

5. TCP Congestion Control

- ✦ TCP congestion control prevents the sender from congesting the network with too much data

- ✦ Sender probes the network capacity by dynamically adjusting its congestion window size (cwnd)

- Sender makes sure: $\text{swnd} \leq \text{cwnd}$ ✓
- Combined with TCP flow control, we have

$$\text{swnd} = \min(\text{rwnd}, \text{cwnd})$$

$$\text{swnd} \leq \text{rwnd} \checkmark$$

- ✦ Congestion detection

- ✦ Upon detecting congestion, sender slows down its transmissions

$$\text{cwnd} \downarrow$$

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TCP Congestion Control: Probing the Network Capacity

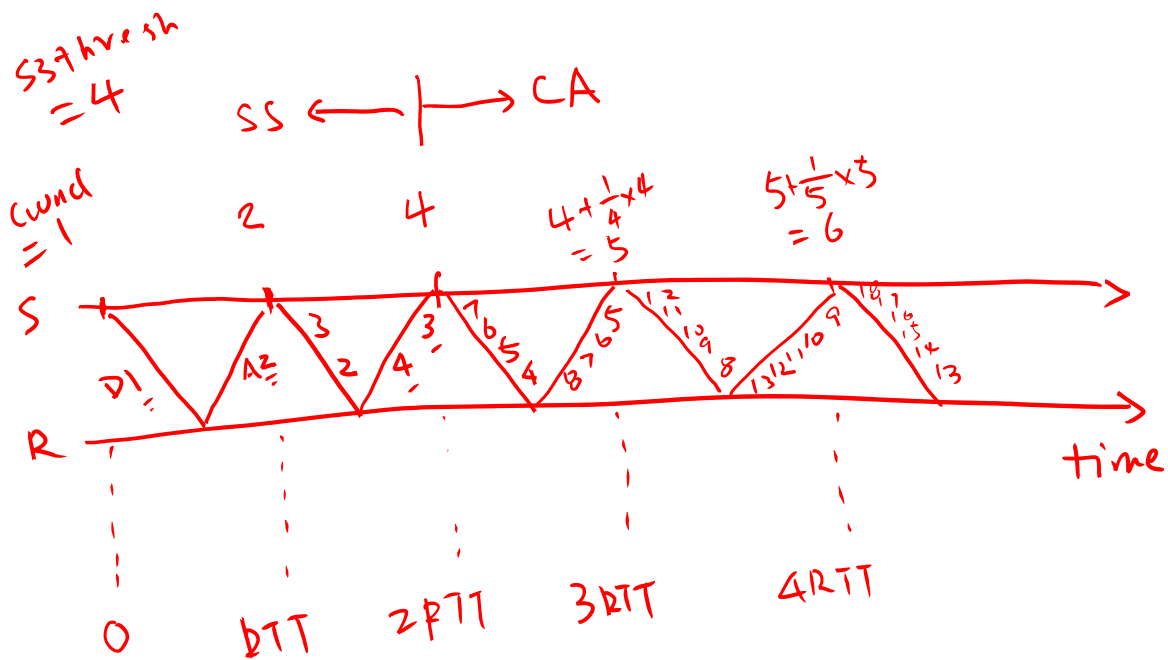
- ✦ Probing the network capacity in two phases:

- ✦ Phase 1: Slow Start (SS)

- Starts with $\text{cwnd} = 1$ (MSS)
 - MSS (Maximum Segment Size) for TCP is 536 bytes by default
- Each time a non-duplicate ACK is received, increment cwnd
$$\text{cwnd} \leftarrow \text{cwnd} + 1$$
- i.e., exponential growth of cwnd over time
$$\text{each RTT: } \text{cwnd} \leftarrow 2 \times \text{cwnd}$$

$$\text{rwnd is large}$$
$$\text{swnd} = \text{cwnd}$$

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TCP Congestion Control: Congestion Detection

⊕ How to detect congestion?

