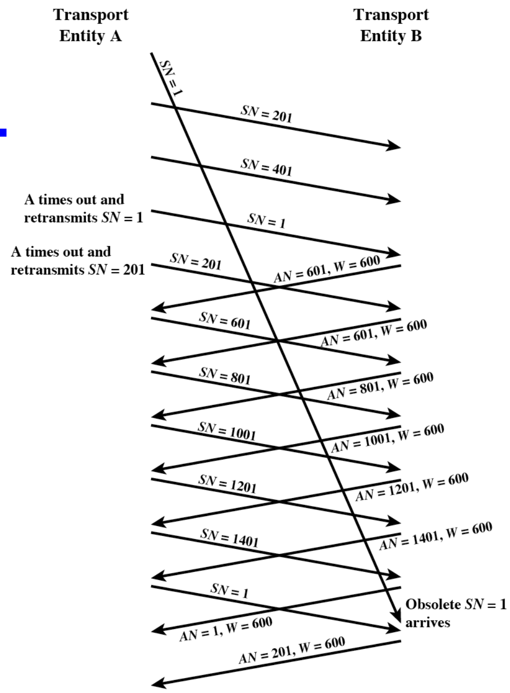
Table 15.1
Transport Protocol Timers

Retransmission timer	Retransmit an unacknowledged segment
MSL (maximum segment lifetime) timer	Minimum time between closing one connection and opening another with the same destination address
Persist timer	Maximum time between ACK/CREDIT segments
Retransmit-SYN timer	Time between attempts to open a connection
`Keepalive timer`	Abort connection when no segments are received

Duplicate Detection

- Receiver must be able to recognize duplicates
- Segment sequence numbers help
- Complications arise if:
  - —A duplicate is received prior to the close of the connection
    - Sender must not get confused if it receives multiple acknowledgments to the same segment
    - Sequence number space must be long enough
  - —A duplicate is received after the close of the connection

Incorrect Duplicate Detection



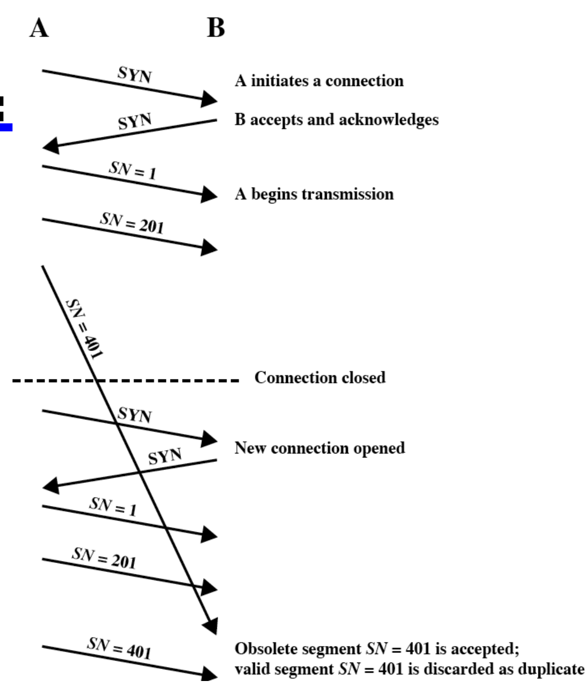
Flow Control

- Future acknowledgments will resynchronize the protocol if an ACK/CREDIT segment is lost
- If no new acknowledgments are forthcoming the sender times out and retransmits a data segment which triggers a new acknowledgment
- Still possible for deadlock to occur

