Channel Quality Metric for Interference-Aware WSN

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Outline

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   - Problem Statement
   - Interference in ISM Band
   - Metric Proposal
2. Experiments
   - Experimental Setup
   - Measurements
3. Preliminary Results
   - Metric Parameters
   - Correlation with PRR
4. Applications
   - FEC Optimization
   - Multichannel
   - Adaptive Power

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Problem Statement

Suppose:

- we want to receive an 802.15.4 packet of 50 bytes (∼2 mS)
- the channel has some interference from 802.11 networks
- we want to quantify the *quality of the channel*
- notice, time average of channel energy is misleading

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ISM Band Interference

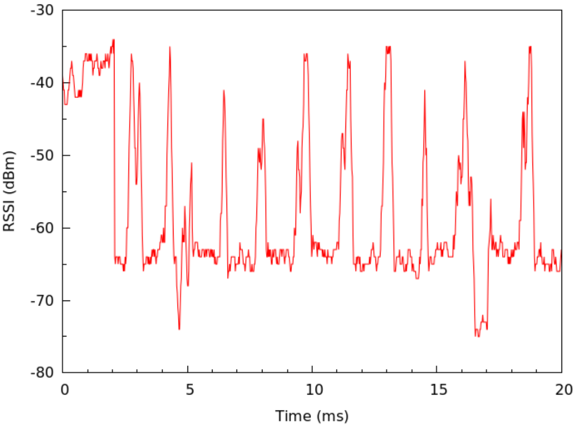

Figure: Interference from WLAN

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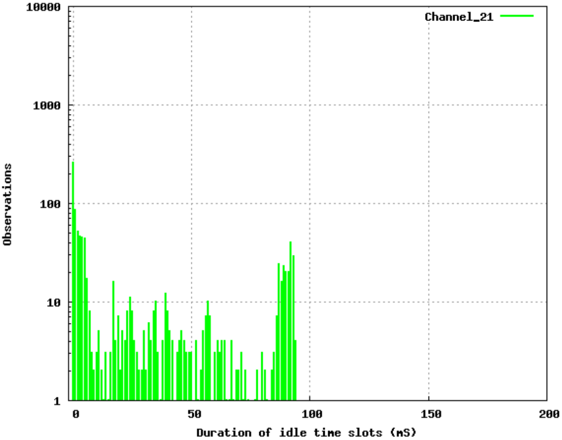

Figure: Idle time distribution

Observations

- A metric to quantify the impact of Interference in the quality of the channel is needed
  - This metric should be *agnostic* to the *interference source*
  - One typically needs the channel for a specific time window
  - Only interference signals above certain power level (R_{THR}) matter
  - We sample the energy in the channel at the receiver with period P

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Average Channel Availability

We define the average channel availability as:

$$CA(\tau_r) = \frac{1}{n-1} \sum_{j|(j-1)P>\tau_r} j m_j \tag{1}$$

where:

- n is total number of RSSI samples, taken with period P
- j is a number of consecutive clear samples $(RSSI < RSSI_{THR})$
- m_j is the frequency of occurrence of j
- m the total number of channel vacancies, i.e. $m_0 + m_1 + \ldots + m_n = m$
- τ_r be the time window of interest, for $\tau_r > 2P$

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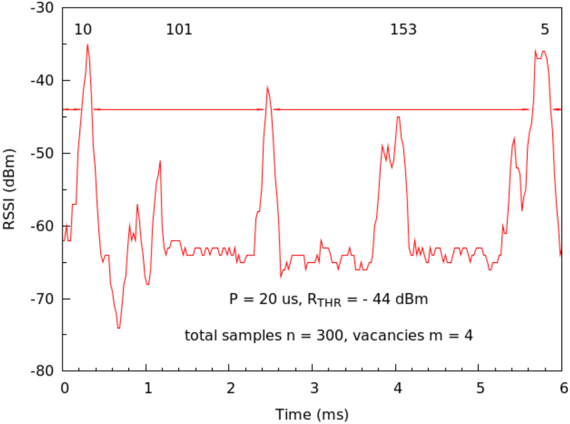

