Poster Abstract: A Channel Quality Metric for Interference-Aware Wireless Sensor Networks

Claro Noda[†], Shashi Prabh[†], Carlo Alberto Boano[‡], Thiemo Voigt[*], Mário Alves[†]
{cand,ksp,mjf}@isep.ipp.pt[†], cboano@iti.uni-luebeck.de[‡], thiemo@sics.se[*]

[†]CISTER Research Unit, ISEP
Porto, Portugal

[‡]University of Lübeck
Lübeck, Germany

[*]Swedish Institute of Computer Science
Kista, Sweden

ABSTRACT

Wireless sensor networks share the spectrum with other wireless technologies. Hence, in order to minimize the effects of external interference they must carefully choose the channels for packet transmissions and reception. The identification of the best channels is, however, non-trivial. In this poster we present and evaluate a new channel quality metric that is based on the availability of channels over time rather than on the average energy in channels.

Categories and Subject Descriptors

C.4.3 [**Performance of Systems**]: Measurements Techniques. Reliability, availability, and serviceability

General Terms

Experimentation, Measurement, Performance, Reliability, and Verification.

Keywords

Interference, ISM Bands, Wireless Sensor Networks

1. INTRODUCTION

Wireless technologies have grown exponentially during the last decade and are increasingly more appealing for many applications. Many standardized technologies operate in crowded and lightly regulated ISM frequency bands. Wireless networks in these bands are now ubiquitous in residential and office buildings as they offer great flexibility and cost benefits. However, their most significant disadvantage, compared to wired networks, is reliability.

Packet Reception Rate (PRR) is a well known reliability metric. A high PRR indicates the wireless channel and the link are optimum. However, since PRR is a high level metric, affected by many factors, a medium/low PRR lacks information about factors responsible for poor performance. Furthermore, PRR-based solutions cannot react to instantaneous changes in the channel condition as they are usually designed to select channels and routes using long-term observations.

Interference from coexisting networks, also referred as Cross Technology Interference (CTI), represents a well known problem [1, 2, 3, 4] not thoroughly addressed in WSN. This problem is hard to solve for two reasons: a) unfeasible cooperation for spectrum access across different technologies and b) large RF power and spectral footprint asymmetry.

CTI could be avoided by sophisticated communication protocols that are sensitive to instantaneous spectrum occupation. However, low-cost hardware and limited energy-budget of nodes make the typical spectrum sensing techniques as proposed for other systems [5] unsuitable for WSN. We present a *Channel Quality* (CQ) metric that quantifies interference. It provides a quick and accurate estimate of interference in the channel, based on its fine-grained availability over time. We use the energy detection (ED) feature in IEEE 802.15.4 compliant radios to measure evolution of signal strength in the channel and validate our CQ metric on data collected from real-world experiments. We find it has strong correlation with PRR and can be useful in interference-aware protocols for WSN.

2. INTERFERENCE ASSESSMENT

Interference sources in the radio channel can be diverse, namely any device that produces RF signals which are concurrently present in the wireless medium and contain spectral components within the receiver passband. Interference causes decrease in the Signal-to-Noise plus Interference Ratio (SNIR) which can result in packet losses.

Channel Quality Metric. Average energy in the channel has been used as an indicator of its usage in previous literature. Unfortunately, such metric is unable to distinguish between a usable channel and a noisy channel. For example, consider two cases of intermittent bursty traffic and streaming media traffic. In the first case, the average energy may be high but successful transmissions are possible. However, in the second case, the probability of successful transmission is very low, despite the average energy is typically small. Motivated by this observation, we propose a metric based on the fine-grained channel availability over time.

Consider RSSI levels in some channel are measured with period P. There is a threshold R_{THR} below which interference does not harm a signal we intend to receive. Thus, the channel can be considered idle as far as $RSSI < R_{THR}$. For example, Figure 1 shows RSSI samples over time along with idle intervals, which we refer as *Channel Vacancies* (CV). Let m_j denote the number of CV made of consec-

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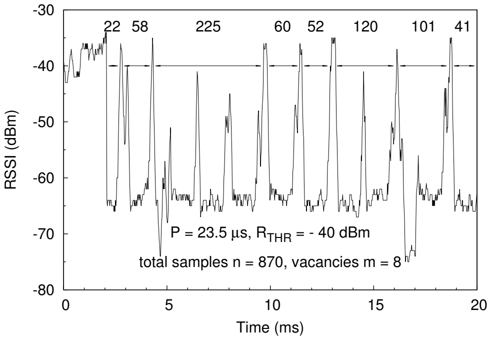

