Congestion Control in TCP

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Outline

- Intro to congestion control
- Input rate vs. output throughput
- Congestion window
- “Congestion avoidance”
- “Slow start”
- “Fast recovery”

Understanding Congestion

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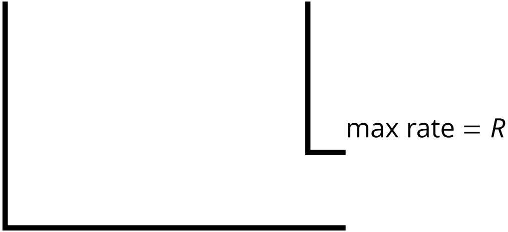

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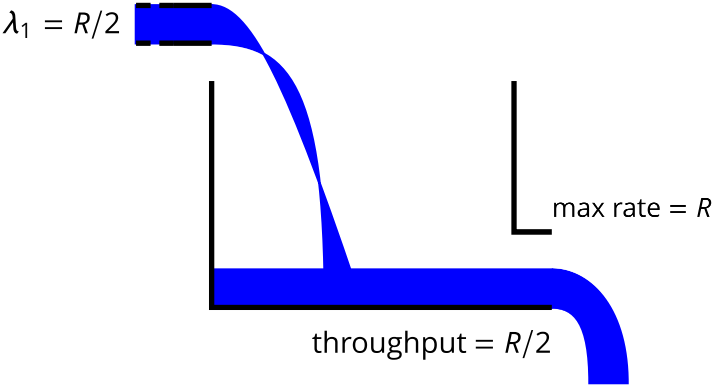

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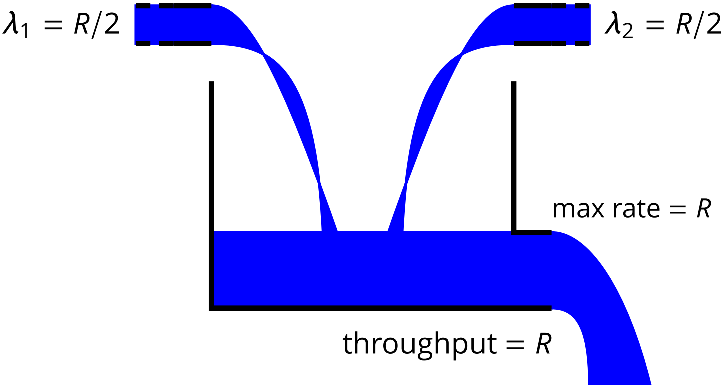

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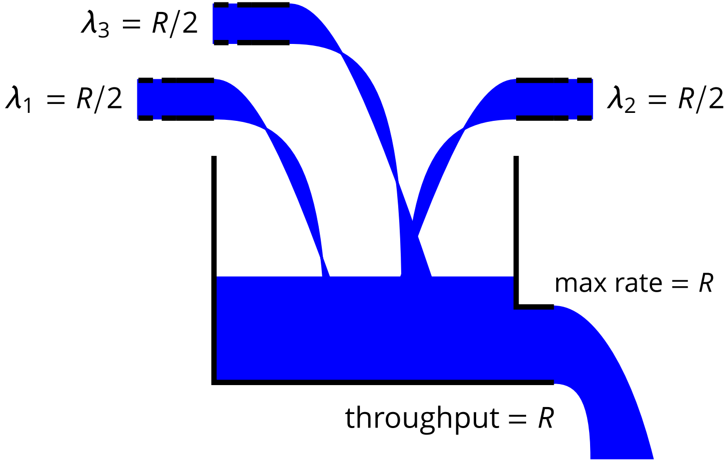