Figure: *Case 1* $CA = 0.88$

Average Channel Availability

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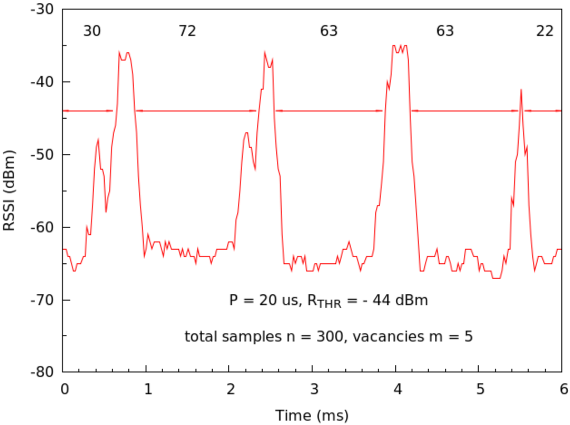

Figure: *Case 2* $CA = 0.83$

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Stuff that matters: Fragmentation

Notice:

- *CA* is close in both cases, i.e. $CA_1 = 0.88$ and $CA_2 = 0.83$
- the likelyhood our 50 bytes (~2ms) packet collide is *visibly larger* in *Case 2*
- *Indeed, due to channel availability time made of shorter intervals*

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Channel Quality Metric

For this reason we bias the previous expression as follow:

$$CQ(\tau_r) = \frac{1}{(n-1)^{(1+\beta)}} \sum_{j|(j-1)P>\tau} j^{(1+\beta)} m_j \tag{2}$$

where $\beta > 0$ is the bias.

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Experimental Setup

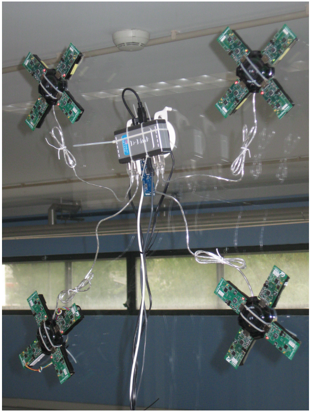

Figure: Lab deployment

Testbed with 17 telosb
(16 motes read RSSI on each 802.15.4 Ch's & 1 for time synch)
Contiki script to scan and dump readings to a file in the PC
Exploratory data analysis to be done off-line

Experimental Setup

Figure: Deployment at FEUP Library

RSSI Measurements

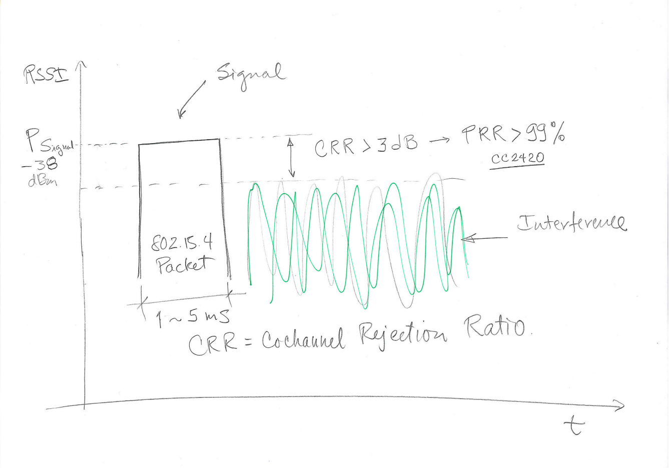

Figure: RSSI Measurements

Signal + Interference

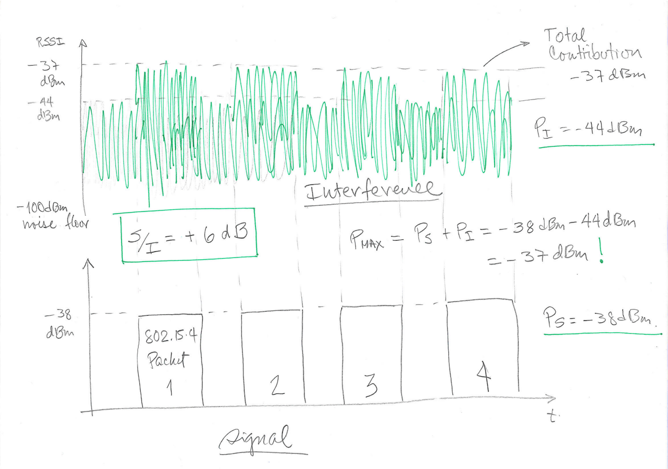

Figure: RSSI Measurements

Wireless Traces

- Extensive trace collection from 802.11 networks, including some with *heavy traffic*.
- 802.11 RSSI traces collected every 8 s (sample 130 ms –> mem buffer, then write to HDD on notebook)
- Also other traces from microwave oven and Bluetooth