Figure 1: Channel vacancies at -40 dBm, with number of idle samples j indicated on top.

utive j idle samples, n the total number of samples and $m_1 + m_2 + \ldots + m_n = m$, total number of CV. Thus, j consecutive clear samples imply that the channel was free for at least $(j-1)P$ time units. We define the average CV as:

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

where τ is the time window of interest, which could be the duration of certain packets, and $\tau > 2P$. Now, a channel where $m_{2j} = k$ is more desirable than a channel where $m_j = 2k$, although jm_j is the same for both cases. Therefore, we bias CV to rank channels with larger vacancies higher and hence define the channel quality metric as:

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

where $\beta > 0$ is the bias. CQ in equation (2) take values between 0 and 1, the higher the value the better the channel. Also, this expression is agnostic to the interference source.

3. PRELIMINARY EVALUATION

Our experimental setup is conceived to study interference in the 2.4 GHz ISM band and experimentally investigate our metric proposal. We scan all 802.15.4 channels simultaneously, employing a set of 17 TelosB sensor nodes, which use the CC2420 Radio transceiver, and one mote is employed for time synchronisation. The motes are connected via USB hubs to a notebook and RSSI readings are collected on the CC2420 during certain scanning time and repeated periodically, every 8 seconds. The ensemble was used in our laboratory, with moderate interference hitting few 802.15.4 channels, and in a measurement campaign at the library of the Faculty of Engineering of the University of Porto, where we found very heavy traffic from 802.11 WiFi networks. In our experiments, signals are well above the noise floor (10 - 70 dB), but more relevant is the time distribution of burst patterns that varies from microseconds to tens of milliseconds.

In order to do multiple channel readings simultaneously we use one of the motes to transmit a scanning beacon on channel 26, which instructs all other nodes to switch to their respectively assigned channels and begin scanning. After completing 5600 samples, in approximately 130 ms, all nodes return to listen on channel 26 and wait for the next scanning beacon, while all RSSI readings we kept in a memory buffer are dumped to a file. We then perform off-line experiments based on these traces to validate our metric proposal.

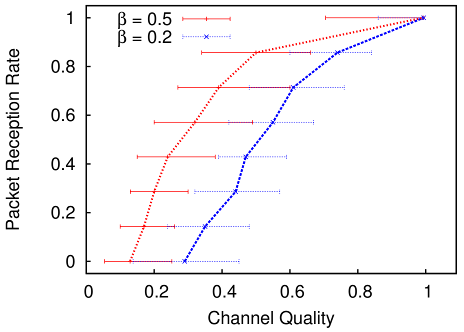

Figure 2: PRR from 140,000+ off-line transmissions.

A fraction of each 130 ms RSSI trace is used to compute the metric and the remaining to verify packet reception. If RSSI readings remain under a predetermined value ($RSSI < R_{THR} - 5dBm$), for the duration of each packet, then the transmission is considered successful. PRR is computed out of multiple packets transmitted periodically over each trace and scheduled with a fixed inter-packet interval.

Figure 2 shows the results of 140,000 off-line packet transmissions on traces obtained from the library WiFi Network. The curves correspond to the median and the error bars represent the interquartile range, from 25 to 75% of available data points. We find strong correlation with PRR and rapid decay of CQ with channel fragmentation, as the bias grows. We explore the influence of parameters in (2) and find that CQ becomes less sensitive to the desired packet size, τ, for larger bias. We also examine the effect of sampling time and find it could be optimized, provided bursts in the channel are less correlated as they are more distant in time.

4. CONCLUSIONS

We propose a channel quality metric that quantifies the extent of interference in wireless channels for sensor networks. It uses energy detection to determine channel availability with packet length granularity. We evaluate its performance in the 2.4 GHz ISM band in an environment of excessive interference from 802.11 WLANs and find strong correlation with PRR. This implies that our CQ metric can estimate the channel condition accurately. This is useful for interference-aware protocols based on adaptive RF power and frequency schemes, Forward Error Correction and cross-layer optimization in WSN.

5. REFERENCES

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