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Probe-based Transmission Power Control for Dependable Wireless Sensor Networks

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Dependable Wireless Sensor Networks

GINSENG

- WSN for mission-critical, real-time applications
- Purpose-built, mostly static topologies, up to 30 nodes
- TDMA technology

TDMA Schedules for Dependable WSNs

- Static schedules with exclusive slot usage
- Late packets are dropped and lost
- Schedule has to allow for timely retransmissions
- No. of RTX slots must be based on worst-case losses

Spatial Channel Reuse: Motivation and Challenges

Sines Oil Refinery in Portugal

- 35,000 active (wired) sensors in place at the moment
- Up to 30 nodes per WSN

⟶More than 1000 WSNs in parallel on (up to) 16 channels*

In General

- Reuse of channels cannot be avoided
- But: exclusive slot usage is neglected by neighboring networks
- With interference, more retransmission slots are necessary

→Interference has to be minimized

(*) When using IEEE 802.15.4 in the 2.4 GHz band

Burstiness of Links

- Packet losses occur in bursts; so-called **burstiness**
- TDMA schedule has to be provisioned for worst-case losses

How to express burstiness [Munir et al., 2010]?

- B_{max}: Longest packet loss burst on a link
- B_{min}: Shortest no-loss period on a link

Example

- Pattern: 11 00 10 11 (8 Probes, 1 = ACK, 0 = Loss)
- B_{max} = 2; 1 = B_{min}

TDMA schedules are made to handle links with specific B_{min}/B_{max}

Transmission Power Control

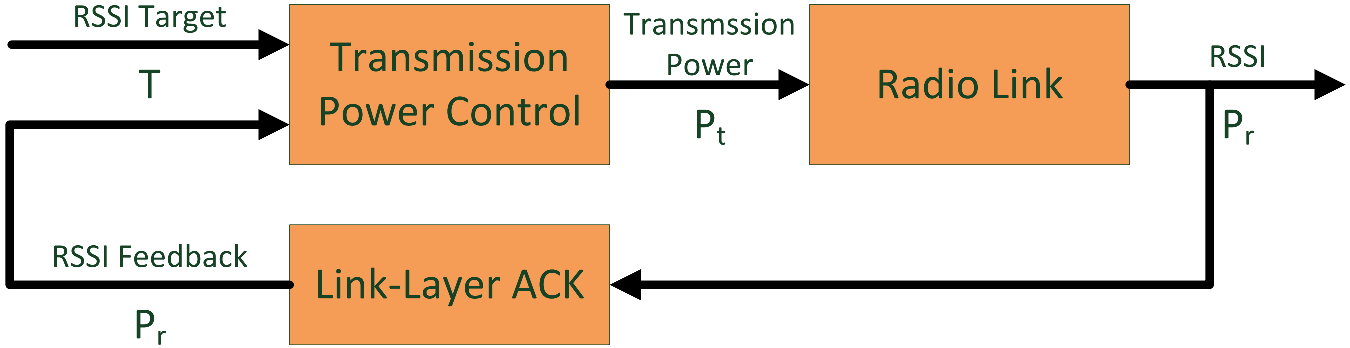
Goal

- Minimize interference; maintain reliability

⟶Minimize TX power and losses; retain burstiness

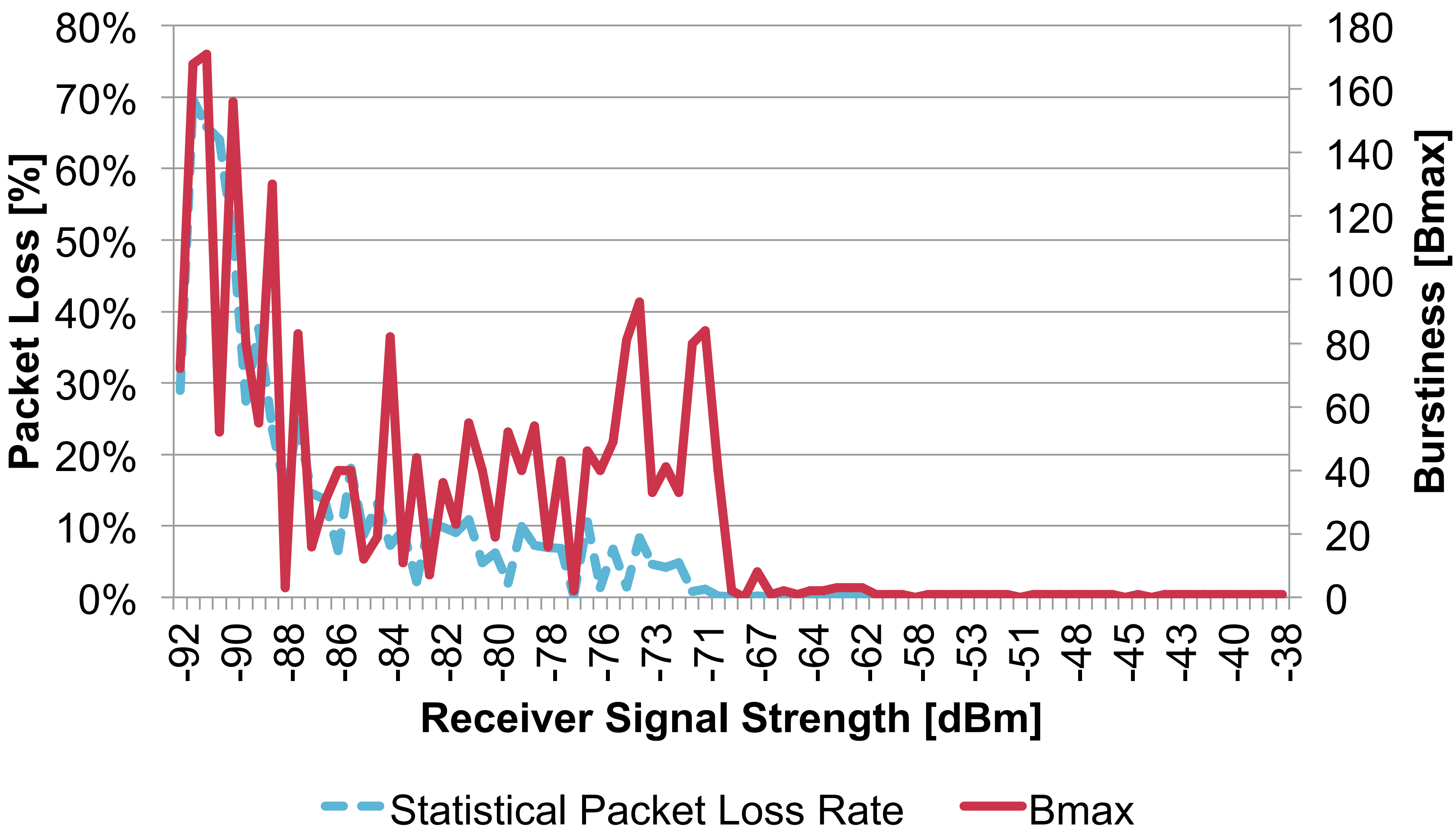
- Secondary: reduce energy consumption to conserve lifetime

Attenuation-based TPC in literature [Bergamo et al., 2004]:

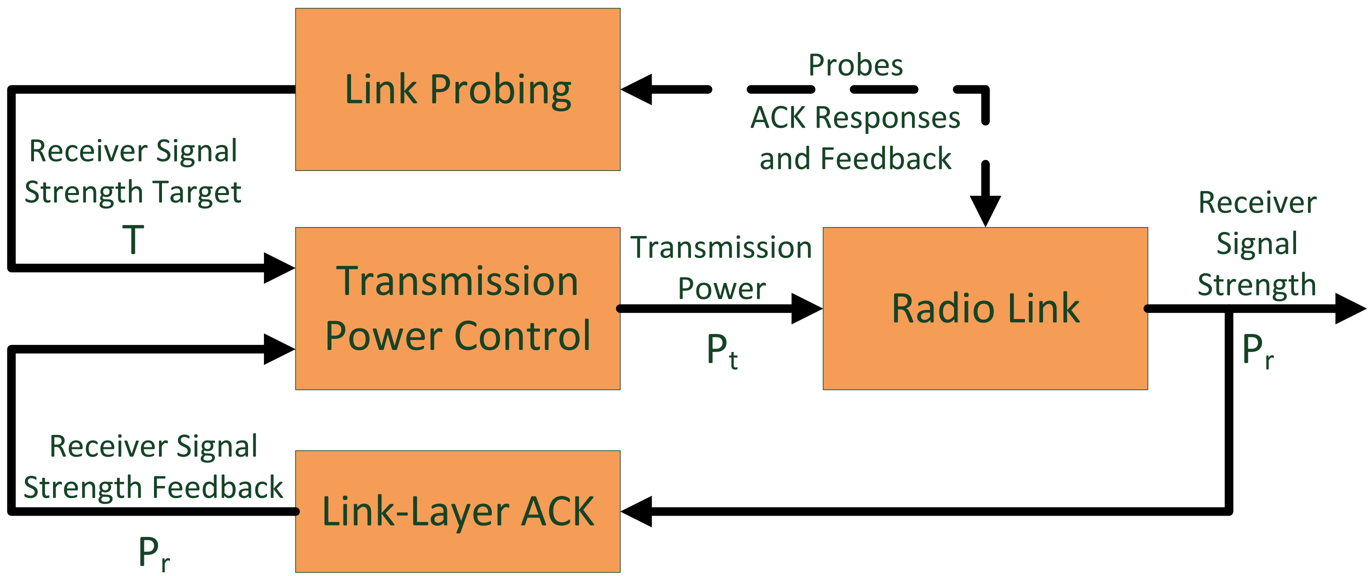


But: how to determine RSSI target T that retains burstiness?

Burstiness of all links in Sines Refinery



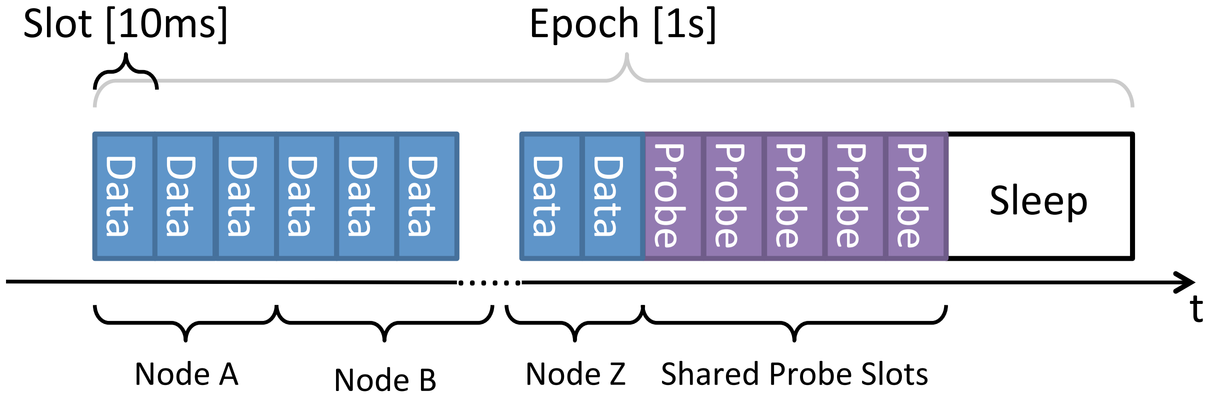
Probe-based Transmission Power Control Architecture



1. Nodes probe outgoing link at all TX power levels
2. Determine B_{min}/B_{max} for probing period together with P_r
3. Select lowest P_r with burstiness at least as good as schedule
4. Use P_r as receiver signal strength target T

Probing links to determine their burstiness

- Append n probe slots to end of epoch; round-robin use
- Send n probe packets to upstream node at certain TX power
- Average P_r over all received probes; calculate B_{min}/B_{max}
- Continuously repeat to catch channel changes over time



Tradeoff between accuracy and time

- Literature: 8 slots are enough [Brown et al., 2011]