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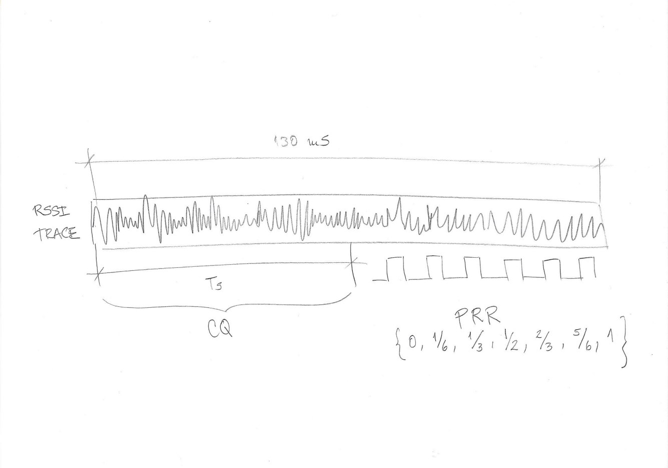

Figure: CQ and PRR computations

Off-Line Experiment

Off-line experiment for investigating correlation with PRR:

- traces are 130 ms long
- use a segment to compute CQ metric
- the remaining is used to check eventual packet reception
- packets expected periodically with inter-arrival time IPI
- check if $RSSI < RSSI_{THR} - 5dBm$ throughout the entire packet length
- compute PRR

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Time Window: τ

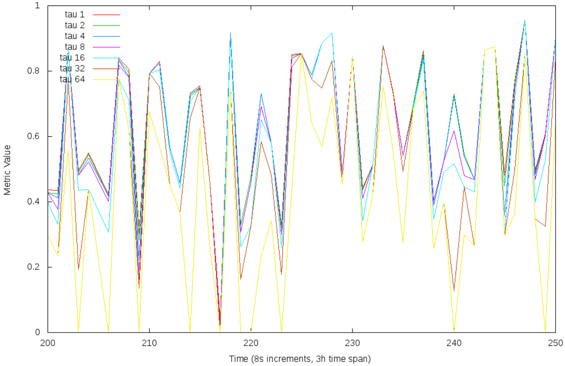

Figure: Varios τ, -65 dBm, $\beta = 0.1$

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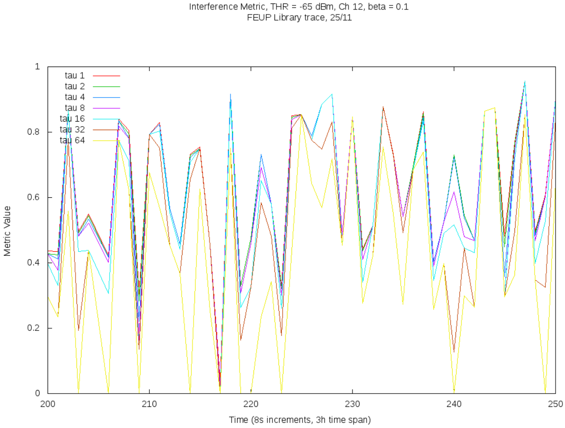