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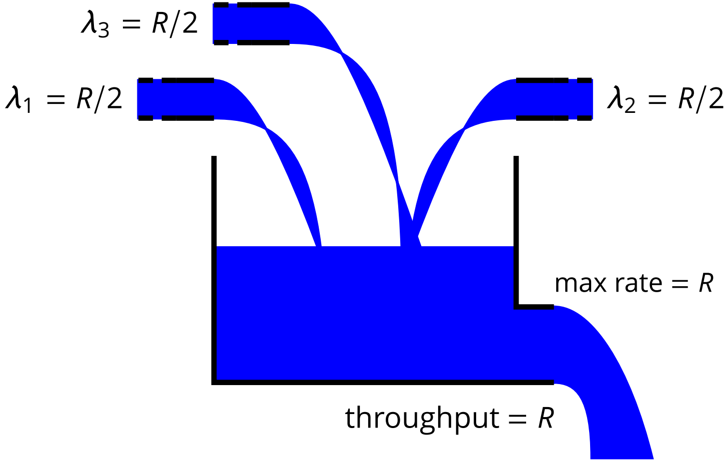

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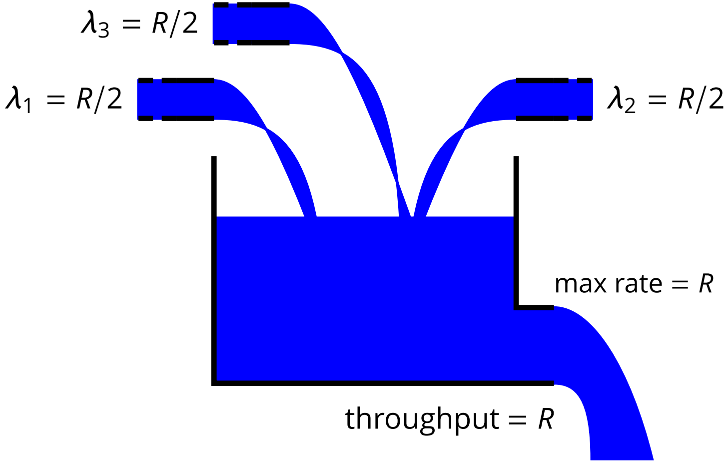

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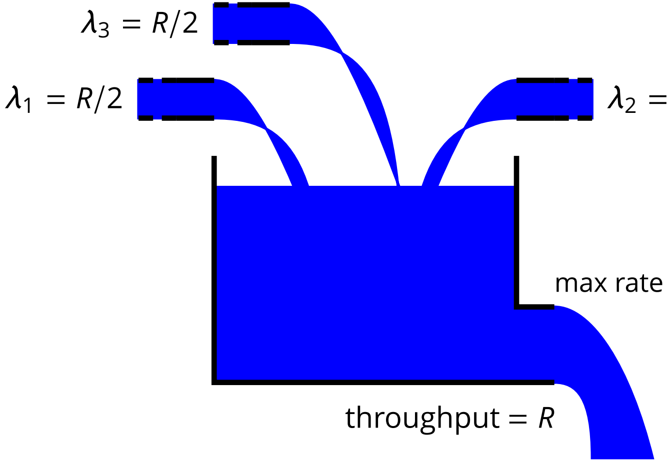

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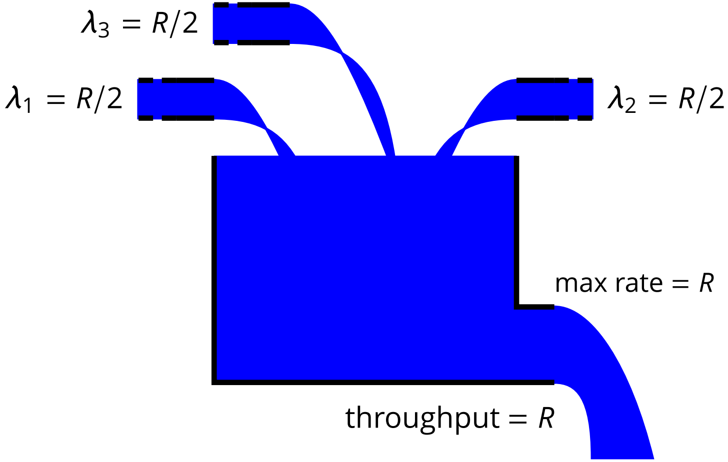