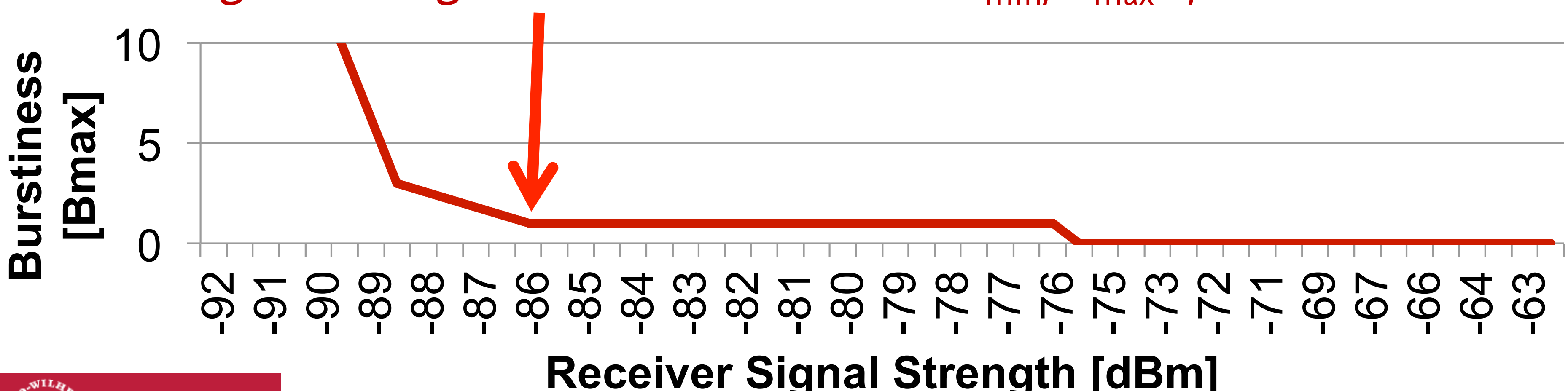
One Probing Epoch

Slot	1	2	3	4	5	6	7	8
Probe Response	1	0	1	1	1	1	1	1
RSSI Feedback	-80		-80	-80	-79	-80	-80	-81

→ $B_{min} = 1$, $B_{max} = 1$

→ RSSI = -80 dBm

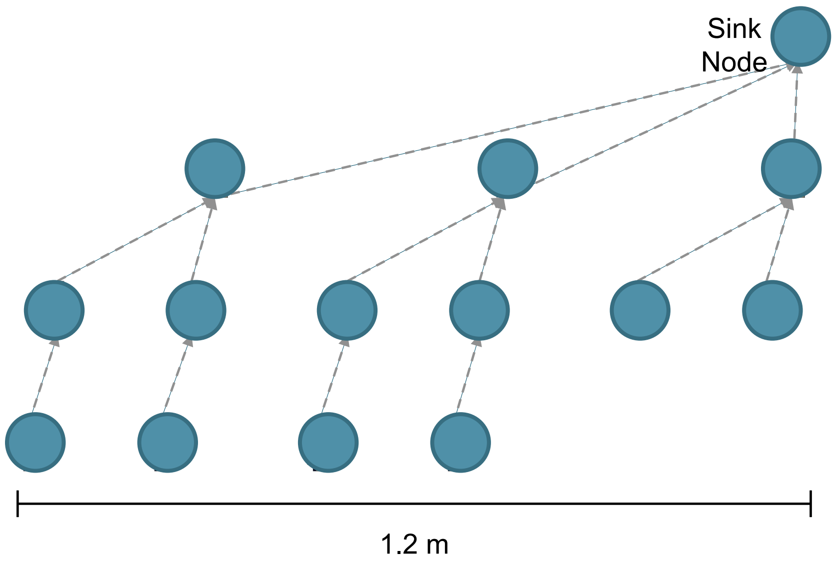
Selecting RSSI target T for schedule with B_{min}/B_{max} 1/1



