Experimental Analysis of Concurrent Packet Transmissions in Wireless Sensor Networks

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Introduction

Concurrent Transmission in WSNs

Even though the bandwidth utilization of the network is low, concurrent packet transmission is prevalent in WSNs because of

- Event based, bursty nature of traffic pattern
- Multi-Source to single destination *or* flooding (sink→source) type of packet communication

Interference Model & Capture Effect

- Simplified model consider concurrent packet transmission as a packet collision
  - This overestimate the likelihood of packet drop due to packet collision
- Capture effect is not considered in state of the art wireless simulators and theoretical analysis
  - Realistic models of wireless links are essential for developing and evaluating protocols for sensor networks

Black-Gray-White Region

- Black: Concurrent packets collide and both are lost (both at about the same receive power (< 10% Packet Reception Rate (PRR))
- White: Packet from the strongest sender dominates weaker sender and is received successfully (≥ 90% PRR)
- Gray: Intermediate, unreliable packet reception (10~90% PRR)

SINR Threshold (SINR_Θ)

- Signal to Interference plus Noise ratio (SINR) which guarantees successful packet reception with high probability (e.g., over 90% PRR).

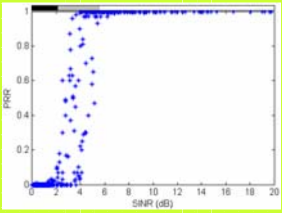
Regression Model

- Our regression model is based on Zuniga and Krishnamachari's link layer model (SECON'04) and used for drawing SINR to PRR fit-line.
- Used Regression Model: PRR = $(1-0.5*\exp^{-\beta_0*SINR+\beta_1})^{8(2f-l)}$
  - New parameters(β_0, β_1) are added to adopt real-world difference in the model
  - f: frame size of the packet l: preamble size

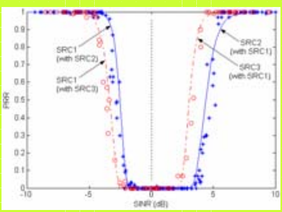
Transmitter Hardware and SINR_Θ

Experiment Methodology

- Experiments with two pairs of nodes : SRC1-SRC2 and SRC1-SRC3
  - One node performs as a packet sender and the other as an interferer
  - Two experiments for each pair with switched role between two nodes
- The sender transmits at constant power (i.e. received signal strength at the receiver is constant) and the interferer varies transmission power



(a) Three different Senders



(b) Replace SRC2 with SRC3

SINR and PRR

- When we present the experiment results in SINR to PRR relationship, we can see 2.84 dB wide gray region.
- PRR is unpredictable with SINR value in the gray region

Hardware Effects

- Results for each experiment with different node pair is separately presented in (b).
- For the same transmitter, it has different SINR_Θ with different interferers.
  - SRC1 with SRC2 or SRC3 as an interferer
- For different transmitter, it may have different SINR_Θ with same interferer.
  - SRC2 and SRC3 with SRC1 as an interferer

- For each sender and interferer combination, the SINR threshold is different and gray region is narrower (SRC1-SRC2: 1.1 dB-1.51dB, SRC1-SRC3: 1.62 dB-1.48 dB) with predictable SINR to PRR mapping.
- We perform the same experiment after swapping the location between SRC1 and SRC2 and it does not make noticeable difference in SINR threshold for both node.
  - This confirms that the difference in SINR_Θ between the SRC1 and SRC2 is from the transmitter hardware, not from the location difference.

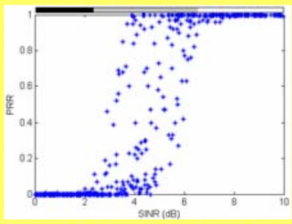
- Different transmitters generate signals with different level of distortion from nonlinearity in the transfer function.
- Signals from different transmitters may have different actual effect (or signal strength) even when the receiver measure the same level of signal strength.

•Full paper reference: Experimental Analysis of Concurrent Packet Transmission in Wireless Sensor Networks. In preparation

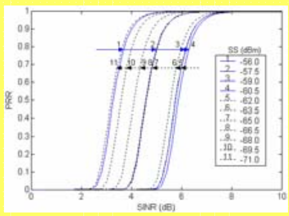
SINR_Θ as Signal Strength Varies

Experiment Methodology

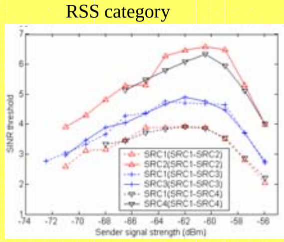
- Experiments with two node SRC1(Sender) and SRC2 (Interferer)
- We use the same sender and interferer hardware throughout the experiment to see if the same transmitter has a constant SINR_Θ.
- We vary both sender and interferer signal strength over the wide range.



(a) SINR to PRR as RSS change



(b) Regression lines for each RSS category



(c) SINR threshold change

Effect of Received Signal Strength (RSS) Change

- Even with same transceiver hardware pair, it shows wide (4.19 dB) gray region with signal strength change at the receiver (Shown in (a)).

RSS and SINR_Θ

- Experimental results are categorized based on the received sender signal strength (for each 1.5 dB interval).
- Each category is presented with a regression line in figure (b)
  - Strong Correlation: Every regression line has higher than 0.96 R^2 value.
- Results show signal strength level is closely related to the SINR_Θ.

SINR threshold change

- We perform extended experiments of received signal strength variation with three different pairs of nodes :
  - SRC1-SRC2, SRC1-SRC3, SRC1-SRC4
- There is a turning point of the line for all regression line in the figure around -61 dBm of received signal strength
  - Highest SINR_Θ at this turning point

- Implication of SINR changes at different signal strength level and different factor dominates in each side of this turning point

- Wide gray region does exist for the same sender and interferer hardware
- Distinct SINR_Θ is identified for each measured received sender signal strength (RSS) level at the receiver.

Conclusion

- **SINR threshold (SINR_Θ) is not a constant value.**
- **Identified two causes of the high variation in SINR_Θ**

[1] Different Transmitter Hardware

- **Different level of signal distortion from different transmitter hardware cause different effect from the signals with same received signal strength measurement at the receiver.**

[2] Different Received Signal Strength

- **For the same sender and interferer hardware, we identify distinct SINR threshold at different received signal strength level at the receiver.**

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