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- ***Extreme case:*** constant input data rate

$$\lambda_{in} > R$$

In this case $|q| = (\lambda_{in} - R)t$ and therefore

$$d_q = \frac{\lambda_{in} - R}{R} t$$

Queuing Delay

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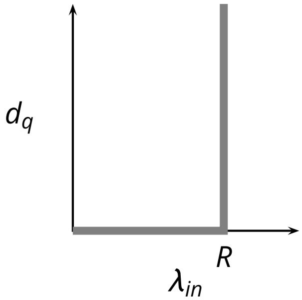

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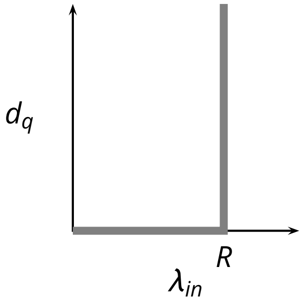

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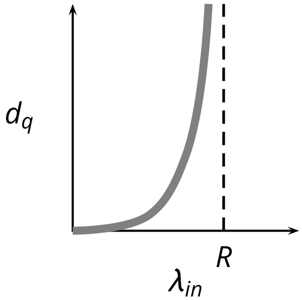

realistic input flow
λ_{in} variable

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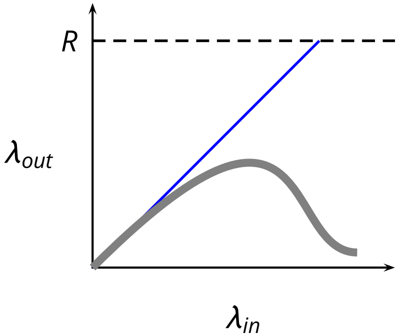

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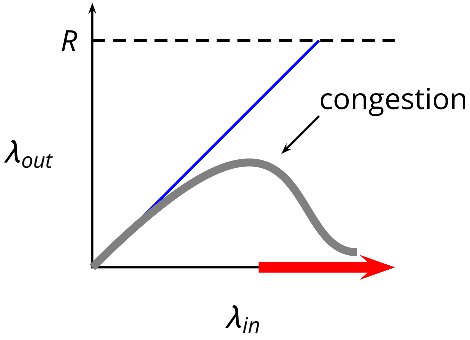

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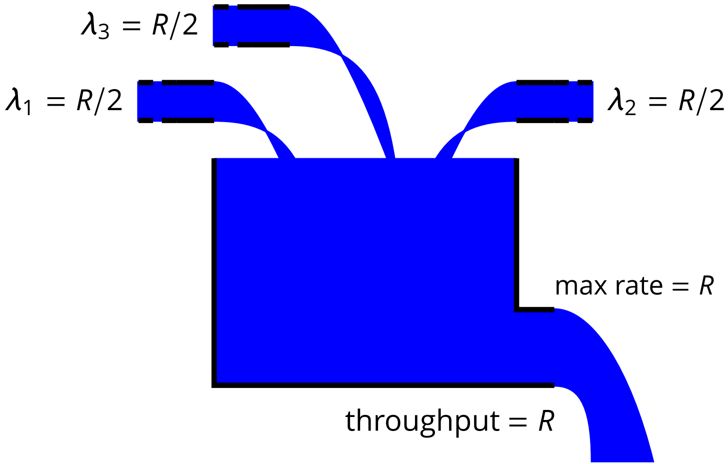

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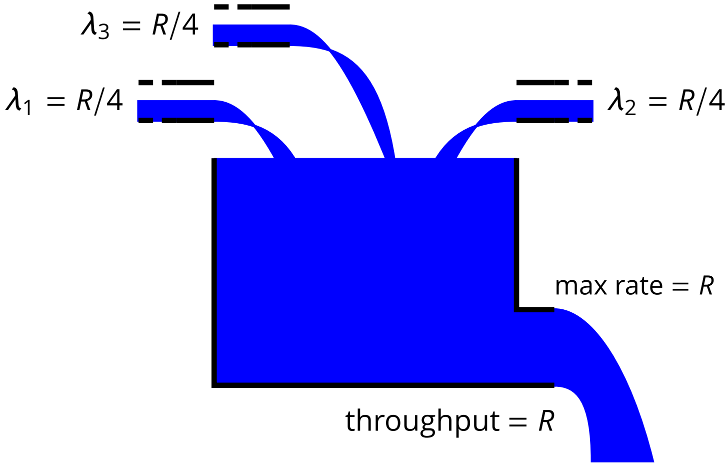