Evaluation setup and metrics

Setup

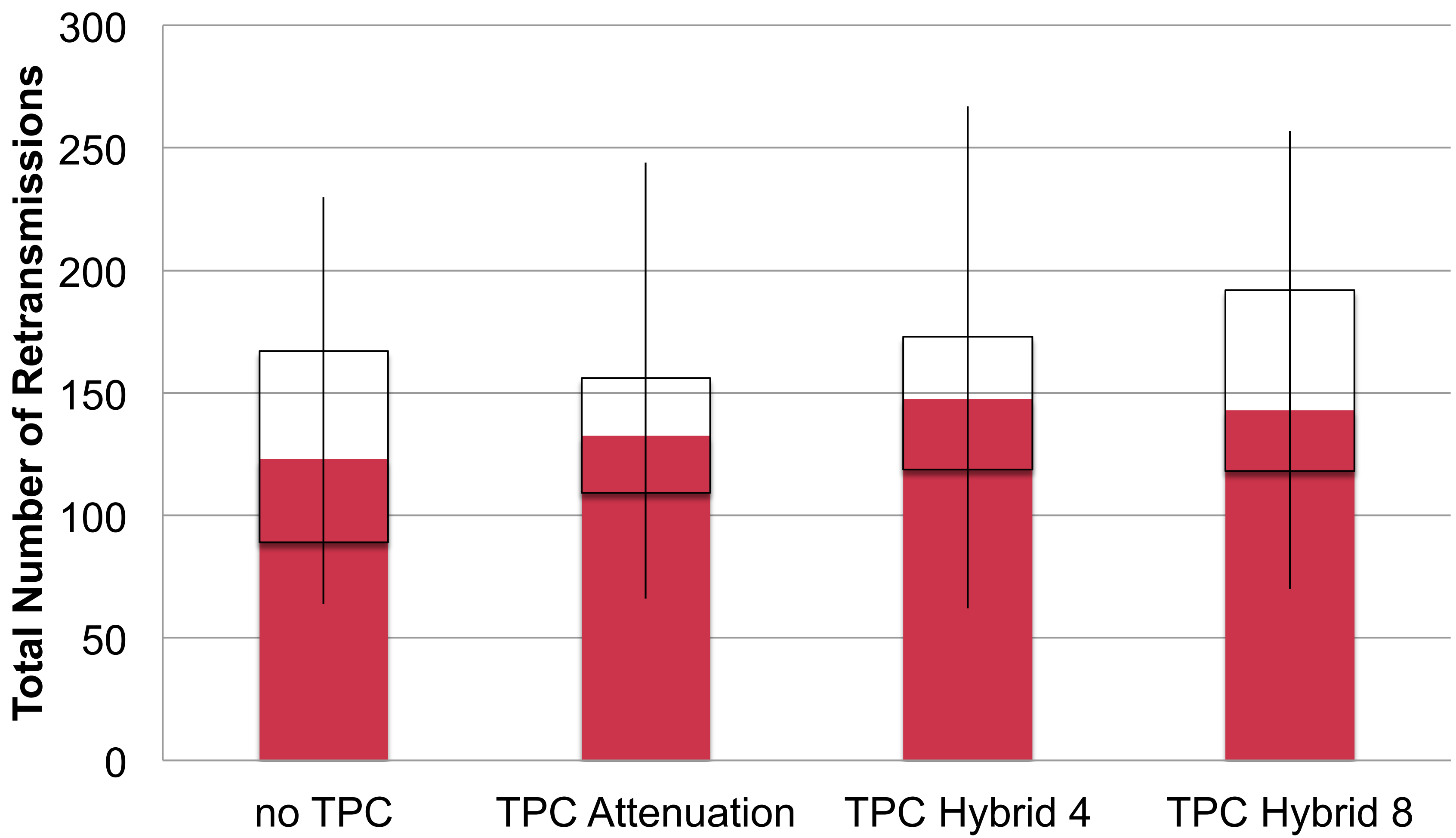
- Basement of office building
- 14 Tmote Sky nodes
- GinMAC based on Contiki 2.4
- 94 experiments, 190 min. each



