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Interference Analysis of Coexisting LR-WPAN and WLANs Networks

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Abstract
Wireless sensor networks coexist with the other wireless networks such as WLANs, Bluetooth, ZigBee, other IoT technologies and hence suffer from the co-channel and cross channel interference. This paper presents the experimental studies of received signal strength indicator and link quality indicator in wireless sensor networks in presence of co-channel and neighboring channel interference. We have analyzed and discussed the dependency of these parameters on each other and how can these parameters be used in estimation of the interference.

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I. INTRODUCTION

The recent research in wireless sensor networks (WSN) has proved that these networks will play important role in sensing and actuating applications. WSNs consist of a potentially huge number of small, independent nodes with wireless communication capabilities [1]. Important characteristics of a WSN include scalability in terms of the number of nodes, self-organization, self-healing, energy efficiency, minimal complexity and size of the nodes, and adequate communication between nodes. WSNs are applicable to a vast array of applications, including home automation and security, consumer products, healthcare, environmental monitoring, vehicle monitoring and tracking, agriculture, and many more [2 - 5].

IEEE 802.15.4 is the global standard designed for low power and low rate wireless personal area network (LR-WPAN) applications, it is also known as the LR-WPAN standard. The standard describes the physical and media access control (MAC) layers' properties. To encourage widespread deployment, it has been placed in the unlicensed 2.4 GHz Industrial Scientific and Medical (ISM) spectrum as well as the 868 and 915 MHz bands, despite the fact that the majority of commercial implementations are in the 2.4 GHz bands with 16 channels [6], although majority of commercial implementations are in 2.4 GHz bands with 16 channels [3]. The standard uses CSMA/CA based media access and operated in one of the two modes, viz. beaconed or unbeaconed.

The common challenging factors of existing and upcoming wireless networks are the limited transmit power and the insufficiency of available spectrum and security [7]. This makes the design and optimization of these networks more difficult and critical. In wireless communication, the signals are broadcasted and it get attenuated and distorted due to pathless, shadowing, time varying fading, and co-channel and cross channel interference from the same and other networks. The reception of packets at the receiver without any error is probabilistic and depends on the transmit power and frequency along with other parameters. To get the reception without any error, the signal to interference and noise (SINR) has to be greater than the defined threshold level [8], [9]. Wireless sensor networks can be coexistence with other networking technologies such as IEEE 802.11 wireless local area networks (WLANs), IEEE 802.15.1 (Bluetooth) and IEEE 802.15.4(ZigBee/LR-WPANs). For instance, there is drawback of poor reliability due to coexistence of various networks in same band causing co-channel and cross channel interference. Such issue can be addressed by static design, in which fixed non-interfering channels are allocated to different co-located networks. But in case of networks with mobile nodes such as Body area networks (BANs), fixed allocation of the channels cannot be a viable remedy to avoid interference. Carrier sense multiple access with collision avoidance (CSMA/CA) enables multiple users to sense the carrier prior to transmit packet. If the carrier signal strength of pilot of network is more than the threshold, means the channel is idle and can be used for transmission. In case of the carrier power below threshold, the channel is treated as busy and waits for random back-off period to repeat the sensing operation. Though CSMA/CA is used in IEEE 802.15.4, still there will be the interference from co-located networks.

II. RSSI AND LQI

In this work, we investigate the effect of controlled interference on IEEE 802.15.4 network. We measured the received signal strength indictor (RSSI) and link quality indicator (LQI) along with other parameter to analyse the results. Our multi-channel measurements, conducted with Sun SPOT sensor nodes [10]. The nodes have Texas Instruments CC2420 based radio transceiver [11]. For low-power and low-voltage wireless applications, the CC2420 is a 2.4 GHz IEEE 802.15.4-compliant RF transceiver. It contains a digital direct sequence spread spectrum baseband modem with an O-QPSK spreading gain of 9 dB and an effective data rate of 250 kbps. It has the features for measurement of RSSI and LQI. The packets can be transmitted on one of 16 channels having the bandwidth of 2 MHz each. The channels are placed 5 MHz apart from each other and occupy the frequencies band of 2.4 GHz – 2.4835 GHz. The same frequency band is also used by wireless local area network (WLAN) IEEE 802.11b/g and Bluetooth [12 - 15].

