

L4 – practical examples



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- A connection
 - 5-tuple

- Setup a connection
 - UDP – no setup
 - TCP
 - 3 way handshake
 - Why it is needed?

Ports on a computer



- Netstat command

```
TCP 127.0.0.1:1906 localhost:1907 ESTABLISHED
TCP 192.168.1.147:53699 13.77.87.52:https ESTABLISHED
TCP 192.168.1.147:53703 91.190.216.57:12350 ESTABLISHED
TCP 192.168.1.147:53737 64.4.23.152:40008 ESTABLISHED
TCP 192.168.1.147:53759 108.177.96.188:5228 ESTABLISHED
TCP 192.168.1.147:53772 40.77.226.192:https ESTABLISHED
TCP 192.168.1.147:54512 a104-96-129-73:https CLOSE_WAIT
TCP 192.168.1.147:54513 a104-96-129-73:https CLOSE_WAIT
TCP 192.168.1.147:54514 a104-96-129-73:https CLOSE_WAIT
```

- Data segments
- Error handling
 - ICMP: port unreachable
 - Loss: no feedback
- Delay, bandwidth
 - Multicast!

The Evolution of TCP



BME-TMIT

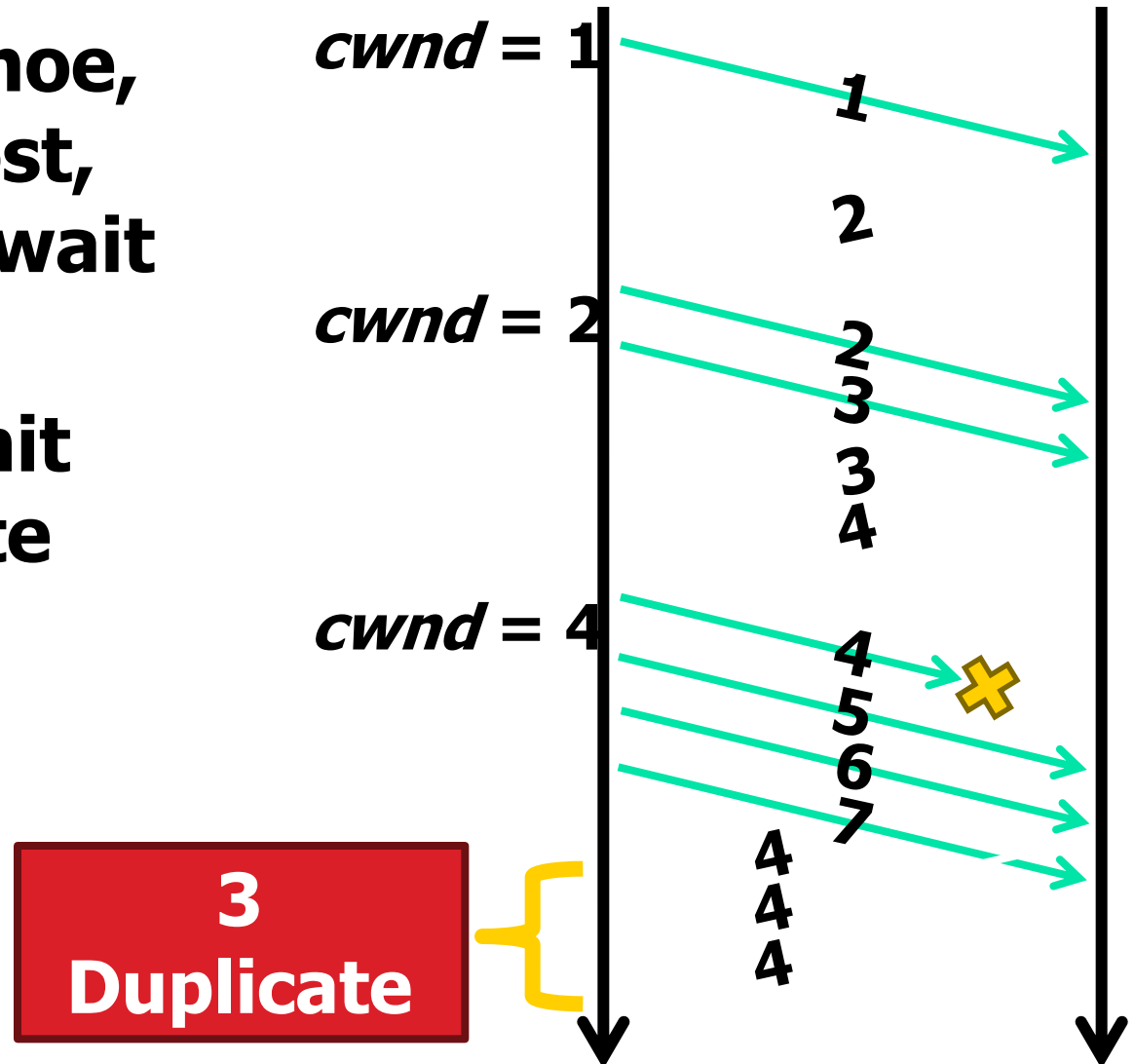
- TCP Tahoe
 - Initial version
- The TCP was developed in 1974!
 - Today there are many versions of TCP
- A widely spread initial version: TCP Reno
 - Tahoe, plus...
 - Fast retransmit
 - Fast recovery