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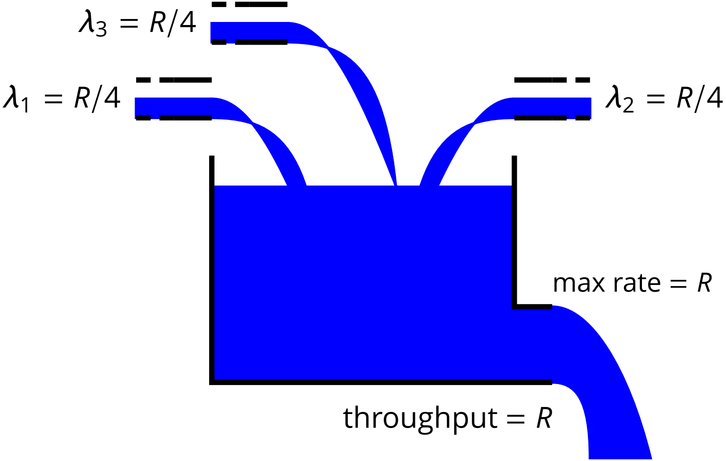

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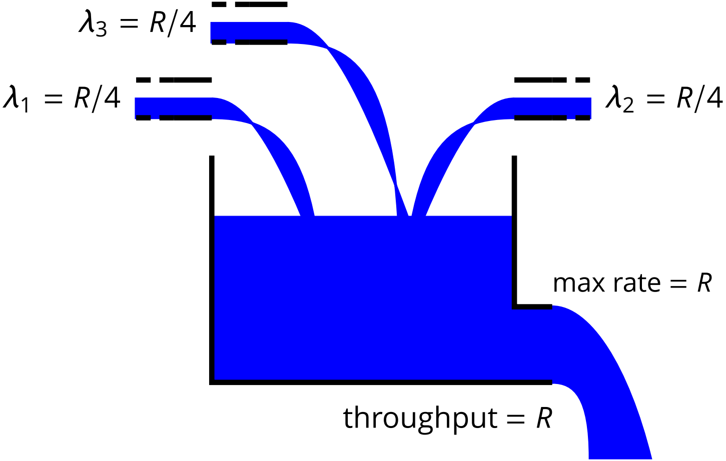

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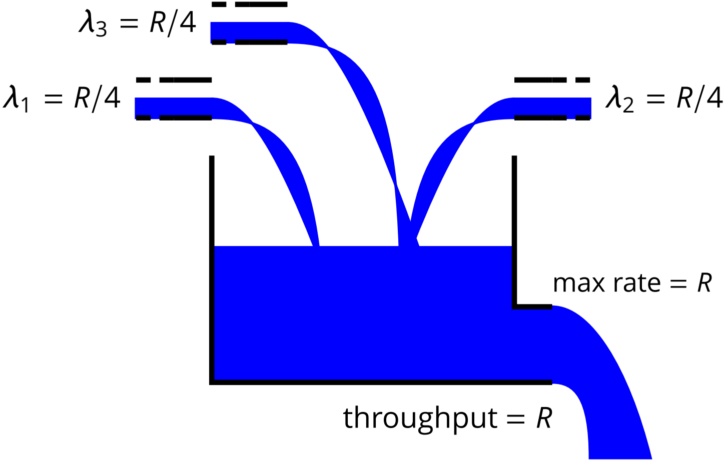

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  - how should the sender “modulate” its output rate?
    - i.e., what algorithm should the sender use to decrease or increase its output rate?

