

Multi-Channel Interference in Wireless Sensor Networks

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1. INTRODUCTION

One solution for increasing the network throughput of a WSN is to use multiple orthogonal channels for transmission instead of a single channel. Multiple transmissions can take place on these orthogonal channels to increase the spectral efficiency. Typical WSN devices are equipped with a single transceiver with channel switching capabilities. These devices provide support for the use of multiple channels operating at different frequencies e.g., CC2420 radios used for MicaZ and Telos motes can use 16 different channels in the 2.4 GHz band.

Use of multiple channels in WSN has been explored in previous research efforts and multi channel MAC and routing protocols has been proposed to improve the network throughput. Most of these protocols assume the presence of multiple orthogonal channels for parallel communications. One problem with use of multichannel in WSN is that channels are not truly orthogonal i.e., multiple simultaneous transmissions on adjacent channels do cause interference [1], [2]. Moreover interference caused by external networks e.g., WiFi operating in the same frequency band is also non trivial. It is thus imperative to consider these interference issues at the design stage of a multi channel protocol to avoid performance degradation during operation. We perform a detailed empirical study of these interference issues in multi channel WSN and present guidelines, based on this study, for design of efficient multi channel protocols for WSN.

2. EXPERIMENTS

We first study the effect of WiFi interference on the transmission from mote operating on different ZigBee channels. We conducted our experimental study using the MicaZ platform that provides 16 channels for use operating between 2.405 to 2.480 GHz frequency

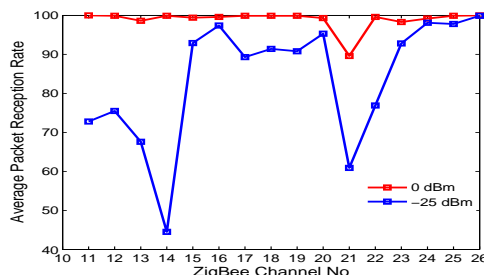


Figure 1: Effect of WiFi Interference

range. The experiments were performed indoors in an office building. A pair of transmitter and receiver motes were placed 1.5m apart on a table raised about 0.5m above the floor level. The transmitter sends a total of 5000 packets at the rate of 20 packets/second with each packet containing a unique sequence number. The receiver logs the sequence number and RSSI of each packet that it receives. There were active WiFi transmissions, operating at WiFi channels 1 and 11 with -55 dBm and -62 dBm average received signal power (measured with a spectrum analyzer, co-located with the receiver). We used two power levels (maximum 0 dBm and minimum -25 dBm) for the transmitter and repeated the experiment for 16 different ZigBee channels. The average RSSI recorded at the receiver was -62 dBm and -88 dBm for the maximum and minimum transmission level, respectively

Figure 1 shows that the transmitter is able to maintain a packet reception rate (PRR) above 90%, when using any of the ZigBee channels, at maximum transmission power. For the case when the mote is transmitting at lowest power level, effect of WiFi interference is more pronounced with average PRR values falling as low as about 44% (for channel 14). The relative received signal to interference power differ by about 33 dBm for ZigBee channel 14. Channel 11-14 and 21-23 show decline in average PRR values as these channels are affected by WiFi Channel 1 and 11.

We next conducted experiments to study the effect of using adjacent and alternate ZigBee channels simultaneously. This experiment is conducted in the same room with WiFi channel 1 in use with received power of -68 dBm. A transmitter sends out packets to a re-

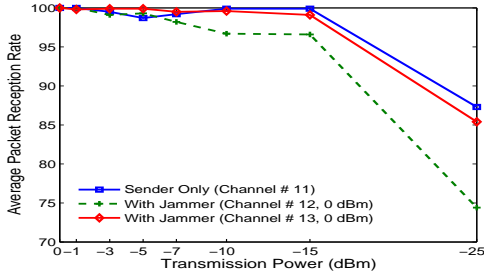


Figure 2: Channel Interference

ceiver tuned at channel 11 with transmission power varied from 0 dBm to -25 dBm. The experiment is first repeated with a jammer mote sending out packets at 0 dBm power at channel 12 (adjacent channel) and then channel 13 (alternate channel). The jammer mote is colocated and synchronized with the transmitter. Figure 2 shows that the transmitter mote is able to maintain an average PRR > 95% when the mote transmission power is greater than -15 dBm. For lowest transmission power of -25 dBm, the presence of a jammer mote operating on an adjacent channel 12 lowers the average PRR from about 87% (no multichannel transmission) to about 76%. For the case when jammer is operating on channel 13 (alternate channel), the PRR is only about 2% lower than the case when there is no multi-channel transmissions.