TCP Reno: Fast Retransmit



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- **Problem: in Tahoe, if segment is lost, there is a long wait until the RTO**
- **Reno: retransmit after 3 duplicate ACKs**



TCP Reno: Fast Recovery



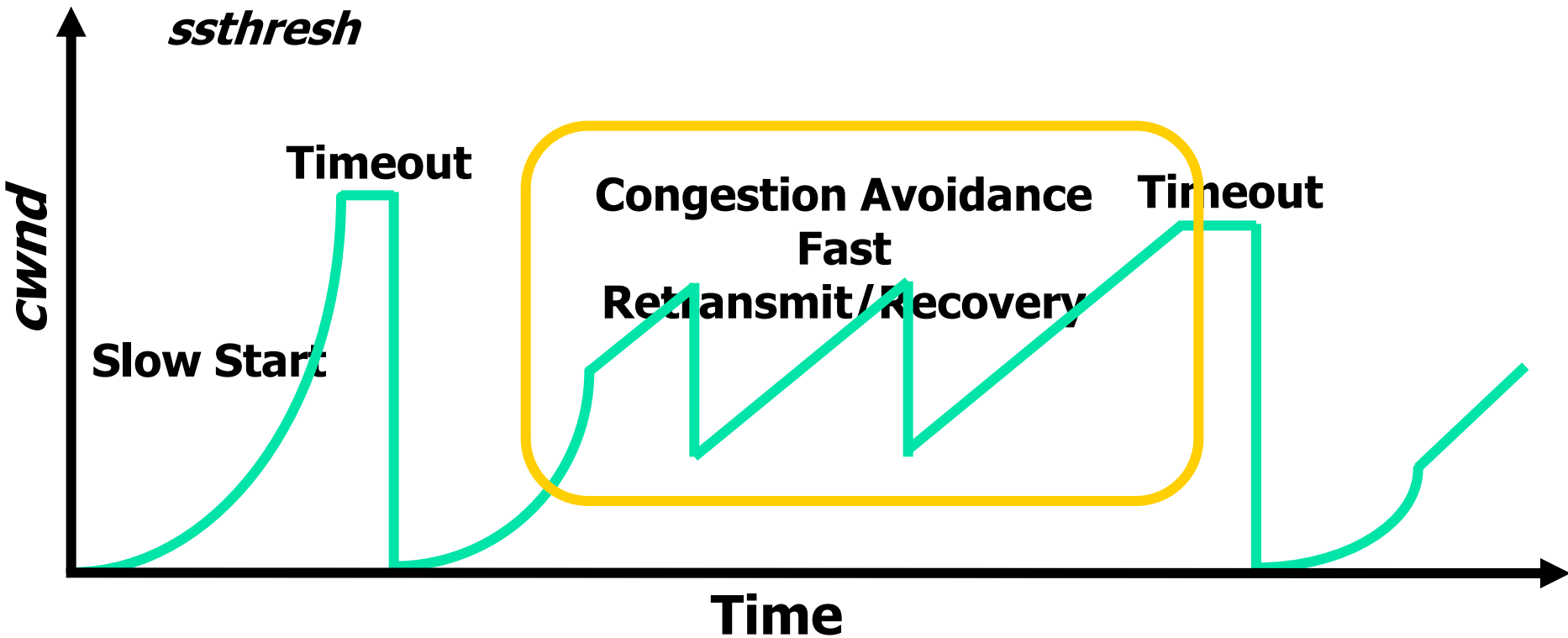
BME-TMIT

- After a fast-retransmit set $cwnd$ to $ssthresh/2$
 - i.e. don't reset $cwnd$ to 1
 - Avoid unnecessary return to slow start
 - Prevents expensive timeouts
- But when RTO expires still do $cwnd = 1$
 - Return to slow start, same as Tahoe
 - Indicates packets aren't being delivered at all
 - i.e. congestion must be really bad