- ➡ Interprets segment loss as congestion signal
- ➡ Retransmits the lost segment upon
 - RTO ✓
 - Reception of the 4th ACK with the same sequence number ✓
 - This is called Fast Retransmit

3rd dup ACK

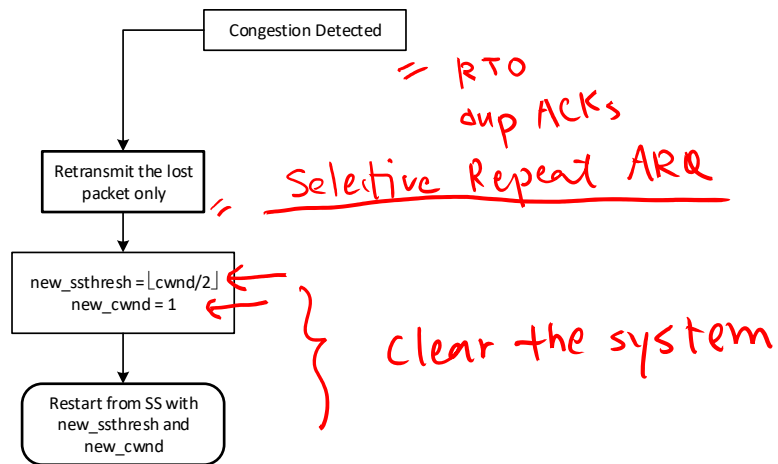
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TCP Congestion Control: Slowing Down Transmission

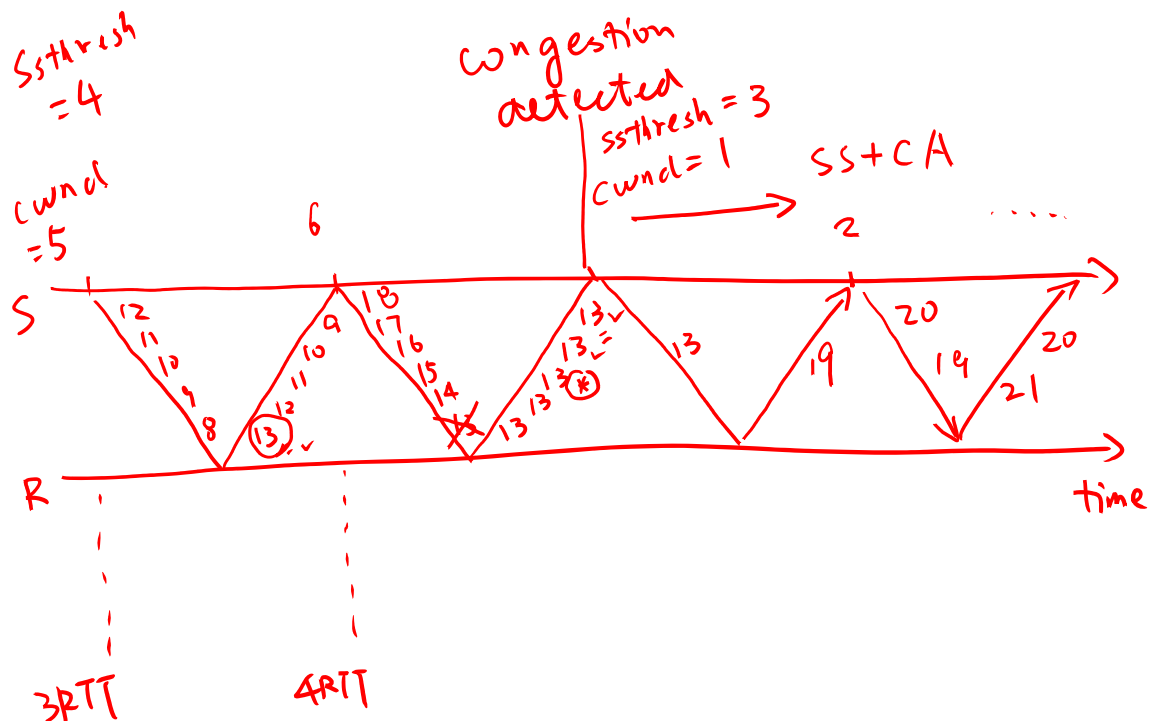
⊕ Sender slows down its transmissions upon congestion detection

- ➡ TCP Tahoe
- ➡ TCP Reno
- ➡ TCP New Reno

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