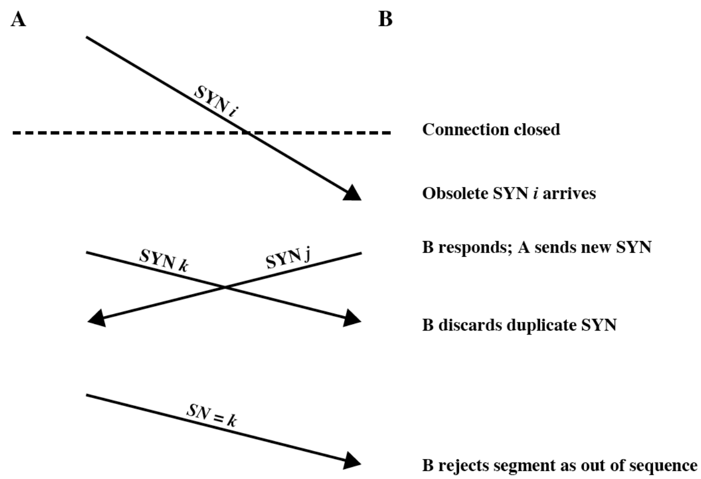
Connection Establishment

- Two way handshake
  - — A sends SYN, B replies with SYN
  - — Lost SYN handled by re-transmission
    - Can lead to duplicate SYNs
  - — Ignore duplicate SYNs once connected
- Lost or delayed data segments can cause connection problems
  - — Segment from old connections
  - — Start segment numbers fare removed from previous connection
    - Use SYN i
    - Need ACK to include i
    - Three Way Handshake

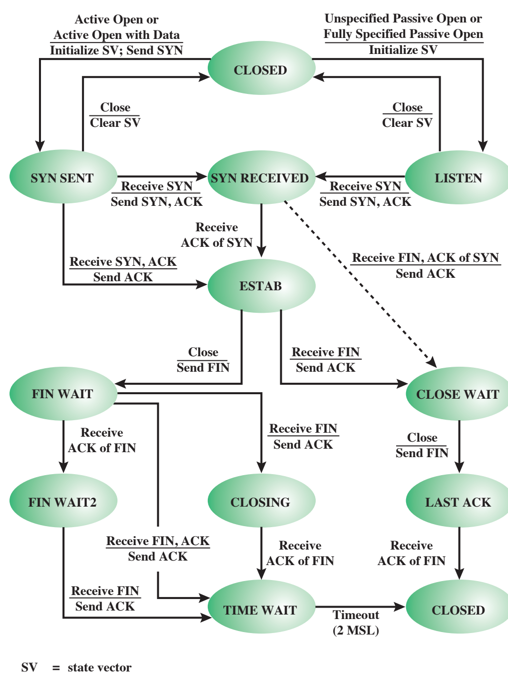
Two Way Handshake: Obsolete Data Segment



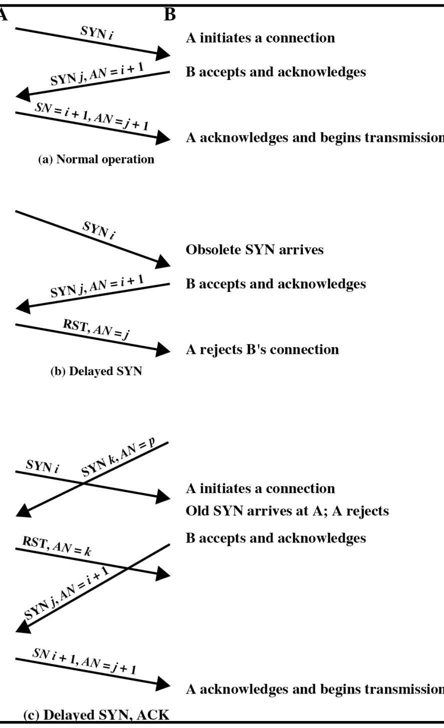
Two Way Handshake: Obsolete SYN Segment



Three Way Handshake: State Diagram



Three Way Handshake: Examples



Connection Termination

- Two-way handshake was found to be inadequate for an unreliable network service
- Out of order segments could cause the FIN segment to arrive before the last data segment
  - To avoid this problem the next sequence number after the last octet of data can be assigned to FIN
  - Each side must explicitly acknowledge the FIN of the other using an ACK with the sequence number of the FIN to be acknowledged

Failure Recovery

- When the system that the transport entity is running on fails and subsequently restarts, the state information of all active connections is lost
- Connection is half open
  - Side that did not crash still thinks it is connected
- Close connection using persistence timer
  - Wait for ACK for (time out) * (number of retries)
  - When expired, close connection and inform user
- Send RST *i* in response to any *i* segment arriving
- User must decide whether to reconnect
  - Problems with lost or duplicate data