Fast Retransmit and Fast Recovery



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- At steady state, $cwnd$ oscillates around the optimal window size
- TCP always forces packet drops

Many TCP Variants...



- Tahoe: the original
 - Slow start with AIMD
 - Dynamic RTO based on RTT estimate
- Reno: fast retransmit and fast recovery
- NewReno: improved fast retransmit
 - Each duplicate ACK triggers a retransmission
 - Problem: >3 out-of-order packets causes pathological retransmissions
- Vegas: delay-based congestion avoidance
- And many, many, many more...

TCP in the Real World



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- What are the most popular variants today?
 - Key problem: TCP performs poorly on high bandwidth-delay product networks (like the modern Internet)
 - Compound TCP (Windows)
 - Based on Reno
 - Uses two congestion windows: delay based and loss based
 - Thus, it uses a *compound* congestion controller
 - TCP CUBIC (Linux)
 - Enhancement of BIC (Binary Increase Congestion Control)
 - Window size controlled by cubic function
 - Parameterized by the time T since the last dropped packet

TCP window



- Bandwidth delay product
- 8k – bandwidth is limited
 - Window is a limiting factor when delay is high
- 64K – maximum possible without options
 - better
 - Window scale option – scale up the window field

Bandwidth delay product



- Optimal value for window can be calculated
 - $\text{Win} = \text{RTT} * \text{Bandwidth}$
- Similarly,
 - $\text{Bandwidth} = \text{win} / \text{RTT}$
- Assuming that there is no other bottleneck in the network

TCP options example



No.	Time	Source	Destination	Protocol	Length	Info
4	0.168986	192.168.0.11	239.255.255.250	SSDP	175	M-SEARCH * HTTP/1.1
5	0.221892	fe80::d0f9:8c1:d62f:eb63	ff02::1:3	LLMNR	86	Standard query 0x7e01 A isatap
6	0.000117	192.168.0.11	224.0.0.252	LLMNR	66	Standard query 0x7e01 A isatap

