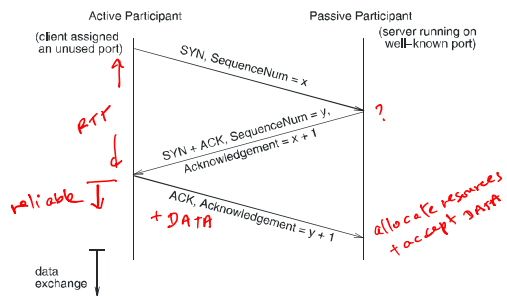


TCP Connection Establishment

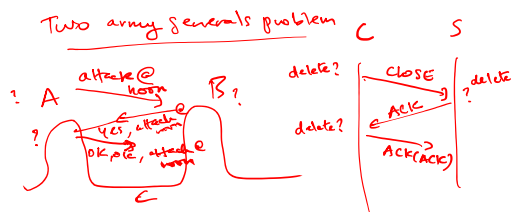
Three-Way Handshake



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TCP Closing

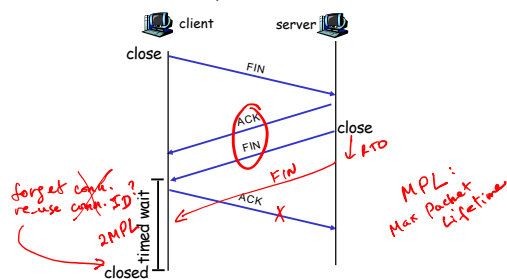


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TCP Closing

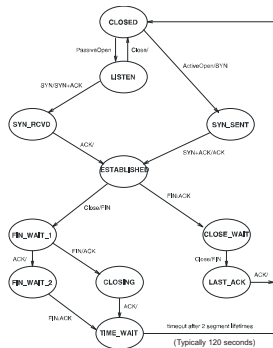
Modified Three-Way Handshake



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TCP State Transition Diagram



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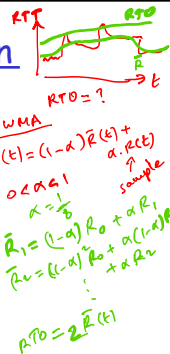
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Adaptive Retransmission

Original Algorithm

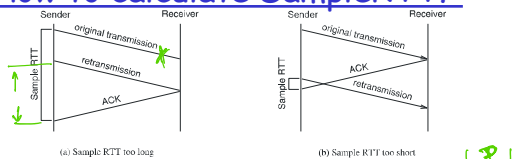
- Measure **SampleRTT** for a segment/ACK pair
- Compute weighted average of RTT (EWMA)
 - ▢ **EstimatedRTT** = $(1-\alpha) \times \text{EstimatedRTT} + \alpha \times \text{SampleRTT}$
 - where α is recommended to be 0.125 ($=1/8$)
- Set timeout based on **EstimatedRTT**
 - ▢ **TimeOut** = $2 \times \text{EstimatedRTT}$

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How to calculate SampleRTT?



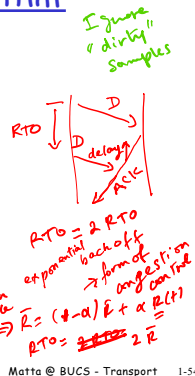
- in (a), **EstimatedRTT** can grow without bound as datagrams get lost
- in (b), **EstimatedRTT** is observed to converge to half the correct estimate

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Karn/Partridge Algorithm

- Ignore RTT samples for retransmitted segments
- Problem: ??**
- timeout not updated to reflect increased delay!
- Solution: ??**
- double timeout after each retransmission (**exponential backoff** - a form of congestion control!)
- Back to RTT estimation formula when receiving ACK for a segment that did **not** require retransmission

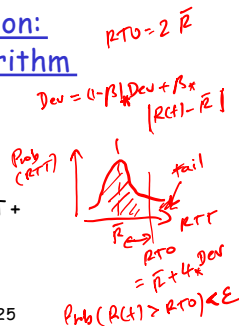


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Adaptive Retransmission: Jacobson/Karels Algorithm

- New calculation for average RTT
 - Difference = SampleRTT - EstimatedRTT
 - EstimatedRTT = EstimatedRTT + ($\alpha \times$ Difference)
 - Deviation = Deviation + β (|Difference| - Deviation)
 - where β is recommended to be 0.25
- Consider variance when setting timeout value
 - TimeOut = EstimatedRTT + $\phi \times$ Deviation



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Jacobson/Karels Algorithm

- Fast computation using integer arithmetic
 - $\bar{R} = (1-\alpha)\bar{R} + \alpha R(t)$
 $\alpha = \frac{1}{8}$
 - $\bar{R} = \bar{R} + \alpha(R(t) - \bar{R})$
 $\frac{1}{8} \cdot \bar{R} = 8 \cdot \bar{R} + (R(t) - \bar{R})$
 $5 \cdot \bar{R} = 5 \cdot \bar{R} + (R(t) - \bar{R})$
 $5 \cdot \bar{R} = \bar{R} \ll 3$
- scale by α and β , i.e. multiply by 8 ($\gg 3$) and 4 ($\gg 2$)
- keep **SampleRTT** and **TimeOut** unscaled
- Difference = SampleRTT - EstimatedRTT' $\gg 3$
- EstimatedRTT' = EstimatedRTT' + Difference
- If (Difference < 0) Difference = - Difference
- Deviation' = Deviation' + (Difference - Deviation') $\gg 2$
- TimeOut = EstimatedRTT' $\gg 3$ + Deviation'

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