Transport Protocols

ITS323: Introduction to Data Communications

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Contents

Transport Protocols

- Send data between application processes on source and destination hosts
- End-to-end (or host-to-host) communications
- Internet transport protocols: TCP, UDP, SCTP, DCCP (and other legacy or domain-specific protocols)
- Transmission Control Protocol: connection-oriented, error control, flow control, congestion control
- User Datagram Protocol: unreliable connection-less delivery (same as IP)
- Addressing is common to all transport protocols (TCP, UDP, SCTP, DCCP)
  - Port is abstract view of end-point for communications; actual end-point is process

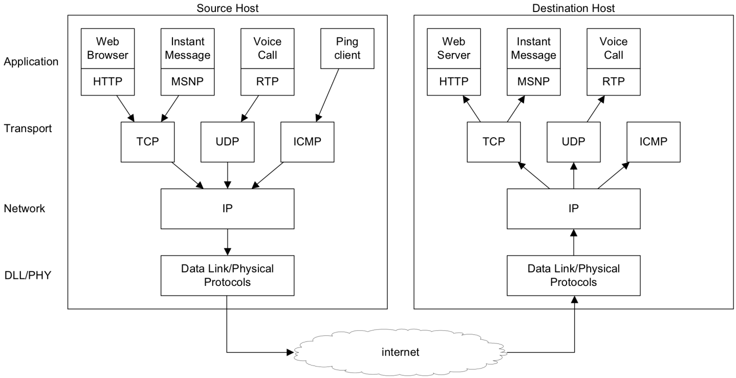
Internet Applications

- Most Internet applications follow a client/server model of initiating communication:
  1. Client initiates communication
  2. Server waits for client to initiate communication
  3. Once the communication is initiated, data can flow in both directions (client to server and server to client)
- For client to initiate communication to server, the client needs to know IP address of server, and:
  - Protocol number: identifies transport protocol used by both hosts
    - 8-bit number; e.g. 6 = TCP, 17 = UDP; 1 = ICMP

    `http://www.iana.org/assignments/protocol-numbers/`
  - Port number: identifies application process on a host
    - 16-bit number; 0–1023 well-known ports; 1024–49151 registered ports; 49152 dynamic/private ports

    `http://www.iana.org/assignments/port-numbers/`

Multiple Applications, Multiple Transport Protocols



Contents

User Datagram Protocol

- UDP is a unreliable connection-less transport protocol
- Takes Data from the application layer, attaches a UDP header, and delivers to IP
- UDP provides checksum over the packet
- UDP segments may be: lost, arrive out of order, duplicated, arrive in error (application that uses UDP must deal with this)
- UDP is simple (standard describes it in 4 pages)
- UDP is used by applications which:
  - Require simplicity, e.g. TFTP, network management in embedded devices
  - Don't require reliability, e.g. voice and video applications, network management
  - Require low overheads, e.g. voice and video applications (require low delay)

UDP Segment

0	16	31
Source Port	Destination Port	
Total Length	Checksum	
Data		

8 Bytes

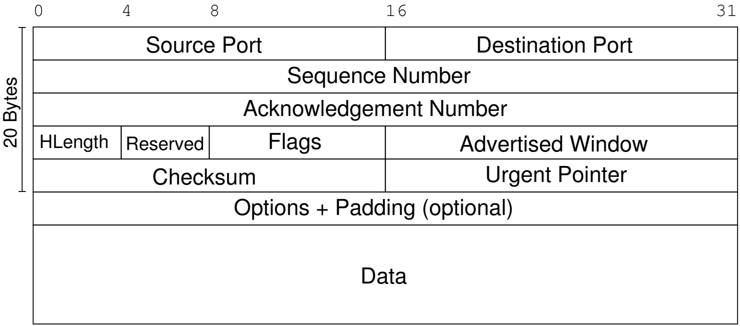
- 8 Byte header plus data
- Length is count of bytes in header and data
- Checksum calculated over UDP header, UDP data, some parts of IP header (e.g. addresses, protocol)

Contents

Transmission Control Protocol

- Most commonly used transport protocol today
  - Web browsing, email, file sharing, instant messaging, file transfer, database access, proprietary business applications, some multimedia applications (at least for control purposes), ...
- Services provided by TCP:
  - Stream-oriented: TCP treats data from application as continuous stream of bytes
  - Connection-oriented data transfer
  - Buffered transfer
  - Full duplex connection
  - Reliabilty (error control)
  - Flow control
  - Congestion control

TCP Segment



- Header contains 20 bytes, plus optional fields
- Optional fields must be padded out to multiple of 4 bytes

TCP Segment Fields

- Source/Destination port
- Sequence number of the first data byte in this segment (or ISN)
- Acknowledgement number: sequence number of the next data byte TCP expects to receive
- Header Length: Size of header (measured in 4 bytes)
- Window: number of bytes the receiver is willing to accept (for flow control)
- Checksum: error detection on TCP segment
- Urgent pointer points to the sequence number of the last byte of urgent data in the segment
- Options: such as maximum segment size, window scaling, selective acknowledgement, ...

