# 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

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### **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

				_
Source	Dest	Length	Check-	
Port	Port	Lengin	sum	
16	16	16	16	←Size in bits

#### 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.

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### **UDP** and ARP

- 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

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#### Other UDP effects

- 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.

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# **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 Shivkumar Kalyanaraman **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. Shivkumar Kalyanaraman Reliability □ Reliability provided by: □ Reliable connection startup: Data on old connection does not confuse new connections □ Graceful connection shutdown: Data sent before

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duplicate data.

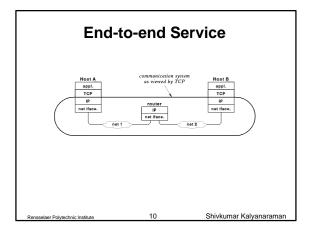
receiver buffers

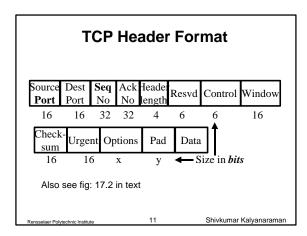
closing a connection is not lost.

□ Data segmented for transmission and acknowledged by destination. Timeout + Retransmission provided if data unacknowledged

□ Resequencing of out-of-order data; discarding of

□ Window flow control => sender cannot overrun





### **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

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□ 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) □ URG ACK PSH RST SYN FIN □ Window (16 bits): Will accept [Ack] to [Ack]+[window] □ 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    Checksum   14   Strokumer feligierance.	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 citests 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.  Source Adri Dest. Adr Zeros Protocol TCP Length [Source Adri Dest. Adr Jess. Adr Jess. Adr Zeros Protocol TCP Length [Source Adri Dest. Adr Jess. Add Jess. Adr Je	words in the header. 4 bits => max header size is 60 bytes  Reserved (6 bits)  URG ACK PSH RST SYN FIN  Window (16 bits): Will accept [Ack] to [Ack]+[window]  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  14 Strükunar Kalganaraman  TCP Checksum  15 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, the TCP header is made to UDP) used in calculations, but not transmitted. RFC 1071.  Source Adr Dest. Adr Zeros Protocol TCP Length TcP Len	words in the header. 4 bits => max header size is 60 bytes  Reserved (6 bits)  Control (6 bits)  URG ACK PSH RST SYN FIN  Window (16 bits): Will accept [Ack] to [Ack]+[window]	
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#### **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.

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### **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.
- $\hfill \square$  4 segments transmitted.

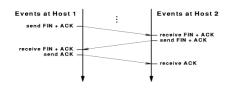
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### **Three-Way Handshake**

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



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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.	
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□ 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	
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MSS	
□ Largest "chunk" sent between TCPs.	
□ Default = 536 bytes.	
□ Announced in connection establishment.	
Not negotiated.	
□ Different MSS possible for forward/reverse paths.	
□ Does <u>not</u> include TCP header	
□ Many BSD systems restrict MSS to be	
multiples of 512 bytes: inefficient.  □ Path MTU restricts size of MSS further.	
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# 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. Shivkumar Kalyanaraman 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 23 Shivkumar Kalyanaraman 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

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## **TCP Options**

Kind	Length	Meaning
0	1	End of Valid options in header
1	1	No-op
2	4	Maximum Segment Size
3	3	Window Scale Factor
8	10	Timestamp

- □ End of Options: Stop looking for further option
- □ No-op: Ignore this byte. Used to align the next option on a 4-byte word boundary

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### **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

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## **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

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#### 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

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