Received signal strength indicator (RSSI) is the estimate of the signal power within IEEE 802.15.4 channel and is calculated over 8 symbol periods and stored in the RSSI_VAL register. The RSSI can be calculated as by adding RSSI_VAL and + RSSI_OFFSET [dBm] found empirically during system development from the front end gain and it is ~ 45 dBm. The link quality indicator (LQI) measurement is a characterisation of a received packet's strength and quality. Each received packet's energy level and signal-to-noise ratio are measured. When energy level and SNR data are combined, they can show whether a corrupted packet was caused by a weak signal or a strong signal with interference [10]. Calculation of the LQI value directly from RSSI has a limitation because the RSSI does not distinguish the signal and interfering power, e.g. a narrowband interferer inside the channel bandwidth will increase the LQI value although it actually reduces the true link quality. The LQI value as specified by [6] must be between 0 and 255, with at least 8 distinct values. Additionally, CC2420 offers an average correlation value for each receiving packet based on the eight symbols that immediately follow the start frame delimiter (SFD).

III. EXPERIMENTATION

Our setup consists of one base station and two sensor nodes working on IEEE 802.15.4. To analyze the effect of interference, we had used two IEEE 802.11g access points for generating the interfering signals. The base station was connected to Windows XP-based host through USB port. For measurement and capturing the radio packets, Wi-DBx, software based spectrum analyzer was used. Wi-Spy DBx is a small portable USB device with external antenna and frequency and amplitude resolution of 26KHz – 3MHz and 0.5 dBm, respectively. The Wi-Spy is supported by the Chanalyzer software and can be used to quickly scan and display all radio activities in 2.4 GHz spectrum. It is useful for identifying the interference, finding the quietest channel, and analyzing the quality of the signal. Additionally, the spectral analysis was also performed on Rohde and Schwarz FSH3 spectrum analyzer.

For latency measurement, we also measured the delay difference between time of transmission and reception. To achieve temporal coherence of the time stamps by the transmitting sensor nodse and base station, prior to each measurement, timing of the base station and both the nodes was synchronized by refreshing the firmware and deploying the software program by using the same host on which measurement were carried out. The host was configured for minimal required processes running during the measurement to avoid its contribution in latency. One of the sensor nodes was placed 3 meters from the base station while other was placed at 6 meters away. Base station and both the nodes were kept at the same height of 1.5 m from the floor level in line of sight (LOS) and in presence of some obstacle at same height, and above and below their height. The interferer nodes were kept 6 meters away from the base station and sensor nodes in different directions.

IV. RESULTS AND DISCUSSION

During the experimentation, a series of measurements were carried for different channel scenarios and transmit power levels. Prior to each measurement, same battery levels were ensured to avoid any undesirable fluctuation in power levels. Each set of reading was carried for 90 minutes and samples were taken at every 10 s. Figure 1 shows the experimental results for a set of number of received packets versus ratios of RSSI with and without interference. The result shows that the ratio of RSSI with co-channel interference and without interference [Fig.1(a)] is higher and having more variation as compare to the variation in the ratio of RSSI with co-channel interference and neighboring channel interference [Fig.1(b)]. This is because of the higher interfering signal power in the former as the signal from IEEE 802.11g interfering access points is getting added with the actual signal of IEEE 802.15.4 signal when they are configured at overlapping channels. The results obtained also shows that the RSSI values are directly related to the distance between the base station and the node and are also quite stable as the coefficient variation was below 2% in almost all the performed measurements. The results are in agreement with the other studies on the characterization of IEEE 802.14.5 links.

