UDP, TCP (Part I)

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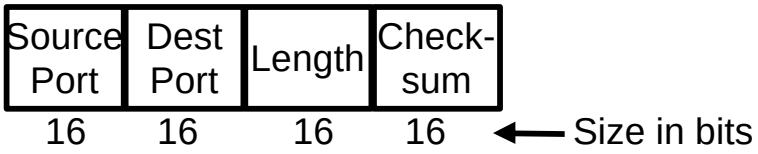
- UDP: connectionless, end-to-end service
- UDP Servers, Interaction with ARP
- TCP features, Header format
- Connection Establishment
- Connection Termination
- TCP options
- TCP Servers

Ref: Chap 11, 17,18; RFC 793, 1323

User Datagram Protocol (UDP)

- Connectionless end-to-end service
- No flow control. No error recovery (no acks)
- Provides port addressing
- Error detection (Checksum) optional. Applies to pseudo-header (same as TCP) and UDP segment. If not used, it is set to zero.
- Used by SNMP, DNS, TFTP etc



More UDP

- Port number: Used for (de)multiplexing. Client ports are ephemeral (short-lived). Server ports are “well known”.
- UDP checksum similar to IP header checksum, but includes a pseudo-header (to help check source/destination). Fig 11.3
- UDP checksum optional, but RFC 1122/23 (host reqts) requires it to be enabled
- Application message is simply encapsulated and sent to IP => can result in fragmentation. Newer systems use some path MTU discovery algorithms at the IP layer.

UDP effects

- When UDP datagram fragments at the host, each fragment may generate an ARP request (results in an ARP reply: ***ARP flooding)***
  - RFC 1122/23 limits max ARP rate to 1 request per second, and requires the ARP Q to be at least of size one
- Datagram truncation possible at destination if dest app not prepared to handle that datagram size ! (note: TCP does not have this problem because it has no message boundaries)
- UDP sources ignore source quench messages => can't respond to packet losses.

UDP Servers

- **Client-Server architecture**: basis for most distributed apps today (eg Web, telnet, ftp)
- Most UDP servers are *"iterative"* => a single server process receives and handles incoming requests on a *"well-known"* port.
- Can filter client requests based on incoming IP address, client IP address, incoming port address, or wild card filters
- Port numbers may be reused, but packet is delivered to at most one end-point.
- Queues to hold requests if server busy

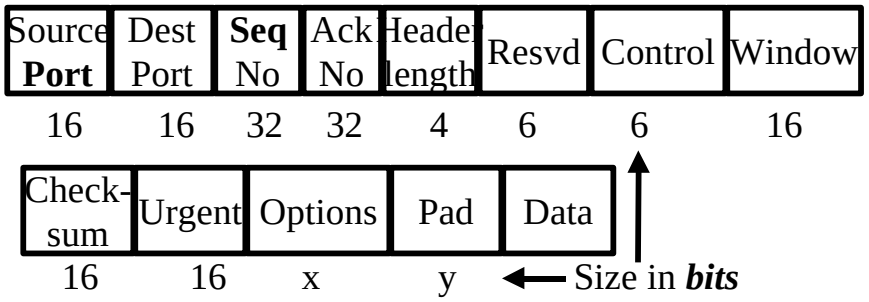
TCP: Key features

- Connection-oriented
- Point-to-point: 2 end-points (no broadcast or multicast)
- Reliable transfer: Data is delivered in-order
- Full duplex communication
- Byte-stream I/f: sequence of octets
- Reliable startup: Data on old connection does not confuse new connections
- Graceful shutdown: Data sent before closing a connection is not lost. Reset or immediate shutdown also possible.

Reliability

- Reliability provided by:
  - Reliable connection startup: Data on old connection does not confuse new connections
  - Graceful connection shutdown: Data sent before closing a connection is not lost.
  - Data segmented for transmission and acknowledged by destination. Timeout + Retransmission provided if data unacknowledged
  - Checksum provided to catch errors.
  - Resequencing of out-of-order data; discarding of duplicate data.
  - Window flow control => sender cannot overrun receiver buffers

TCP Header Format



Also see fig: 17.2 in text

TCP Header

- Source Port (16 bits): Identifies source user process

  20 = FTP, 23 = Telnet, 53 = DNS, 80 = HTTP, ...
- Destination Port (16 bits)
- Sequence Number (32 bits): Sequence number of the first byte in the segment. If SYN is present, this is the initial sequence number (ISN) and the first data byte is ISN+1.
- Ack number (32 bits): Next byte expected

- Header length (4 bits): Number of 32-bit words in the header. 4 bits => max header size is 60 bytes
- Reserved (6 bits)
- Control (6 bits)

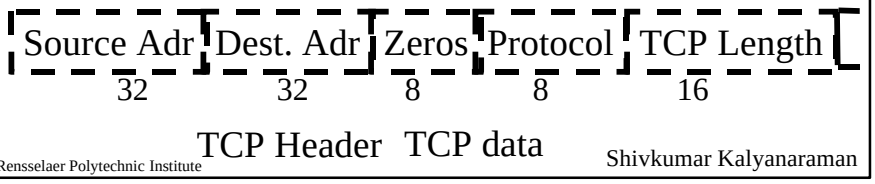
- Window (16 bits): Will accept [Ack] to [Ack]+[window]

TCP Header (Cont)

- Checksum (16 bits): covers the segment + pseudo header. Protection from mis-delivery.
- Urgent pointer (16 bits): Points to the byte following urgent data. Lets receiver know how much data it should deliver right away.
- Options (variable):
  Max segment size (does not include TCP header, default 536 bytes), Window scale factor, Selective Ack permitted, Timestamp, No-Op, End-of-options

TCP Checksum

- Checksum is the 16-bit one's complement of the one's complement sum of a pseudo header, the TCP header, and the data, (padded with zero octets at the end if necessary to make a multiple of two octets.)
  - Checksum field filled with zeros initially
- Pseudo header (similar to UDP) used in calculations, but not transmitted. RFC 1071.