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- Congestion means that the queue of one or more routers between the sender and the receiver overflow
  - the visible effect is that some segments are dropped
- Therefore the server assumes that the network is congested when it detects a segment loss
  - time out (i.e., no ACK)
  - multiple acknowledgements (i.e., NACK)

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- The resulting maximum output rate is roughly

$$\lambda = \frac{W}{2L}$$

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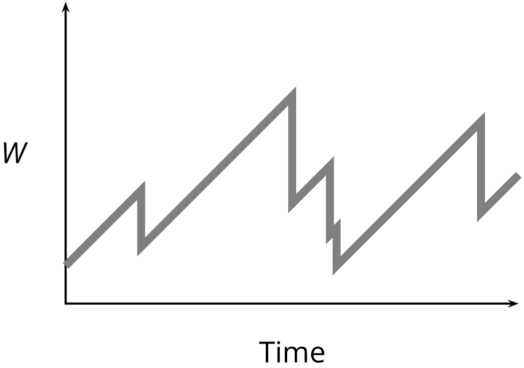
  - e.g., suppose $W = 14600$ and $MSS = 1460$, then the sender increases W to 16060 after 10 acknowledgments acknowledgments

Additive-Increase/Multiplicative-Decrease

- Window size W over time



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- This process is called “slow start” because of the small initial value of *W*

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- So, TCP reacts differently to a timeout and to a triple duplicate ACKs

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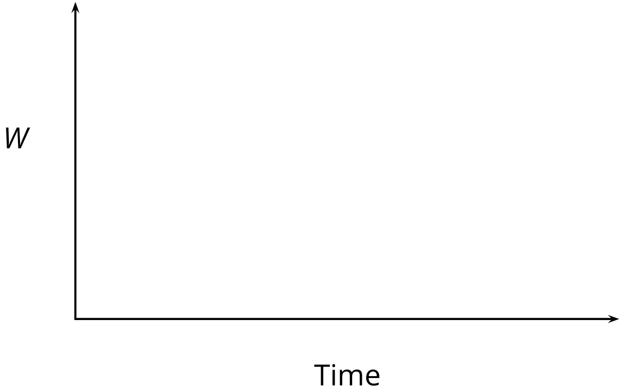
- *NACK* (i.e., triple duplicate-ack)
  - set $ssthresh = \overline{W}/2$
  - cut W in half: $W = \overline{W}/2$
  - run *congestion avoidance*, ramping up W linearly
  - This is called ***fast recovery***


W
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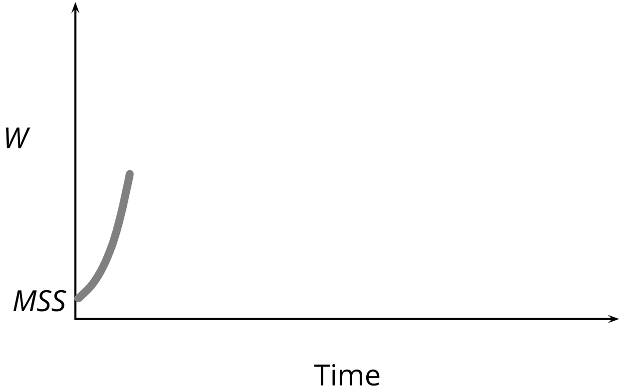

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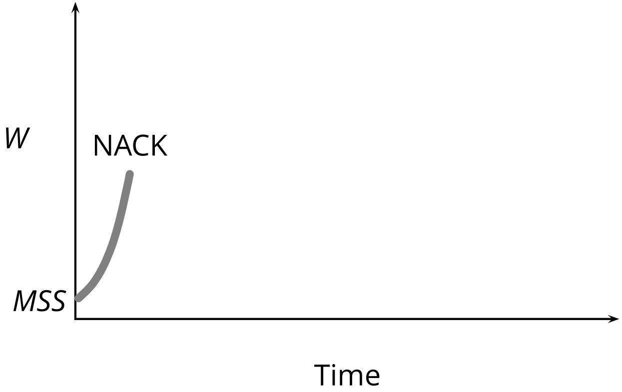
Time

Sender Behavior



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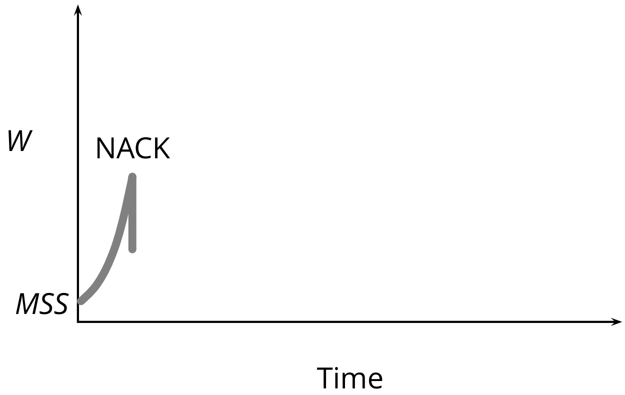

