Transport Reliability: Connection Management and TCP

10/14/2009

Admin.: PS2

proj-sol:

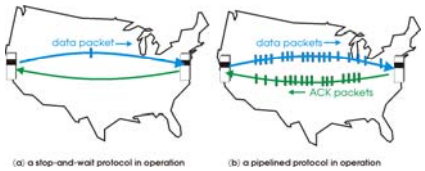
```
 129  400  3045 FishThread.java
 388 1457 12873 Node.java
  51  167  1145 PingRequest.java
  83  250  2106 SimpleTCPSockSpace.java
 181  605  5248 TCPManager.java
 889 3088 26381 TCPSock.java
  60  149  1316 TCPSockID.java
 123  382  3866 TransferClient.java
 147  500  5059 TransferServer.java
2051 6998 61039 total
```

proj:

```
 129  400  3045 FishThread.java
 341 1301 11313 Node.java
  51  167  1145 PingRequest.java
  50  128   909 TCPManager.java
 132  460  3146 TCPSock.java
 123  382  3866 TransferClient.java
 147  500  5059 TransferServer.java
 973 3338 28483 total
```


Recap: Sliding Window Protocols

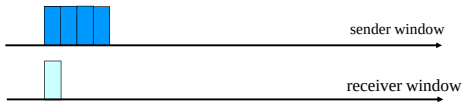
- Basic idea: using pipelining: to make better use of link bandwidth, sender allows multiple, "in-flight", yet-to-be-acknowledged pkts



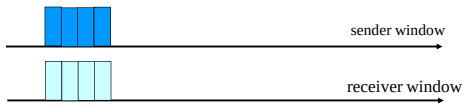
- Two generic forms of pipelined protocols: *go-Back-N, selective repeat*

Window Location

- Go-back-n (GBN)



- Selective repeat (SR)

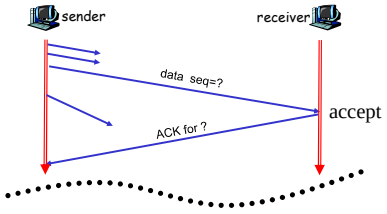


Sliding Window Protocols: Go-back-n and Selective Repeat

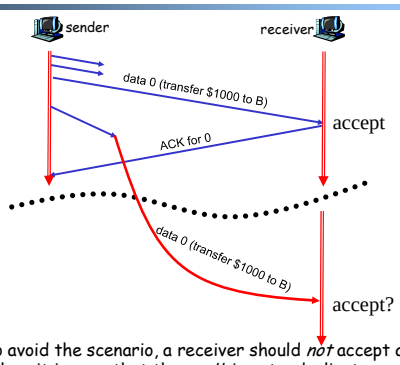
	Go-back-n	Selective Repeat
Buffer size at receiver	1	W
Relationship between M (the number of seq#) and W (window size)	M > W	M ≥ 2W
data bandwidth: sender to receiver (avg. number of times a pkt is transmitted)	Less efficient $\frac{1-p+pw}{1-p}$	More efficient $\frac{1}{1-p}$

p: the loss rate of a packet; M: number of seq# (e.g., 3 bit M = 8); W: window size

Question: What is Initial Seq#?



Question: What is Initial Seq#?



- To avoid the scenario, a receiver should *not* accept a seq# unless it is sure that the seq# is not a duplicate or reordered

Reordering and Duplication

- There are many solutions each with its own pitfalls
- Internet solution: for each connection (sender-receiver pair), ensuring that two identically numbered packets are never outstanding at the same time
  - network bounds the life time of each packet
  - a sender will not reuse a seq# before it is sure that all packets with the seq# are purged from the network
    - seq. number space should be large enough to not limit transmission rate

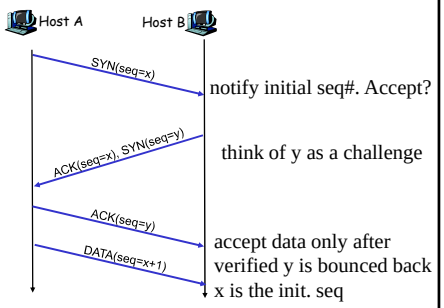
Outline

- Review
- Reliable data transfer
  - perfect channel
  - channel with bit errors
  - channel with bit errors and losses
  - sliding window: reliability with throughput
  - connection management