Figure: Dependency on τ

Sampling Time

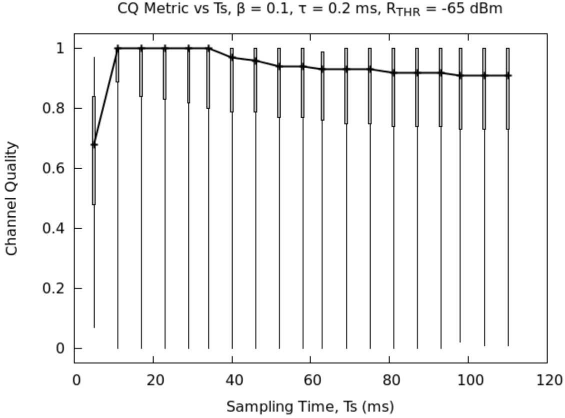

Figure: Computed on 60,000+ traces

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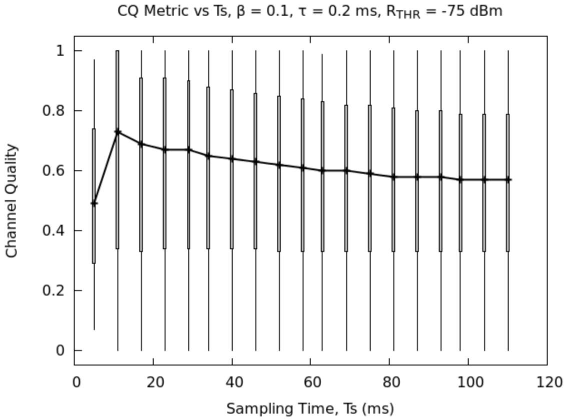

Figure: CQ statistics for various β at -75 dBm

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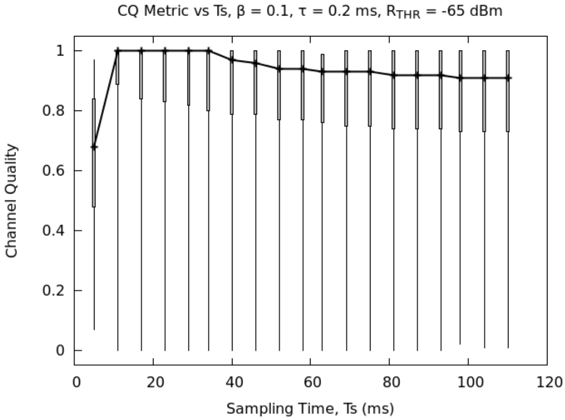

Figure: Statistics for various β at -65 dBm

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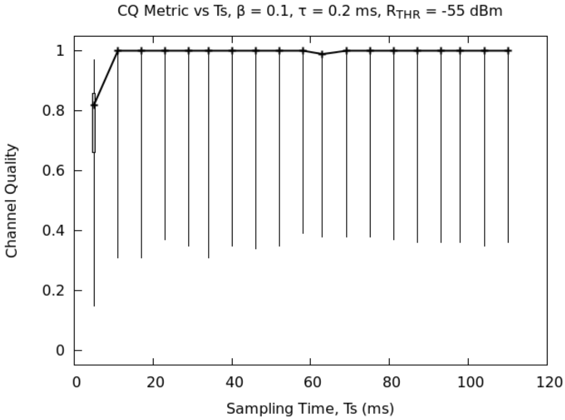

Figure: Statistics for various β at -55 dBm

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RSSI Threshold

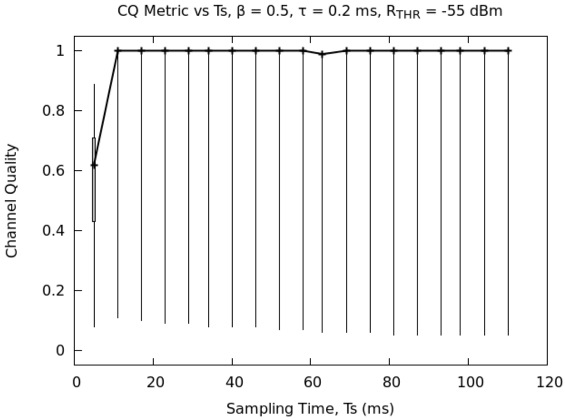

Figure: CQ for varios R_{THR}

Preliminary Results

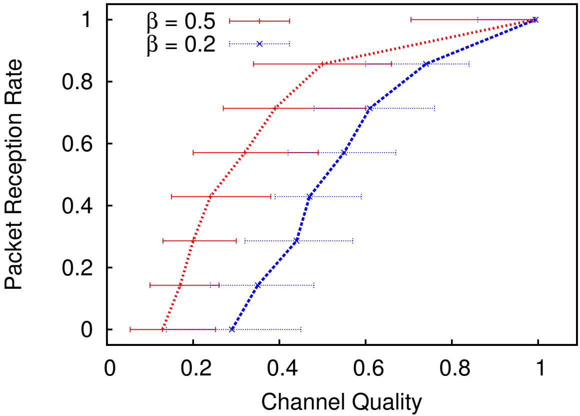

Figure: Strong correlation: 140,000+ packets

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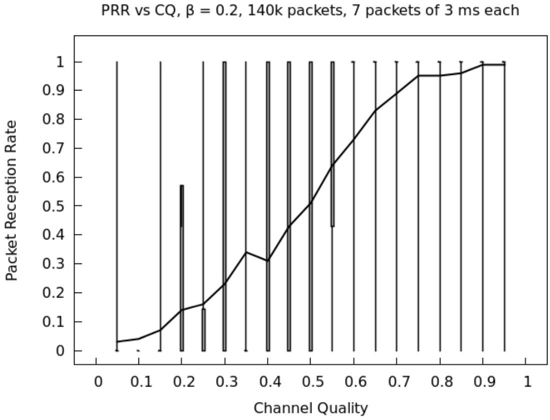