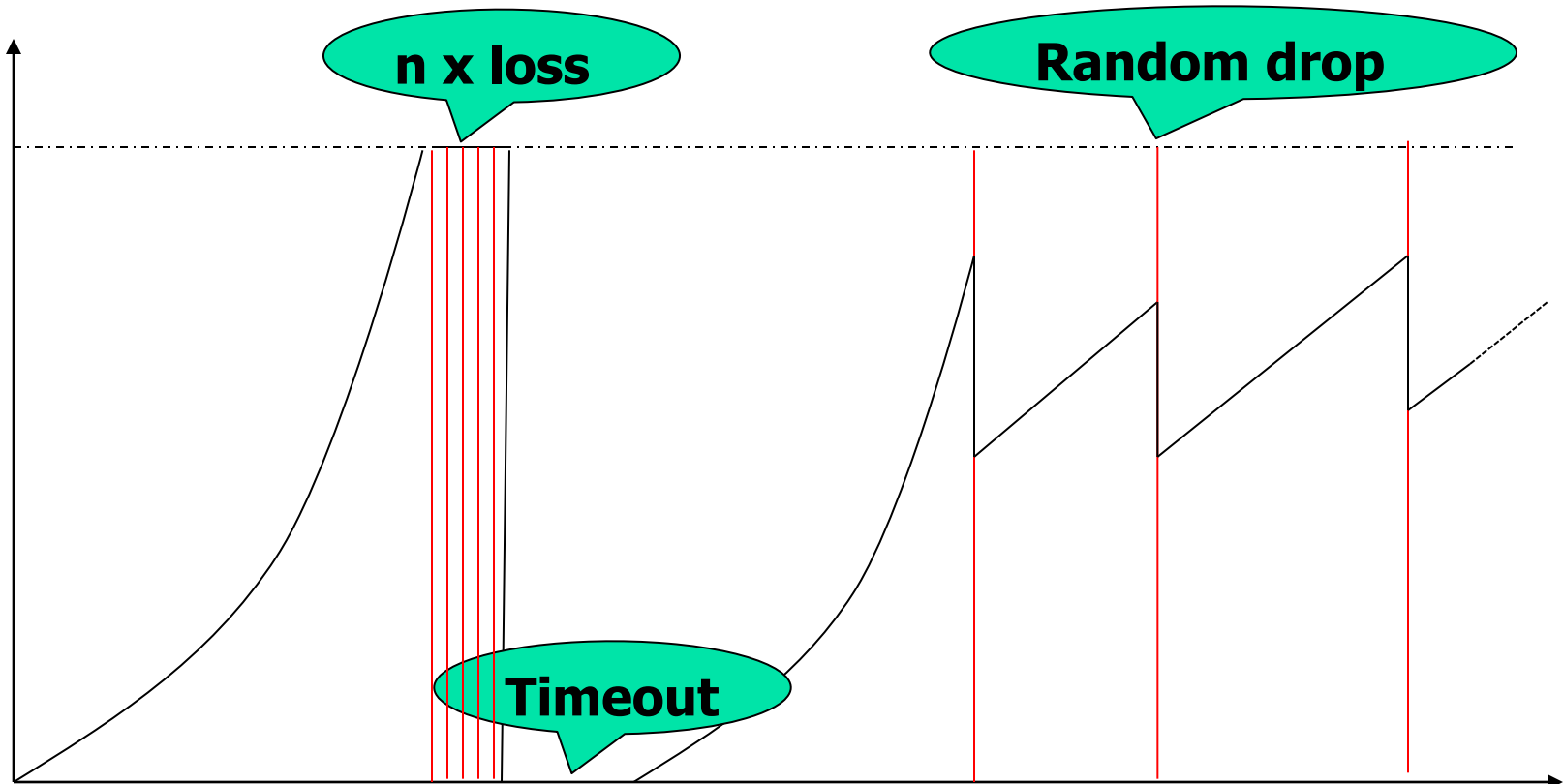
Frame 12: 66 bytes on wire (528 bits), 66 bytes captured (528 bits) on interface 0

- Ethernet II, Src: Wistron_2d:ab:ba (00:1f:16:2d:ab:ba), Dst: 3Com_03:04:05 (00:01:02:03:04:05)
- Internet Protocol Version 4, Src: 192.168.0.11, Dst: 192.168.0.168
- Transmission Control Protocol, Src Port: 29385, Dst Port: 22, Seq: 0, Len: 0
 - Source Port: 29385
 - Destination Port: 22
 - [Stream index: 0]
 - [TCP Segment Len: 0]
 - Sequence number: 0 (relative sequence number)
 - [Next sequence number: 0 (relative sequence number)]
 - Acknowledgment number: 0
 - 1000 = Header Length: 32 bytes (8)
 - Flags: 0x002 (SYN)
 - Window size value: 8192
 - [Calculated window size: 8192]
 - Checksum: 0x822a [unverified]
 - [Checksum Status: Unverified]
 - Urgent pointer: 0
 - Options: (12 bytes), Maximum segment size, No-Operation (NOP), Window scale, No-Operation (NOP), No-Operation (NOP), SACK permitted
 - TCP Option - Maximum segment size: 1460 bytes
 - TCP Option - No-Operation (NOP)
 - TCP Option - Window scale: 2 (multiply by 4)
 - TCP Option - No-Operation (NOP)
 - TCP Option - No-Operation (NOP)
 - TCP Option - SACK permitted
 - [Timestamps]
 - [Time since first frame in this TCP stream: 0.000000000 seconds]
 - [Time since previous frame in this TCP stream: 0.000000000 seconds]

RED – Random Early Drop



- Buffer menedzsment a routerekben
 - Egy dobás jobb mint egy timeout



TCP - Wireless



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- Problem:
 - Wireless – loss due the radio
 - no bottleneck!
 - TCP misunderstands, reduces the cwnd
- Solutions
 - WTCP – proxy
 - SACK – selective acknowledgements

Thank You!

- End -



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