Connection Management: Objectives

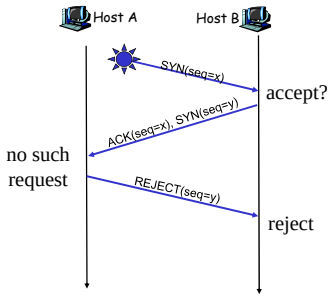
- Agree on initial sequence numbers
  - a sender will not reuse a seq# before it is sure that all packets with the seq# are purged from the network
    - the network guarantees that a packet too old will be purged from the network: network bounds the life time of each packet
  - needs connection setup so that the sender tells the receiver initial seq#
- Agree on other initial parameters

Three Way Handshake (TWH) [Tomlinson 1975]

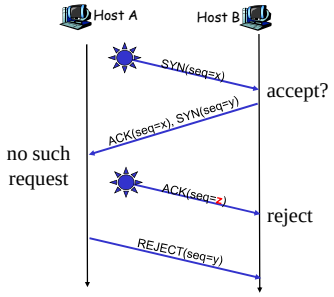


SYN: indicates connection setup

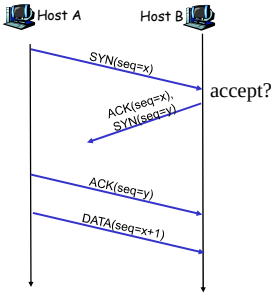
Scenarios with Duplicate Request



Scenarios with Duplicate Request



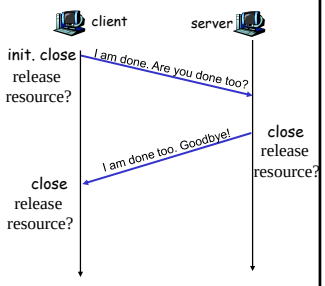
Scenarios with TCP Spoofing



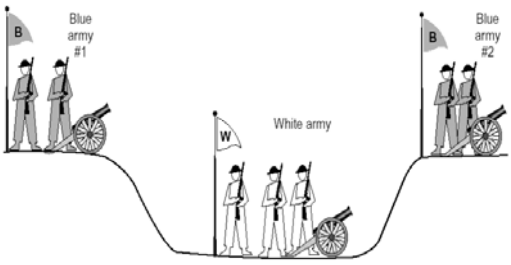
http://www.juniper.net/security/auto/vulnerabilities/vuln670.html

Connection Close

- Why connection close?
  - so that each side can release resource and remove state about the connection (do not want dangling socket)



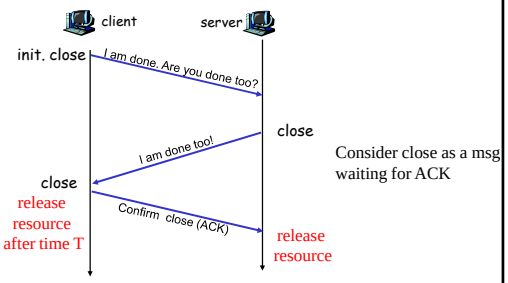
General Case: The Two-Army Problem



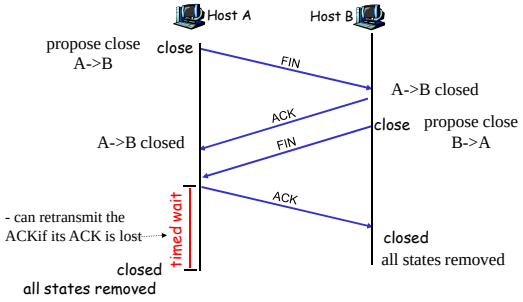
The gray (blue) armies need to agree on whether or not they will attack the white army. They achieve agreement by sending messengers to the other side. If they both agree, attack; otherwise, no. Note that a messenger can be captured!

Connection Close

No message exchange can reach agreement. Need other decision format.



Four Way Teardown



A Summary of Questions

- How to improve the performance of rdt3.0?
  - ✓ sliding window protocols
- What if there are duplication and reordering?
  - ✓ network guarantee: max packet life time
  - ✓ transport guarantee: not reuse a seq# before life time
  - ✓ seq# management and connection management
- How to determine the "right" parameters?

