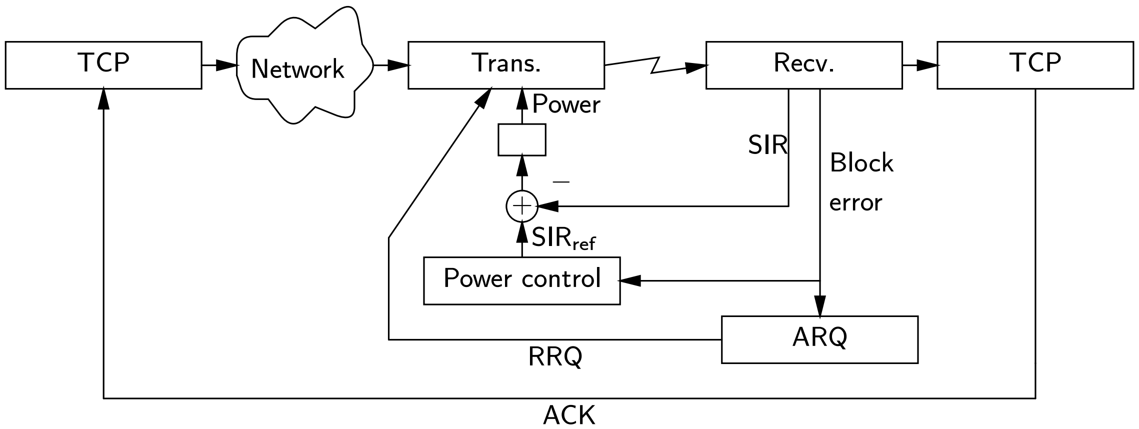
TCP OVER RADIO LINKS EMPLOYING POWER CONTROL AND RETRANSMISSIONS

Niels Möller and Karl Henrik Johansson
Department of Signals, Sensors and Systems, KTH

Automatic Control

Wireless TCP system

Several cascaded feedback loops which interact.



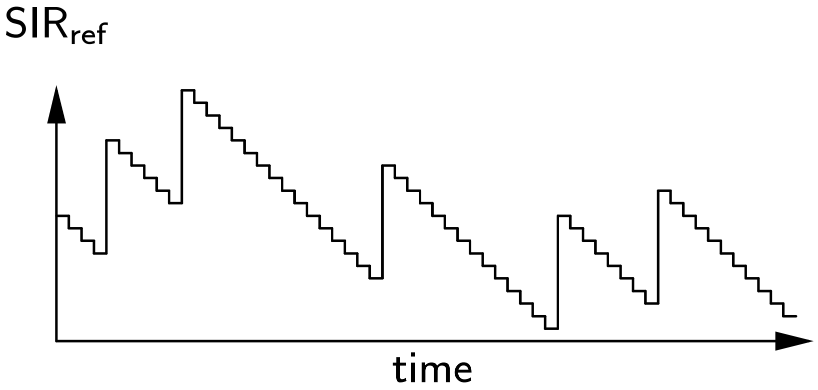
Link layer: Power control and ARQ [Sampath et al, 1997; Khan et al, 2000; Gunnarsson and Gustafsson, 2002].

Transport layer: TCP over general unreliable links [DeSimone et al, 1993; Mascolo et al; TCP Westwood].

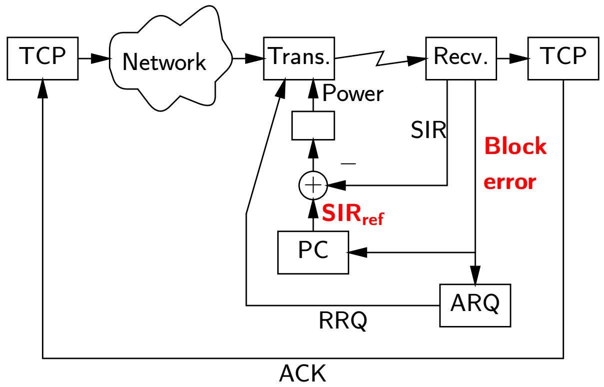
This work: Models both link and transport layer.

Power control

- Outer loop adjusts SIR_{ref} to keep BLER at 10%.
- Inner loop adjusts transmission power to track SIR_{ref}.