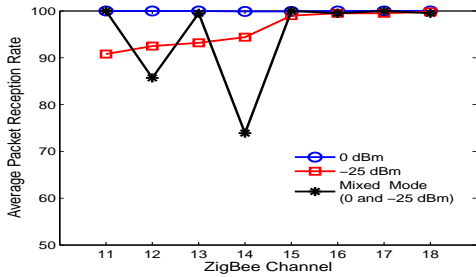


Figure 3: WiFi and Multi Channel Interference (Channel 11-18)

Finally, we conducted experiments with eight pairs of motes, each pair tuned to a separate frequency. Transmitters are placed in one line at a distance of 1.5m from their respective receivers. Simultaneous transmissions occur at multiple frequencies (channel 11-18 and channel 19-26 in separate set of experiments). Three set of experiments were conducted for each set of frequencies. In the first set, all motes transmit at 0 dBm power. In the second set, the mote transmission power was reduced to -25 dBm. The last set, referred to as the mixed mode experiment, motes using odd number channels transmit at full power while other motes operating at even number channels transmit at lowest power. The WiFi channels 1 and 11 were in operation as before, both with average received signal power of about -68 dBm.

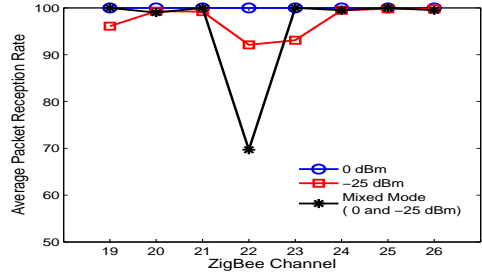


Figure 4: WiFi and Multi Channel Interference (Channel 19-26)

Figures 3 and 4 show that motes are able to maintain an average PRR close to 100% when transmitting at 0 dBm (with RSSI of about -60 dBm). When the transmission power is reduced to -25 dBm (with RSSI of about -88 dBm), PRR is dropped to about 90% for channels that are under the influence of WiFi (channels 11-14 and 22-23 are affected). For the mixed mode experiment, motes transmitting at 0 dBm are able to maintain the PRR close to 100%. For motes transmitting at lowest power (even number channels) that are also under the influence of WiFi interference, the PRR is dropped to 70% - 75% (channels 14 and 22).

The experimental study described in the preceding section has highlighted the following characteristics of the multichannel interference.

- ZigBee transmissions are affected by both WiFi and adjacent channel interference, depending on the received signal power levels.
- ZigBee sources are able to maintain good PRR (> 85%) when the received power from transmitter signal and received power from interference signal differ by less than 25 dBm, for WiFi or adjacent channel transmissions.

These characteristics thus form the design constraints for an efficient multi-channel protocol for WSN e.g., ZigBee channel selection depends on the topology and whether there are WiFi sources in operation in the environment. Effect of WiFi interference can be mitigated by selecting short, multi-hop communication as compared to long distance transmissions. Similarly, if adjacent channels are required for use, interference can be mitigated by topology control based on interference levels from neighbor's transmissions.

3. REFERENCES

- [1] Y. Wu, J. A. Stankovic, T. He, J. Lu and S. Lin, "Realistic and Efficient Multi-Channel Communications in Wireless Sensor Networks", 2008: Infocom, pages 1193-1201.
- [2] O.D. Incel. P. Jansen, "Characterization of Multi-Channel Interference", 2008: WiOpt, pages 429-435.