Metrics

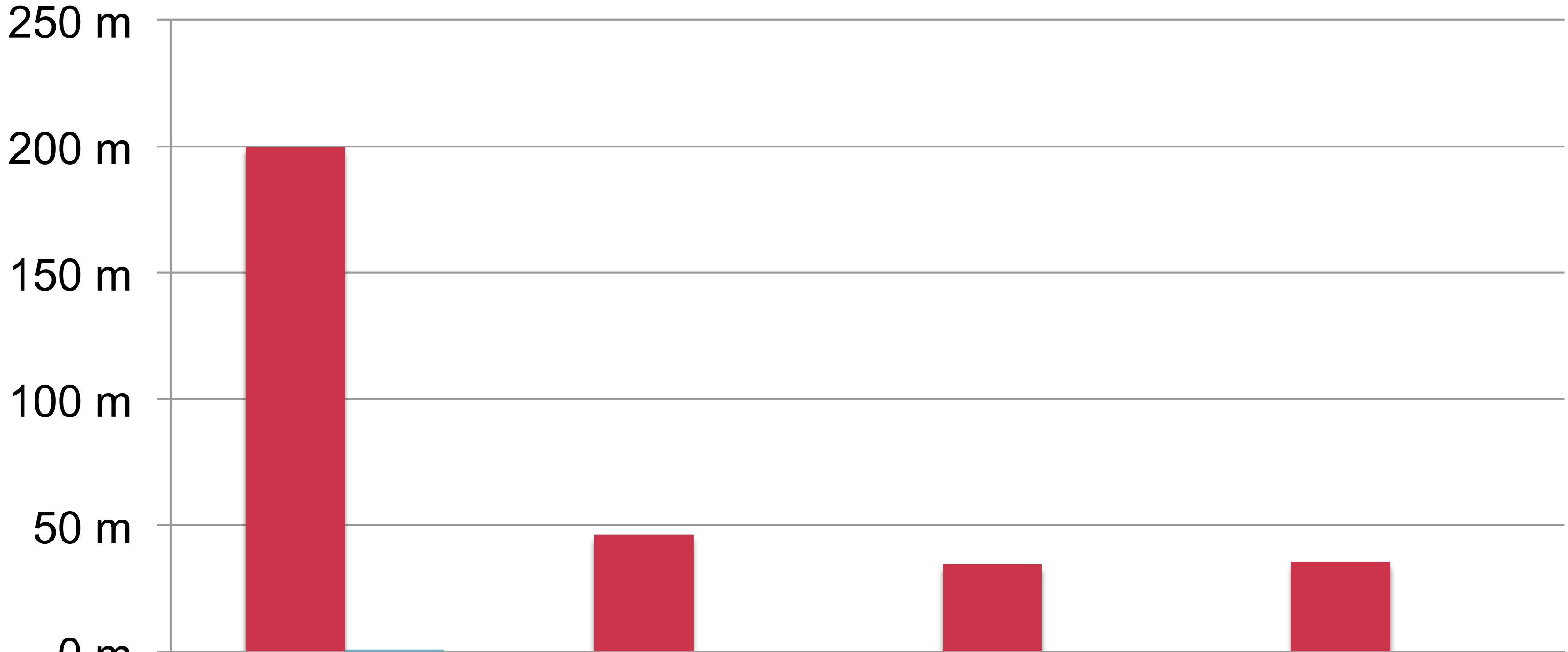
- Retransmissions represent **reliability**
- TX power represents range and hence **interference**
- **Energy consumption**
- Results are statistical aggregates of all tests