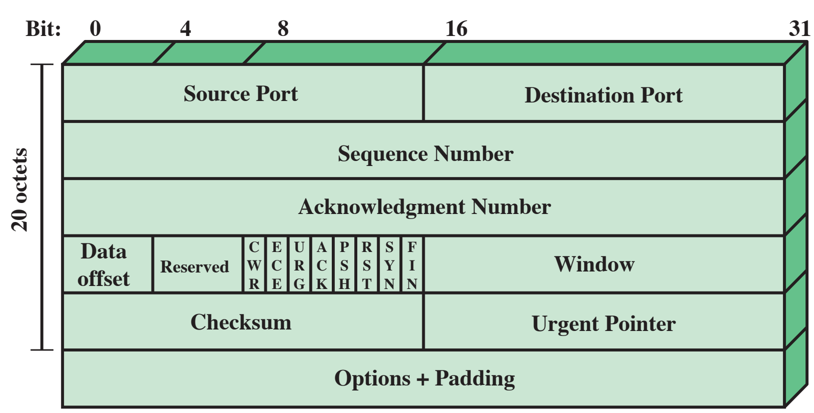
TCP & UDP

- Transmission Control Protocol (TCP)
  - Connection oriented
  - RFC 793
- User Datagram Protocol (UDP)
  - Connectionless
  - RFC 768

TCP Services

- Reliable communication between pairs of processes
- Across variety of reliable and unreliable networks and internets
- Two labeling facilities
  — Data stream push
    - TCP user can require transmission of all data up to push flag
    - Receiver will deliver in same manner
    - Avoids waiting for full buffers
  — Urgent data signal
    - Indicates urgent data is upcoming in stream
    - User decides how to handle it

TCP Header



TCP Mechanisms

- Can be grouped into:

Connection establishment
- Always uses a three-way handshake
- Connection is determined by host and port

Data transfer
- Viewed logically as consisting of a stream of octets
- Flow control is exercised using credit allocation

Connection termination
- Each TCP user must issue a CLOSE primitive
- An abrupt termination occurs if the user issues an ABORT primitive

Implementation Policy Options

- Send
- Deliver
- Accept
- Retransmit
- Acknowledge

Send Policy

- In the absence of both pushed data and a closed transmission window a sending TCP entity is free to transmit data at its own convenience
- TCP may construct a segment for each batch of data provided or it may wait until a certain amount of data accumulates before constructing and sending a segment
- Infrequent and large transmissions have low overhead in terms of segment generation and processing
- If transmissions are frequent and small, the system is providing quick response

Deliver

- In absence of push, deliver data at own convenience
  - —May deliver as each in order segment received
  - —May buffer data from more than one segment

Accept Policy

- If segments arrive out of order the receiving TCP entity has two options:

In-order

- Accepts only segments that arrive in order; any segment that arrives out of order is discarded
- Makes for simple implementation but places a burden on the networking facility
- If a single segment is lost in transit, then all subsequent segments must be retransmitted

In-window

- Accepts all segments that are within the receive window
- Requires a more complex acceptance test and a more sophisticated data storage scheme

Retransmit Policy

- Retransmission strategies:

First-only
- Maintain one retransmission timer for entire queue
- Efficient in terms of traffic generated
- Can have considerable delays

Batch
- Maintain one retransmission timer for entire queue
- Reduces the likelihood of long delays
- May result in unnecessary retransmissions

Individual
- Maintain one timer for each segment in the queue
- More complex implementation

Acknowledge Policy

- Timing of acknowledgment:

Immediate

- Immediately transmit an empty segment containing the appropriate acknowledgement number
- Simple and keeps the remote TCP fully informed
- Limits unnecessary retransmissions
- Results in extra segment transmissions
- Can cause a further load on the network

Cumulative

- Wait for an outbound segment with data on which to piggyback the acknowledgement
- Typically used
- Requires more processing at the receiving end and complicates the task of estimating round-trip time

UDP

- User datagram protocol
  - —RFC 768
- Connectionless service for application level procedures
  - —Unreliable
  - —Delivery and duplication control not guaranteed
- Reduced overhead
  - —e.g. network management

UDP Header

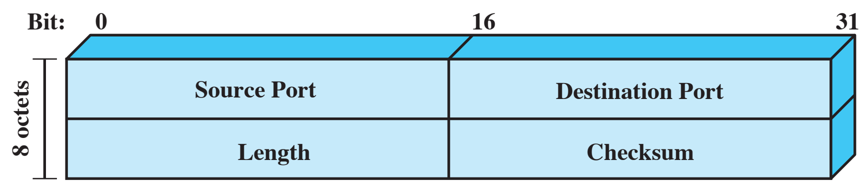


Figure 15.11 UDP Header

Summary

- Connection-oriented transport protocol mechanisms
  - —Reliable sequencing network service
  - —Unreliable network service
- UDP
- TCP
  - —Services
  - —Header format
  - —Mechanisms
  - —Implementation policy options