TCP Segment Flags

- Flags (1 bit each, if 1 the flag is true or on):
- CWR: Congestion Window Reduced
- ECE: Explicit Congestion Notification Echo
- URG: segment carries urgent data, use the urgent pointer field; receiver should notify application program of urgent data as soon as possible
- ACK: segment carries ACK, use the ACK field
- PSH: push function
- RST: reset the connection
- SYN: synchronise the sequence numbers
- FIN: no more data from sender

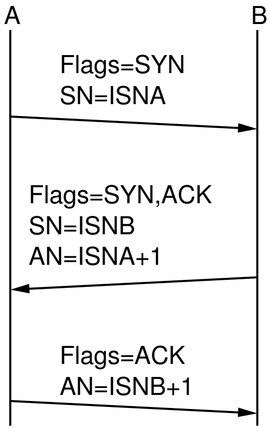
TCP Sequence Numbers

- TCP uses 32-bit sequence numbers to keep track of data sent and receiver (error control, flow control, congestion control)
- Upon connection establishment, Initial Sequence Numbers are chosen by each side
- ISN does not have to be 0; usually larger than last sequence number used in previous connection
- Sequence numbers used in each direction are independent
- Each Byte of data has a sequence number relative to the ISN

TCP Connection Establishment

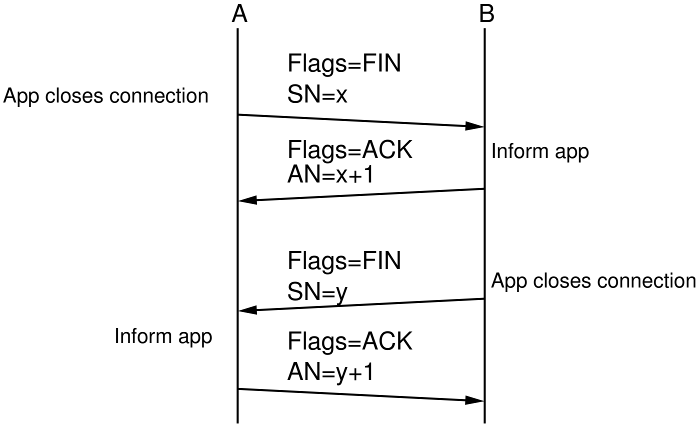
- What is the purpose of connection establishment?
  - Allows each end to assure that the other exists
  - Allows exchange or negotiation of optional parameters, specifically syncronise initial sequence numbers
  - Triggers the allocation of resources for the connection (e.g. allocate buffer space in memory)
- TCP uses a three-way handshake: SYN-SYN/ACK-ACK
- (A two-way handshake: duplicate segments from old connections may cause errors)

TCP Three-Way Handshake



- Initiator A selects an Initial Sequence Number, *ISNA*
- B acknowledges *ISNA* and also chooses its own *ISNAB*
- Data transfer can start after *ISNB* is ACKed
- Optionally, 3rd segment can contain data

TCP Connection Close

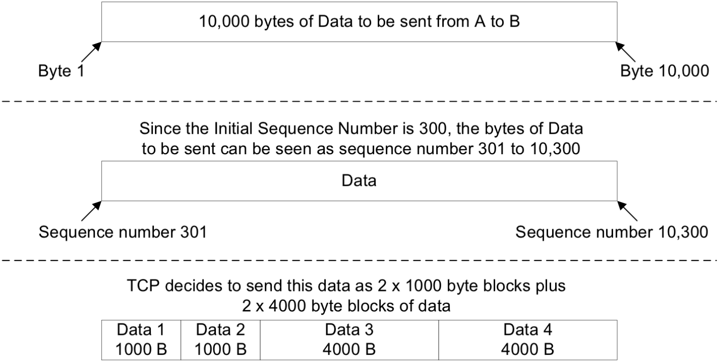


- Both sides should independently close the connection
- E.g. A closes connection, B can still send data to A
- Other approaches are possible, e.g. abort using RST flag

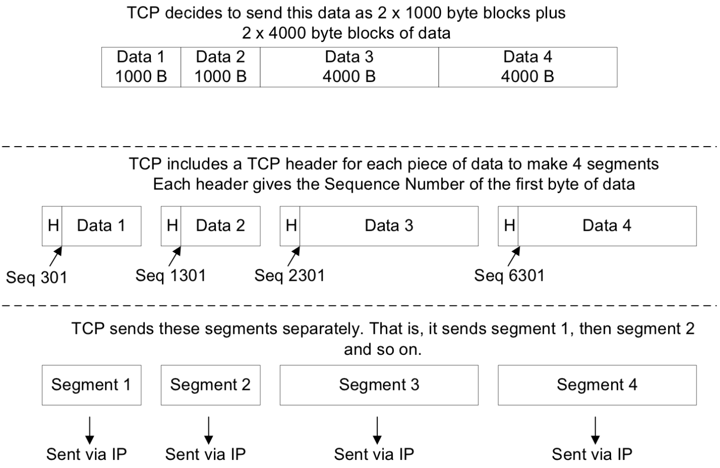
TCP Data Transfer

- TCP uses sliding window mechanism for efficient data transfer
- TCP specifies algorithms for error, flow and congestion control
- Some details are implementation dependent
- E.g. when to send data? when to send an ACK? when is data delivered to application?
- TCP offers stream-oriented data transfer service
  - Application delivers multiple messages to TCP during connection
  - TCP treats all messages as continuous stream of bytes
  - TCP implementation chooses when to send the bytes in a segment