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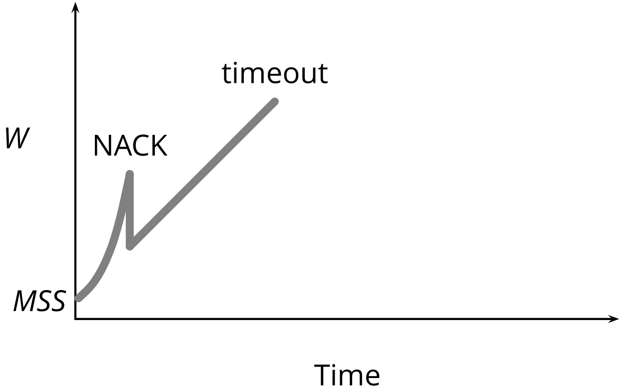

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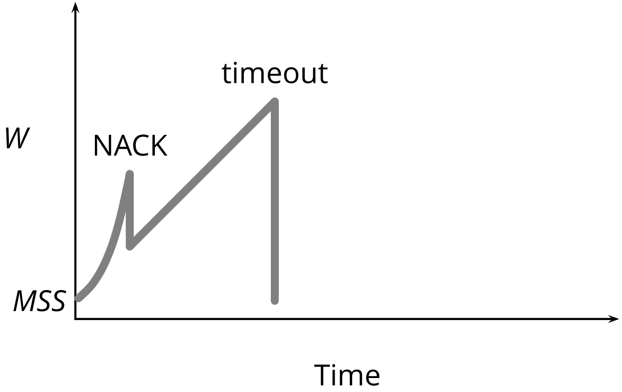

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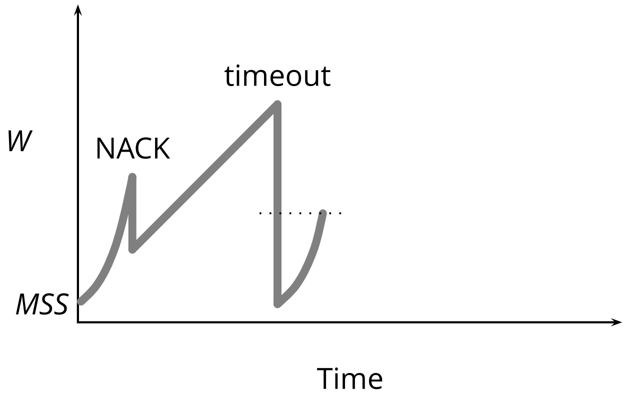

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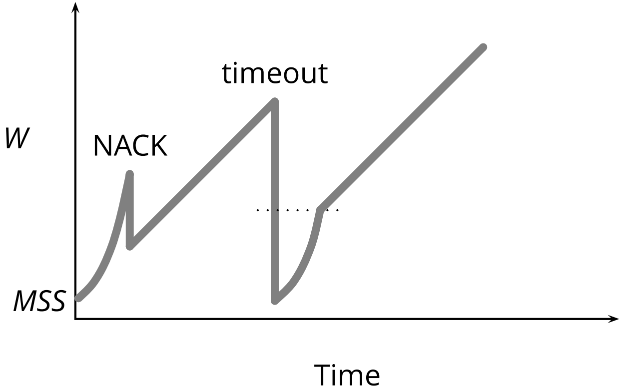

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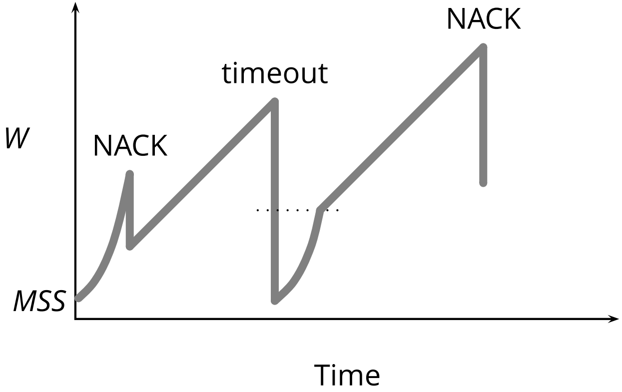