Reliability in terms of retransmissions on all links



159,600 regular transmissions in the network

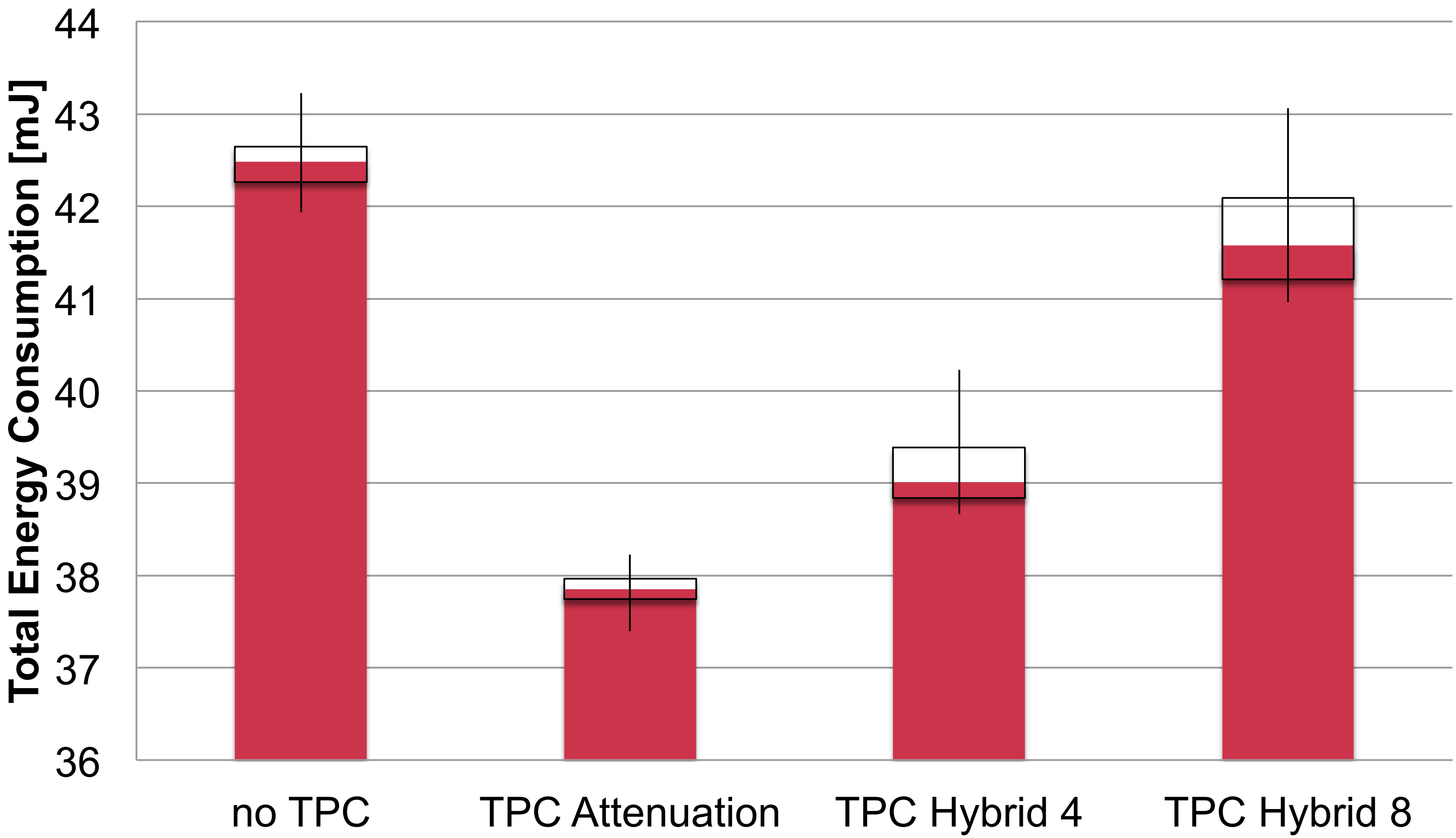
Interference in terms of TX power and resulting range for all nodes



	No TPC	TPC Attenuation	TPC Hybrid 4	TPC Hybrid 8
Range	199.5 m	46.3 m	34.6 m	35.5 m
Avg. Pt	1.0000 mW	0.0029 mW	0.0009 mW	0.0010 mW

Range estimation with 2-ray ground reflection model; h=1m, sensitivity -92 dBm

Energy consumption for all nodes except the sink



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Motivation

- Interference of dependable WSN has to be minimized to allow channel reuse in dense deployment situations
- Existing TPC approaches do not take burstiness into account

Approach

- Measure burstiness for multiple RSSI values
- Select lowest RSSI with acceptable burstiness as target for TPC
- Ensure that burstiness stays within capabilities of schedule

Results

- Significantly reduced interference; slightly decreased reliability