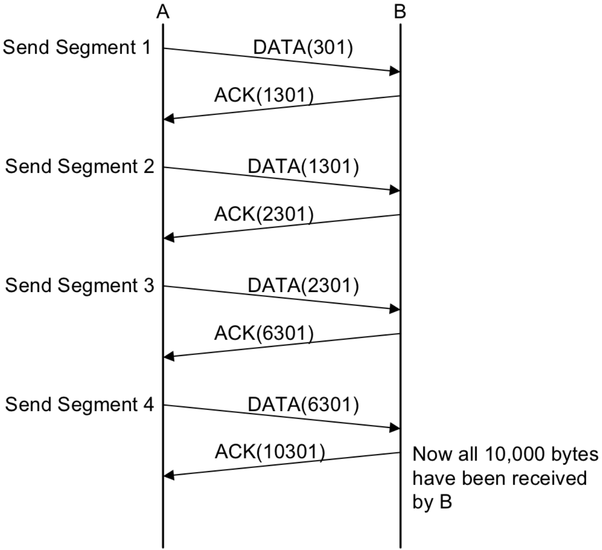
TCP Segment Example



TCP Segment Example (continued)



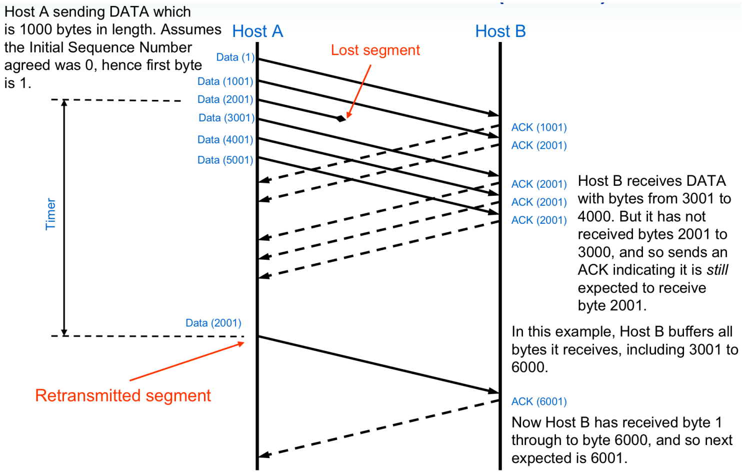
TCP Data Transfer Example



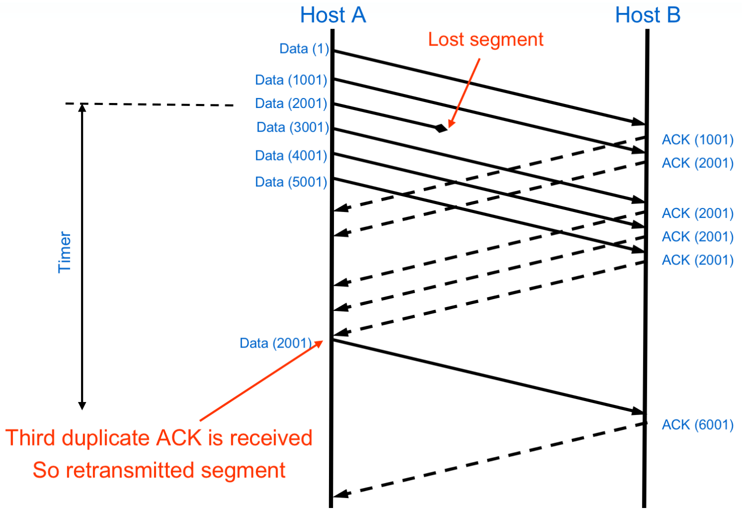
TCP Error Control

- TCP uses selective-retransmission style ARQ
- ACK numbers indicate next in-order sequence number expected
- Receiver buffers out-of-order data received
- If data segment sent is not implicitly ACKed within timeout, retransmit segment
- Cumulative ACKs can be used; ACK number implicitly acknowledges multiple received segments
- Optimization of normal retransmission: Fast Retransmit
  - Timeouts generally have to be long to handle varying round trip times (RTTs)
  - Waiting for a timeout may lead to poor efficiency
  - If 3 duplicate ACKs are received, retransmit segment

TCP Basic Retransmit Example



TCP Fast Retransmit Example



TCP Flow Control

- Aim: prevent sender from overflowing buffers of receiver
- Must consider variable end-to-end round trip times (RTT)
- Uses sliding-window flow control
- Receiver notifies sender amount of buffer space available in Advertised Window field
- Sender cannot send more than advertised window of bytes

TCP Congestion Control

- Aim: prevent sender from overflowing the routers
- Assume segment loss is indicator of congestion
- Decrease sending rate if segment loss detected
- Increase sending rate if ACK received
- Various algorithms/options for how to decrease/increase sending rate