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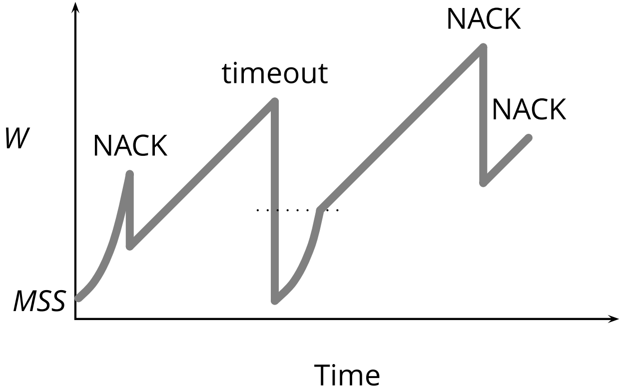

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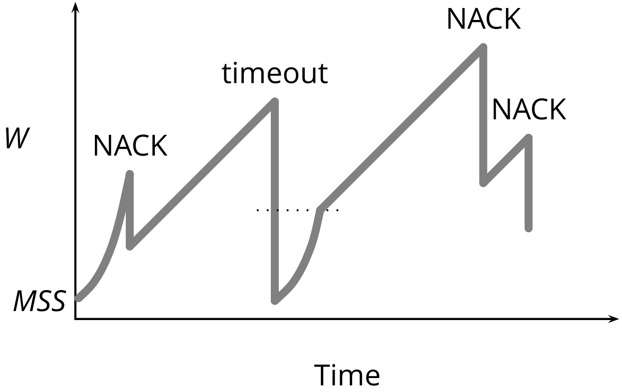

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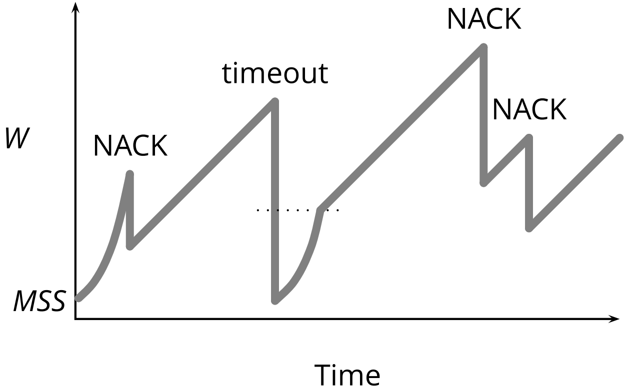

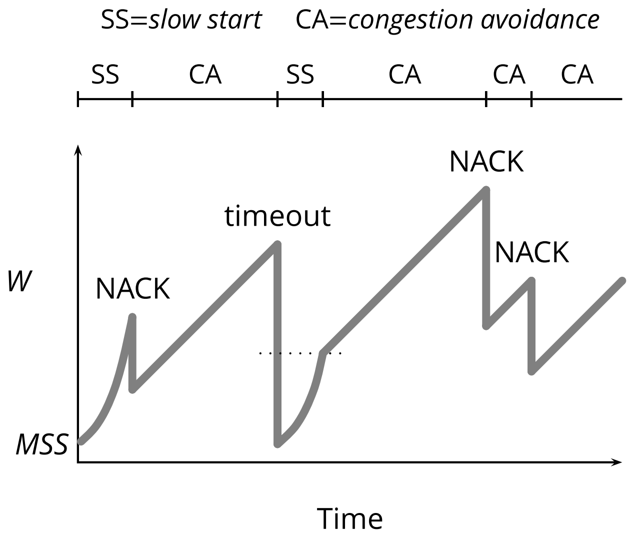
SS=*slow start* CA=*congestion avoidance*
SS
CA
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NACK
timeout
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Time