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Outline

- Recap
- Reliable data transfer
- *TCP reliability*

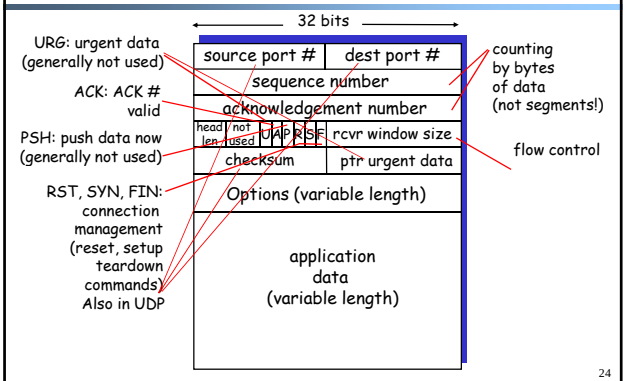
TCP: Overview RFCs: 793, 1122, 1323, 2018, 2581

- Point-to-point reliability: one sender, one receiver
- Flow controlled and congestion controlled

TCP Reliable Data Transfer

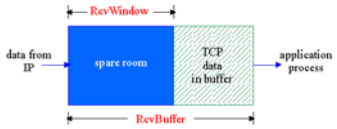
- Connection-oriented:
  - connection management
    - setup (exchange of control msgs) init's sender, receiver state before data exchange
    - close
- Full duplex data:
  - bi-directional data flow in same connection
- A sliding window protocol
  - a combination of go-back-n and selective repeat:
    - send & receive buffers
    - cumulative acks
    - TCP uses a single retransmission timer
    - do not retransmit all packets upon timeout

TCP Segment Structure



Flow Control

- receive side of a connection has a receive buffer:

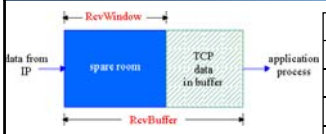


- app process may be slow at reading from buffer

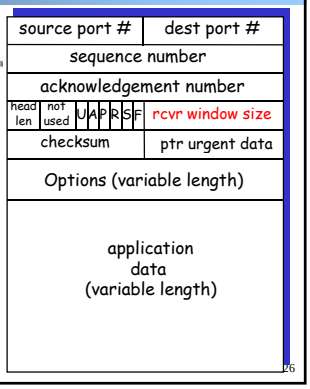
flow control
sender won't overflow receiver's buffer by transmitting too much, too fast

- speed-matching service: matching the send rate to the receiving app's drain rate

TCP Flow Control: How it Works



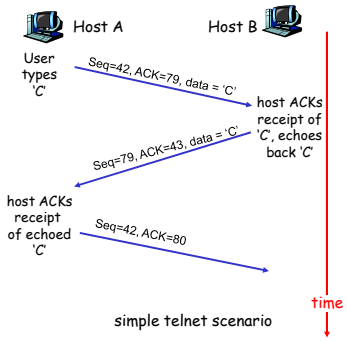
- spare room in buffer
  = `RcvWindow`



TCP Seq. #'s and ACKs

Seq. #'s:
- byte stream "number" of first byte in segment's data

ACKs:
- seq # of next byte expected from other side
- cumulative ACK



simple telnet scenario

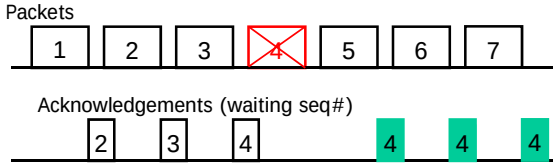
Fast Retransmit

- Problem: Timeout period often relatively long:
  - long delay before resending lost packet

- Detect lost segments via duplicate ACKs
  - sender often sends many segments back-to-back
  - if segment is lost, there will likely be many duplicate ACKs

- If sender receives 3 ACKs for the same data, it supposes that segment after ACKed data was lost:
  - resend segment before timer expires