Figure: Mean PRR + IQ range (80,000+)

Dynamics of 802.15.4 & 802.11

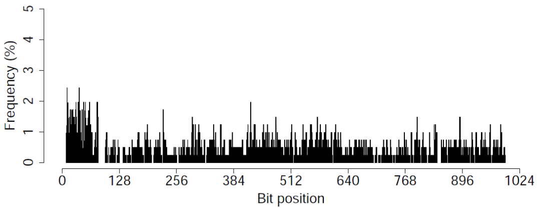

Figure: Bit-error distribution for packets that fail CRC (802.11g, asymmetric). Liang et al (SenSys 2010)

Error-Correction Codes

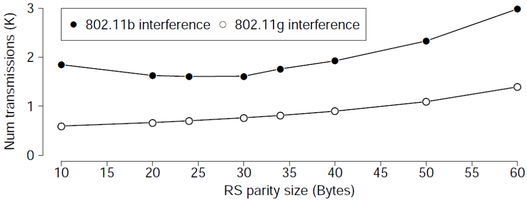

Figure: Nmber. of Tx (38K object, single-hop)

- Reed-Solomon implementation (2.9 Kb ROM / 1.4 Kb RAM)
- RS encoding ~40 ms, decoding ~200 ms (30 byte erasure)
- Recover 50 ~60% packet payloads
- Room for improvement: optimize with CQ !

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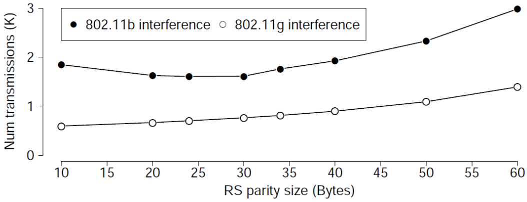

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Multichannel Operation

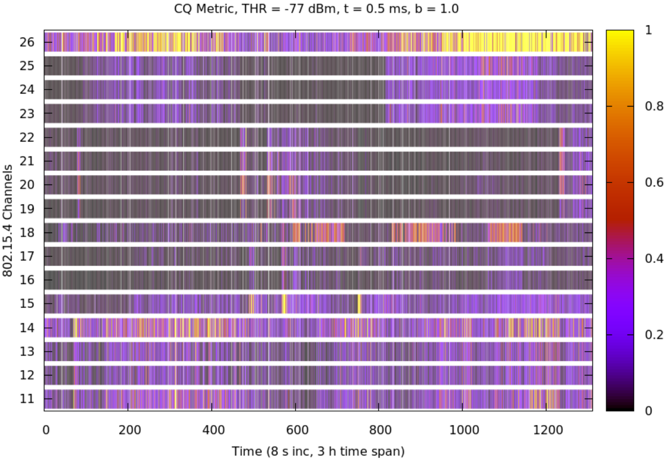

Figure: Spectrogram

Adaptive Power

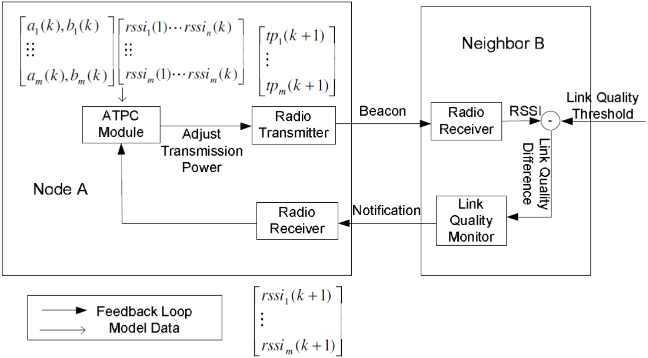

Figure: ATPC (Lin et al, SenSys 2006)

Thank You

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