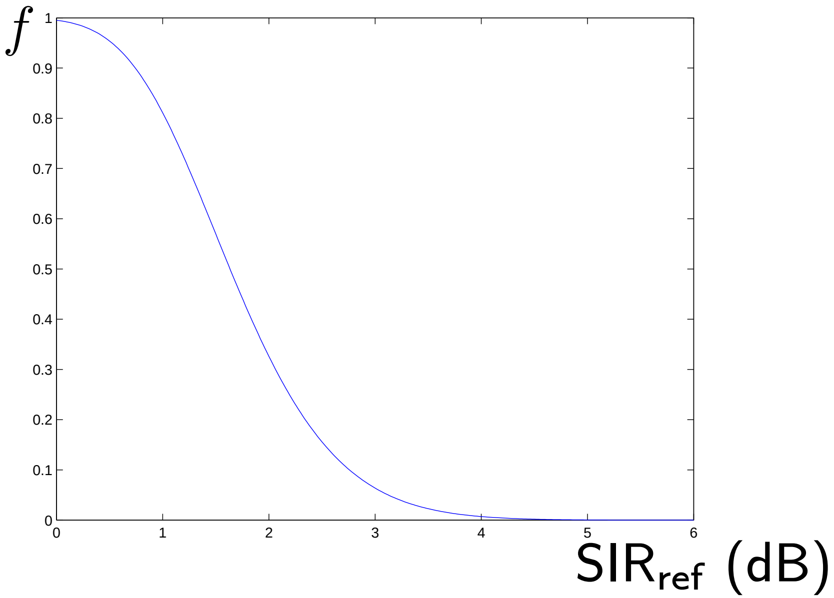


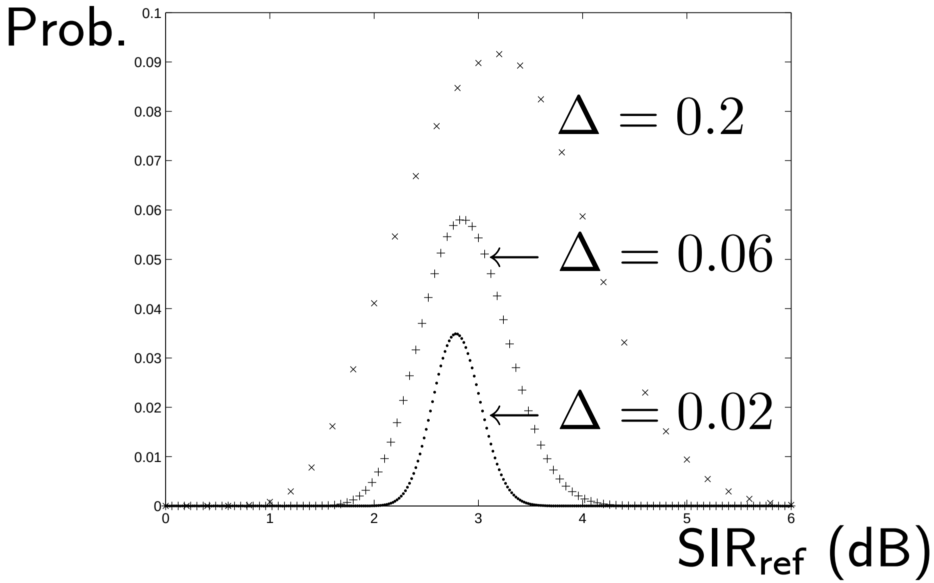
Markov chain driven by block errors.



Stationary power control state

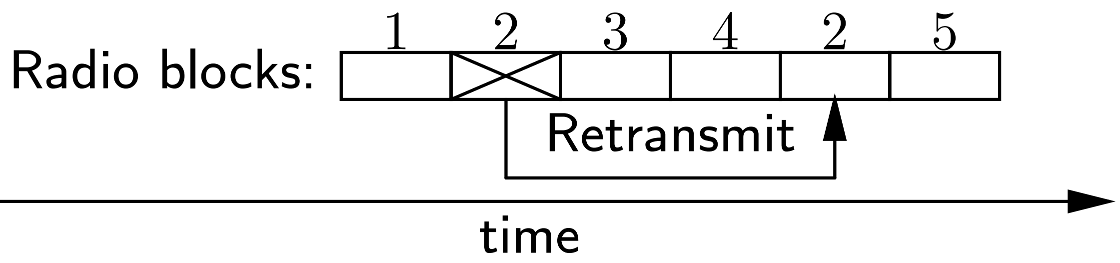
Markov transition probabilities depend on the power control step size Δ, and the radio channel, where $P(\text{block error}) = f(\text{SIR}_{\text{ref}})$.