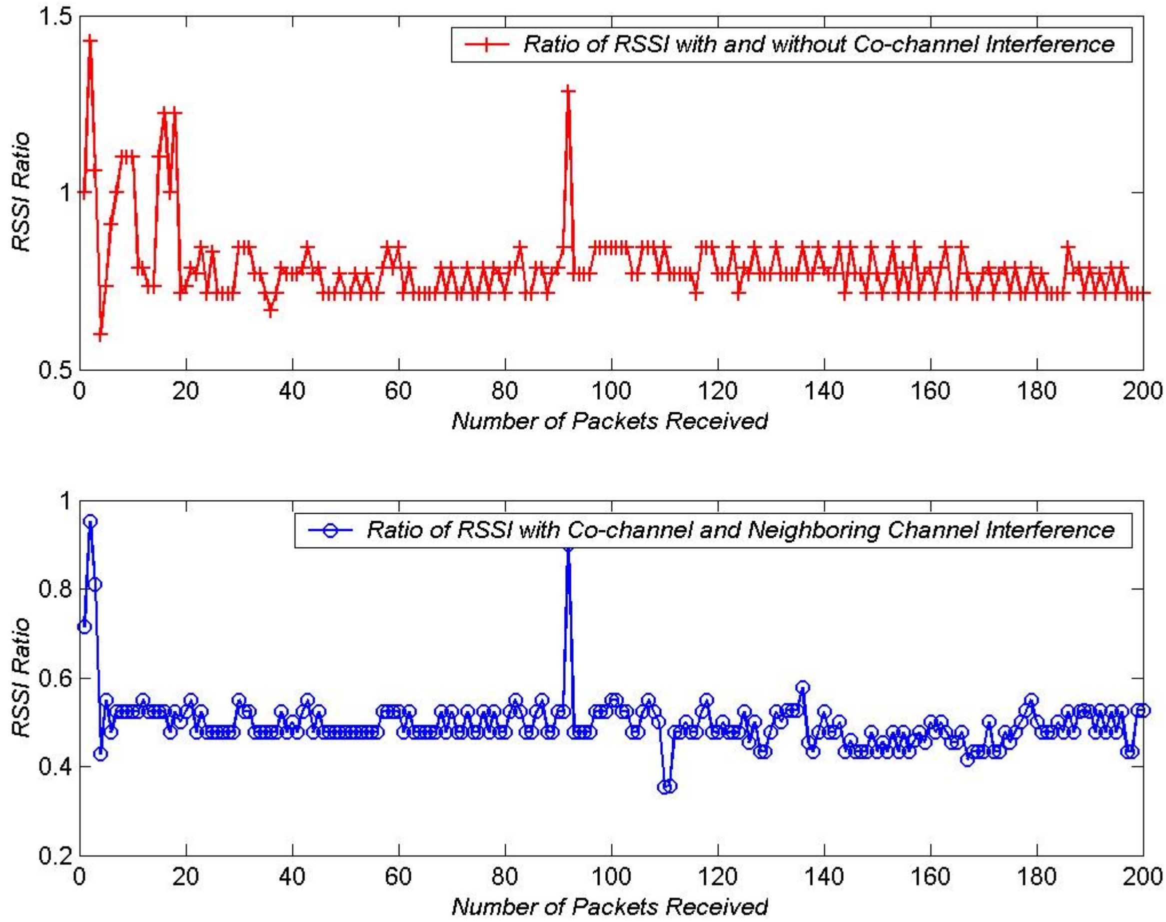

Fig. 1 Number of packets received versus ratio of RSSI

The results of the number of packets received versus ratio of LQI are plotted as shown in Fig. 2. It is observed that the variation in the measured LQI values is in agreement with the variation in the RSSI. The variation in the results of LQI ratio with and without co-channel interference is more and also greater than variation in the ratio of LQI with co-channel and neighboring channel interference. This is because of similar reasons as in case of RSSI fluctuation.