Connection Establishment

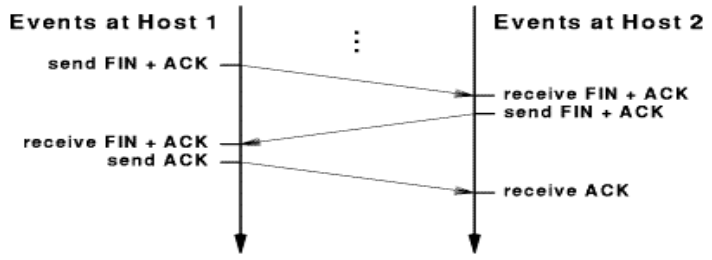
- Fig 18.3
- Client sends SYN, with an initial sequence number (ISN) and a Max Segment Size (MSS). Called ***"active open".***
- Server acks the SYN (for the *forward connection*), and also sets the SYN bit, with its own ISN (for the *reverse connection*). Called ***"passive open".***
- Client acks the reverse direction SYN.
- 3 segments transmitted.

Connection Termination

- Fig 18.3 again, also fig 18.5
- Client sends FIN. Server acks this and notifies its application. However it can keep its half-connection open. Each connection closed separately.
- Server app issues a “close” and server sends FIN to client. Client acks this.
- 4 segments transmitted.

Three-Way Handshake

- 3-way handshake: necessary and sufficient for unambiguous setup/teardown even under conditions of loss, duplication, and delay



More Connection Establishment

- **Socket**: BSD term to denote an IP address + a port number.
  - A connection is fully specified by a ***socket pair*** i.e. the source IP address, source port, destination IP address, destination port.
- Initial Sequence Number (ISN): counter maintained in OS.
  - BSD increments it by 64000 every 500ms or new connection setup => time to wrap around < 9.5 hours.

- SYN pkt lost => retransmitted. Exponential timeout backoff (6, 12, 24 s etc) Connection timeout is 75 s.
- Timer granularity is 500 ms => first timeout between 5.5 and 6s. See Fig. 18.7

MSS

- Largest “chunk” sent between TCPs.
  - Default = 536 bytes.
  - Announced in connection establishment. Not negotiated.
  - Different MSS possible for forward/reverse paths.
  - Does not include TCP header
- Many BSD systems restrict MSS to be multiples of 512 bytes: inefficient.
- Path MTU restricts size of MSS further.

Half close, Half open, Reset

- Possible for one end to close while the other end sends data. Used in “rsh” command. Fig 18.10, 18.11
- Half-open: one side crashed and lost memory of connection while other side thinks connection is open. Usually connection is reset upon communication.
- Reset => used to abort connection. Queued data (if any) is dumped.
- Orderly release => FIN sent after queued data transmitted.

TCP state transition diagram

- Figure 18.12: client (dark line) , server (dashed line) transitions.
- 2MSL wait: wait for final segment to be transmitted before releasing connection (typically 2 min)
  - Socket *pair* cannot be reused during 2MSL
  - Delayed segments dropped
- Conn Establishment: SYN_SENT, SYN_RCVD, ESTABLISHED, LISTEN
- Close: FIN_WAIT_1, FIN_WAIT_2, CLOSING, TIME_WAIT, CLOSE_WAIT, LAST_ACK

Effect of 2MSL wait

- Can't kill server & restart immediately to use the same well known port (1-4 min!)
- Reason: TCP cannot reallocate the socket pair (i.e. the connection) till 2MSL.
- If you kill client and restart, it will get a different port
- 2MSL wait protects against delayed segments from the previous "incarnation" of the connection.
- If server crashes and reboots within 2 MSL wait, it is still safe because RFC 793 prevents having connections for 1 MSL after reboot.

Simultaneous open/close

- Figs 18.17 and 18.19
- Simultaneous open is very rare. Requires same socket **pair** i.e. both the ports must be well known too.
  - Two simultaneous telnets (A to B and B to A) will not create this because client ports are not well-known.
- Possible in long RTT cases
- Requires 4 messages

TCP Servers

- Most TCP servers are *concurrent* i.e. separate process to handle each client - for ease of connection management
- Server listens to well-known port.
  - Socket pair distinguishes connections
  - A separate "endpoint" in the ESTABLISHED state is associated with each connection
  - One endpoint is used to listen (LISTEN state) for new connections

TCP Servers (Contd)

- Endpoints in the ESTABLISHED state cannot receive SYN packets
- Possible to wildcard or select specific interfaces (local IP addresses) to listen to.
- Multiple connection requests => backlog queue of connections established but new process not yet created by server to handle it.
- Queue full => send RESET to new connection requests

Summary

- UDP is connectionless and simple. No flow/error control.
- TCP provides reliable full-duplex connections.
- TCP state diagram, 3-way handshake, Options
- UDP and TCP servers