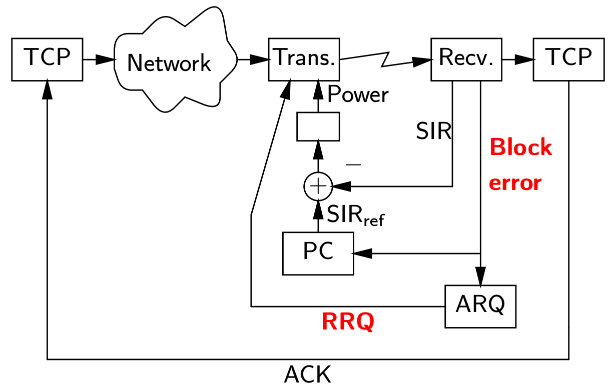


Link-layer retransmissions

Link mechanism eliminates block errors, but adds random delays.

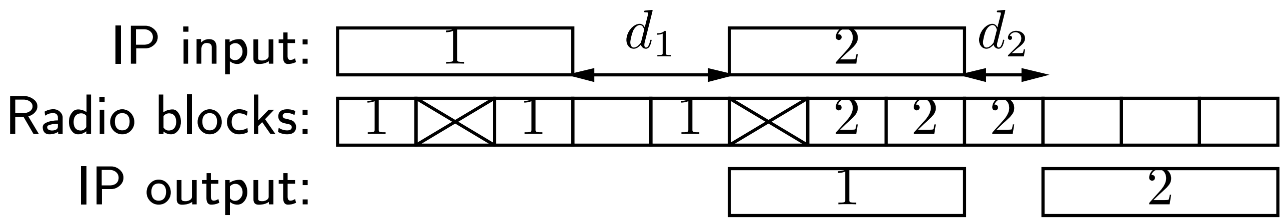


- Delay depends on the block loss process, and on the retransmission scheduling.
- Block lost each time the Markov chain makes an upward step.



IP PROPERTIES

IP delay depends on power control and link retransmission scheme.



Prob.	$d = 0$	1	2	3	4	5	6
$n = 1$	90.0%	0.00%	0.00%	9.35%	0.00%	0.00%	0.63%
2	80.6%	0.00%	8.77%	9.33%	0.00%	0.63%	0.63%
3	71.8%	8.19%	8.75%	9.31%	0.63%	0.63%	0.63%
⋮		⋮					
7	42.7%	29.73%	13.12%	9.57%	3.12%	0.89%	0.64%

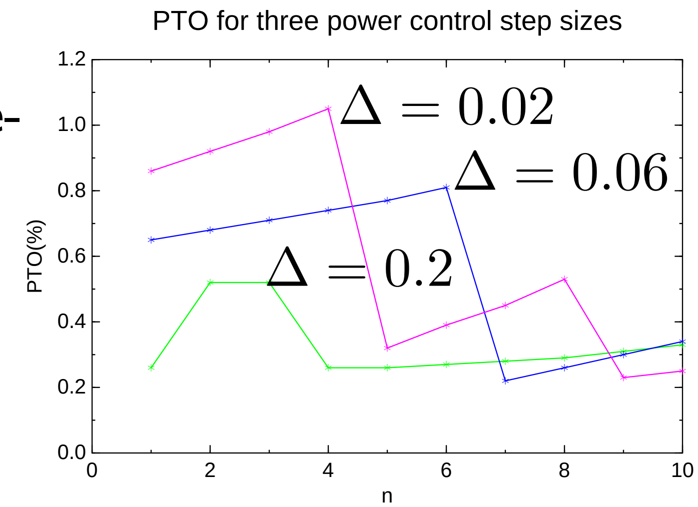
Spurious TCP timeouts

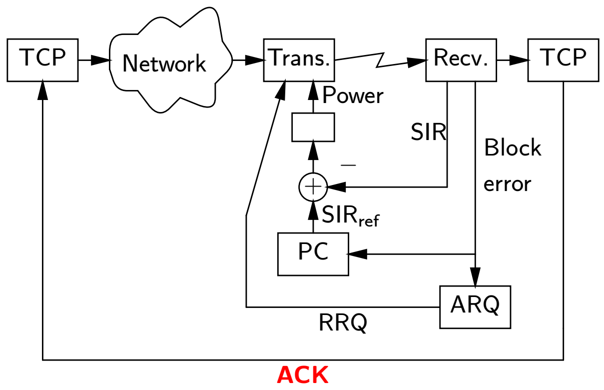
In TCP, timeouts are used for detecting severe congestion.

