Demo: Investigating Concurrent Transmission Using Software Defined Radios

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Abstract

Concurrent Transmission (CT) is one of the most influential techniques for WSNs developed in recent years. Nevertheless, the reason why it works is still under debate. With our SDR-based CT-emulator we can perform reproducable experiments with real WSN hardware. Our evaluation shows that the LQI is a better metric for concurrent transmission performance than RSS. Thus, our CT-emulator contributes to a better understanding of concurrent transmission.

1 Introduction

Concurrent Transmission (CT) is an active research topic and improves the capability of Wireless Sensor Networks (WSNs) in the domain of low-latency networking and reliability by far. In the EWSN reliability competition, the leading competitors in majority utilized CT [6]. This impressively demonstrates the capabilities of CT. Early research like Ferrari et al. [3] or Dutta et al. [2] uses testbeds with up to 94 interconnected nodes in communication range and shows that CT can improve the Packet Reception Ratio (PRR). They state CT works through baseband Constructive Interference (CI). In contrast, there is research that raises doubts on the idea of CT working only because of CI [7, 5, 4]. In [4] the authors state their protocol's performance is based on CI as well as the capture effect. Roa et al. [7] investigated conditions under which CI work and how networks should look like to use the full potential of CI. They also find, that a higher number of concurrent transmitters leads to a higher Bit Error Rate (BER). The rising BER is an indicator for destructive interference. Despite Liao et al. [5] the majority of the experiments were performed in real world testbeds, therefore there was only limited control and knowledge about the environment of the individual nodes in the network. To overcome this lack of control Liao et al. [5] use a vector signal generator to transmit software-generated IEEE 802.15.4 packets to a TI CC2420 [8]-based Receiver. Therefore, they are in full control of noise, carrier frequency offset, phase shift, and delay between transmitters. They have shown, that a small carrier frequency offset is more harmful than a larger one. Further, they evaluated a non-Direct Sequence Spread Spectrum (DSSS) transceiver. The results of this evaluation leads to the conclusion that DSSS is one of the main reasons why CT works. However, they did not investigate the effect of transmission delays or noise to CT. Referring to the discussed research, the reasons why CT works so well in WSNs is still under debate.

As former research is based statistical results on how much the transmission were delayed and what effect this delay had on the reliability of a connection, new tools are needed. To provide the research community a tool to investigate the mechanisms behind CT form scratch, we developed a Software Defined Radio (SDR)-based channel that is able to emulate CT. With this CT-emulator we are able to modify the delay between multiple transmitters for all packets precisely. In Section 2 we explain the design of our CT-emulator and its capabilities in detail. Section 3 shows some results we obtained with the CT-emulator. Section 4 concludes the paper and describes what the demo will look like.

2 Concurrent Transmission Emulator Design

Our CT-emulator is based on two *HackRF One*[1]. The first one receives the signal from a CC2420 transceiver and forwards it to our *GNURadio*[2] implementation. In *GNURadio* we can manipulate the signal according to the situation we need to emulate. Afterwards, the second *HackRF One* transmits the manipulated signal to a second CC2420.

To emulate CT with only one transmitting CC2420, we duplicate the received signal in *GNURadio*. With the *Delay*-block shown in Figure 1 we can model how much the two transmissions are delayed from each other. The two *Gain*-blocks are representing the *Attenuation*-blocks form the *Concurrent Transmission Model* and therefore emulate the different distances and transmission powers. After adding a configurable amount and type of noise to both signals, they are added and transmitted to the second CC2420. If more than two transmitters need to be emulated we can add more delaying branches to the graph. But for our experiments we used only two emulated transmitters. As the *Delay*-block de-

[1] https://greatscottgadgets.com/hackrf/
[2] https://www.gnuradio.org/

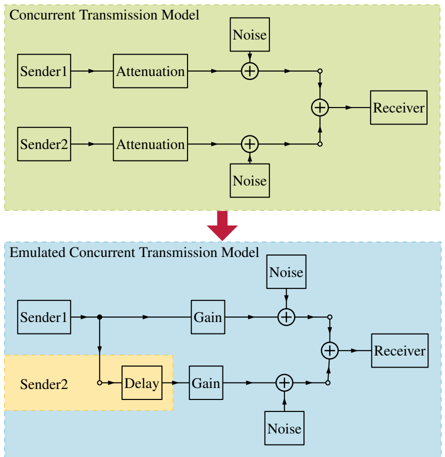

Figure 1. Conversion from the real world CT model to our emulated CT model, using a *Delay*-block to emulate a second, delayed transmitter.

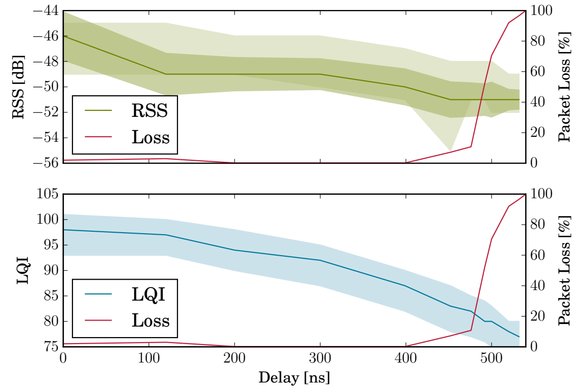

Figure 2. RSS, LQI values and packet loss over transmission delay.

lays the signal by a defined number of samples we are able to perform evaluations where all concurrent transmissions have the same constant delay.

To the best of our knowledge this is the first setup that can evaluate large numbers of packets under the same CT conditions.

3 Evaluation

To give an idea of the potential of our CT-emulator we evaluated the performance of CT with a range of delays, used for the *Delay*-block in Figure 1. During the evaluation we measured the Received Signal Strength (RSS), Link Quality Indicator (LQI), and the packet loss of 500, 13 byte packets for each delay. Figure 2 shows two graphs, the upper one is a comparison of the median RSS and the packet loss over different transmitter delays. The darker area is the standard deviation and the lighter one is the area between the minimum and maximum RSS.

As there is only a minor impact on the RSS between 10% packet loss and 100%, we analyzed the LQI in the lower graph. The standard deviation is around 1.5 for all delays, therefore its area is not visible. Thus, the blue area is the area between the minimum and maximum LQI. The LQI shows a decrease between 10% packet loss and 100%.

As we did one of the first evaluations of the LQI, we explain what it is and why it is a better metric for CT performance than RSS. The LQI gives an estimation of the similarity between the received chip sequence and the most equal one from the IEEE 802.15.4 standard [1]. In IEEE 802.15.4 each four bit (nibble) are represented by a 32 bit long chip sequence on the physical-layer, these bits are called chips. The 16 different chip sequences are defined in the IEEE 802.15.4. If a transceiver receives a chip sequence it selects the nibble with the lowest difference. The LQI is calculated from the difference of the received chip sequence and the selected chip sequence. Hence, the LQI gives an estimation of the chip error rate and estimates how much the signal was interfered. As the RSS only gives the received energy, no matter whether the signal belongs to the received packet or is just noise, the RSS is not suitable to distinguish whether a CT is constructive or destructive. In sum, the LQI is the more appropriate metric to analyze the potential effect of CI during CT.

4 Conclusions

With our CT-emulator we are able to perform reproduceable experiments on the effect of several variables to CT. The evaluation showed that the LQI is a better metric for the CT performance than RSS. During the hands-on demo we will offer the opportunity evaluate the effect of delay, noise level, transmitter gains and packet size to CT live.

5 References

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