Triple Duplicate Ack



Fast Retransmit:

```
event: ACK received, with ACK field value of y
        if (y > SendBase) {
            …
            SendBase = y
            if (there are currently not-yet-acknowledged segments)
                start timer
            …
        }
        else {
            increment count of dup ACKs received for y
            if (count of dup ACKs received for y = 3) {
                resend segment with sequence number y
            …
```

a duplicate ACK for already ACKed segment

fast retransmit

TCP: reliable data transfer

Simplified TCP sender

```
00  sendbase = initial_sequence number agreed by TWH
01  nextseqnum = initial_sequence number by TWH
02   loop (forever) {
03     switch(event)
04     event: data received from application above
05              if (window allows send)
06                 create TCP segment with sequence number nextseqnum
06                 if (no timer) start timer
07                 pass segment to IP
08                 nextseqnum = nextseqnum + length(data)
               else put packet in buffer
09     event: timer timeout for sendbase
10         retransmit segment
11         compute new timeout interval
12         restart timer
13     event: ACK received, with ACK field value of y
14         if (y > sendbase) { /* cumulative ACK of all data up to y */
15            cancel the timer for sendbase
16            sendbase = y
17            if (no timer and packet pending) start timer for new sendbase
17            while (there are segments and window allow)
18               sent a segment;
18         }
19         else { /* y==sendbase, duplicate ACK for already ACKed segment */
20            increment number of duplicate ACKs received for y
21            if (number of duplicate ACKS received for y == 3) {
22               /* TCP fast retransmit */
23               resend segment with sequence number y
24               restart timer for segment y
25            }
26   } /* end of loop forever */
```

TCP Receiver ACK Generation [RFC 1122, RFC 2581]

Event at Receiver	TCP Receiver Action
Arrival of in-order segment with expected seq #. All data up to expected seq # already ACKed	Delayed ACK. Wait up to 500ms for next segment. If no next segment, send ACK
Arrival of in-order segment with expected seq #. One other segment has ACK pending	Immediately send single cumulative ACK, ACKing both in-order segments
Arrival of out-of-order segment higher-than-expect seq. # . Gap detected	Immediately send duplicate ACK, indicating seq. # of next expected byte
Arrival of segment that partially or completely fills gap	Immediate send ACK, provided that segment starts at lower end of gap

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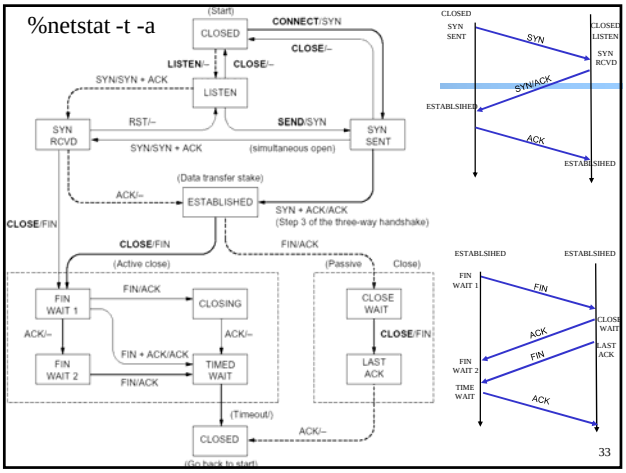
%netstat -t -a



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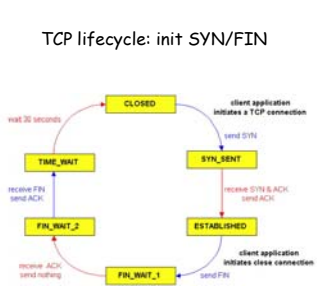
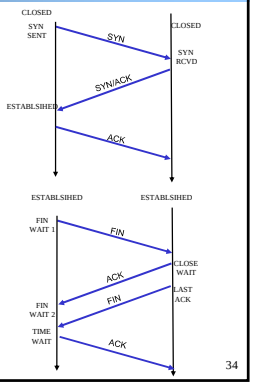
TCP Connection Management

TCP lifecycle: init SYN/FIN





http://dsd.lbl.gov/TCP-tuning/ip-sysctl-2.6.txt

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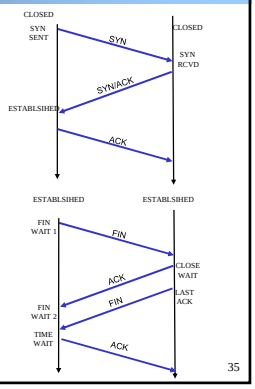
TCP Connection Management

TCP lifecycle: wait for SYN/FIN



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