$$P_{\text{TO}} = P(\text{RTT} > E\{\text{RTT}\} + 4\sigma\{\text{RTT}\})$$

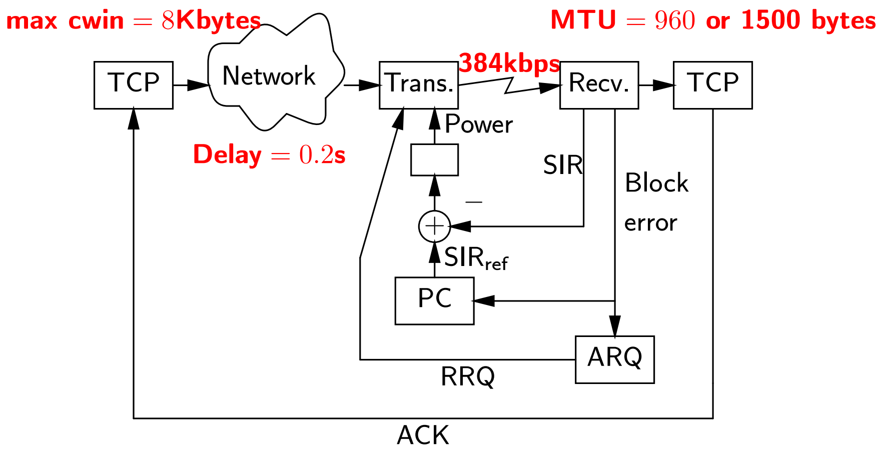
Depends on the delay distribution:

- Uniform distribution: $P_{\text{TO}} = 0$
- Normal distribution: $P_{\text{TO}} \approx 0.006\%$
- General distribution: $P_{\text{TO}} \leq 6.25\%$
- **Wireless link:** $0.2\% \lesssim P_{\text{TO}} \lesssim 1\%$



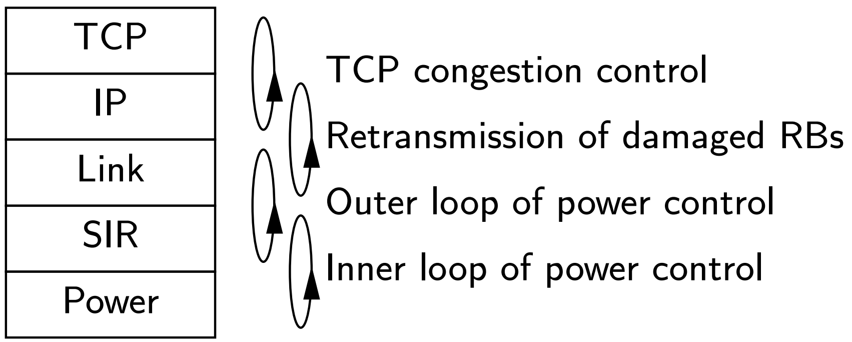


Performance degradation



- Available bandwidth (excluding losses): 42 Kbyte/s
- Ideal TCP throughput: 32 Kbyte/s
- **Actual TCP throughput: 26.5–30.5 Kbyte/s**

Layer interaction



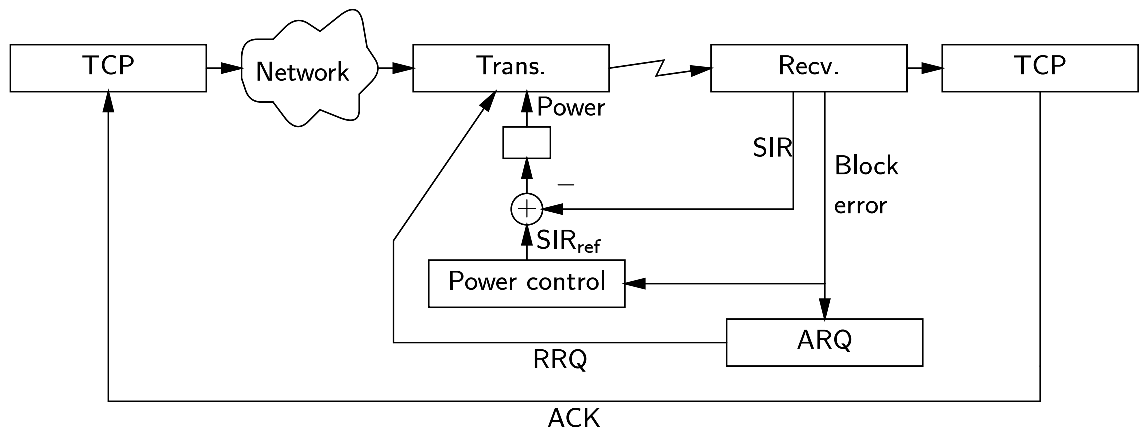
- Link properties shine through to transport layers.
- Link layer coding and retransmission is key to layer decoupling.
- Engineering freedom in link layer.

KTH

VETENSKAP OCH KONST

Automatic Control

Conclusions



- Four cascaded feedback control loops. Undesired interaction.
- Performance degradation in the case of an unsaturated link.
- One approach to improved performance is to decouple layers: Engineer link layer to get a more TCP-friendly delay distribution.