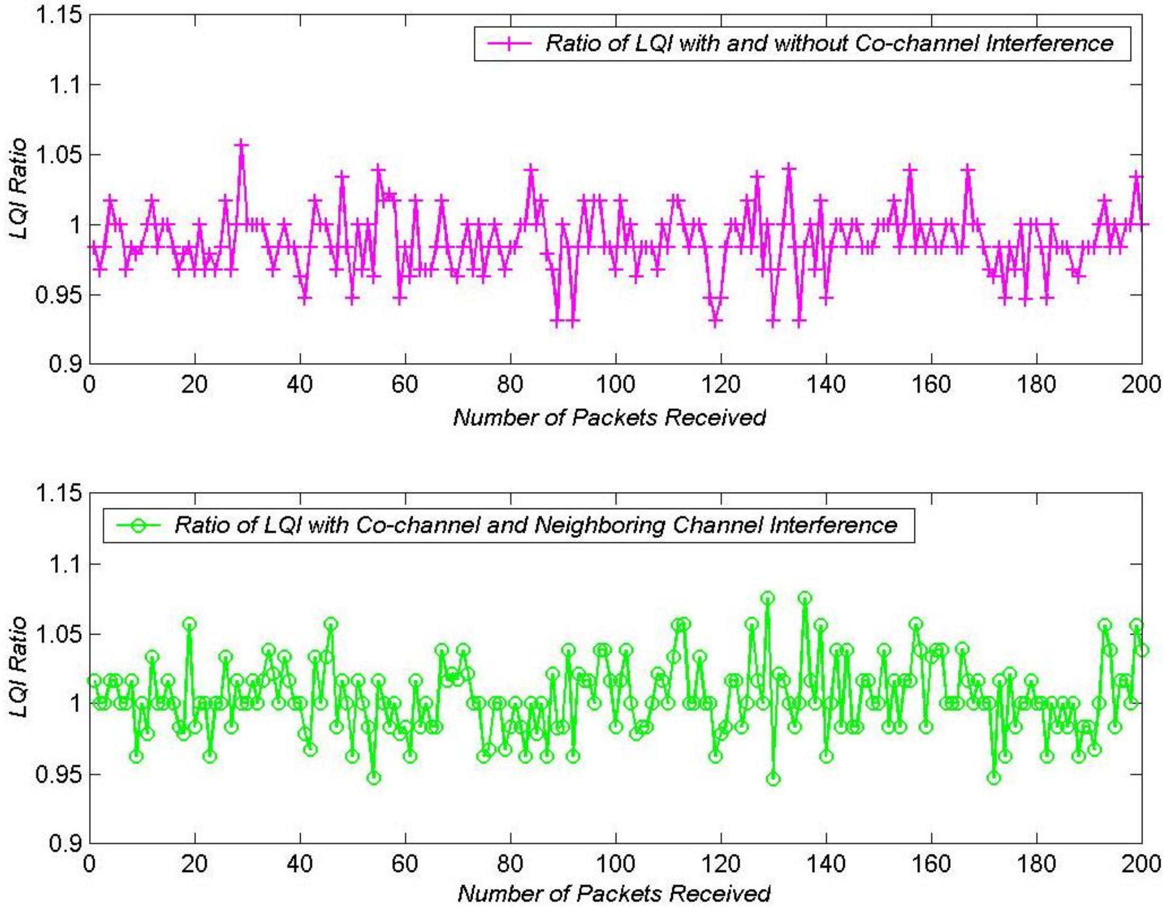

Fig. 2 Number of packets received versus ratio of LQI

Figure 3 (a) shows the spectrum of the signal for neighboring channel interference when both, IEEE802.11g and IEEE802.15.4 are configured for the channels adjacent to each other. The figure shows that cross channel interference contributes to RSSI and hence degrades the LQI. The spectrum of signal when both the networks are coinciding, the RSSI abruptly increases is as shown in Fig. 3(b), causing more interference as compare to former case and hence severe reduction in LQI.

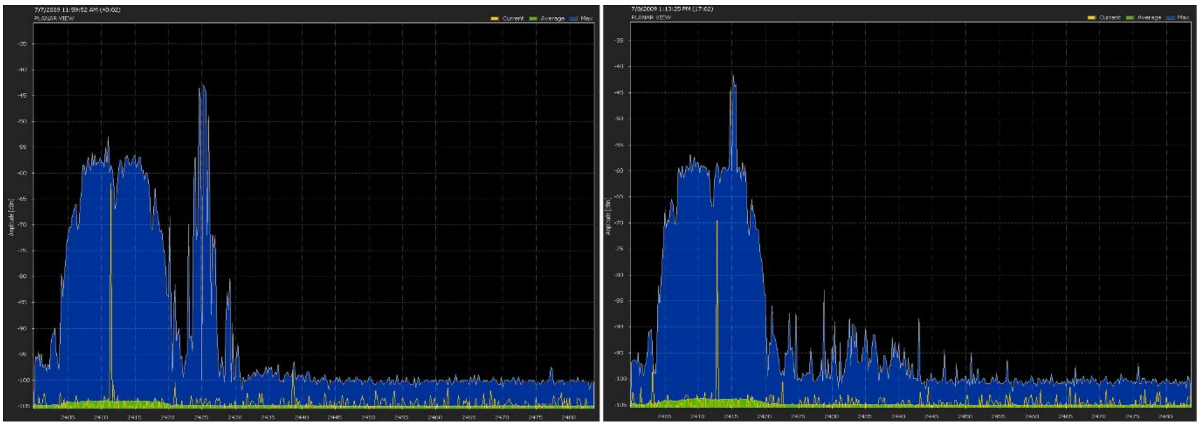

Fig. 3 Spectrum of the signal with interference from (a) Neighboring Channel (b) Coinciding Channel

The ratio of LQI and RSSI, which can be very good measure to determine the impact of interference is as shown in Fig. 4. The ratio for no co-channel interference is moderate where as it is quite lesser in case of co-channel interference.

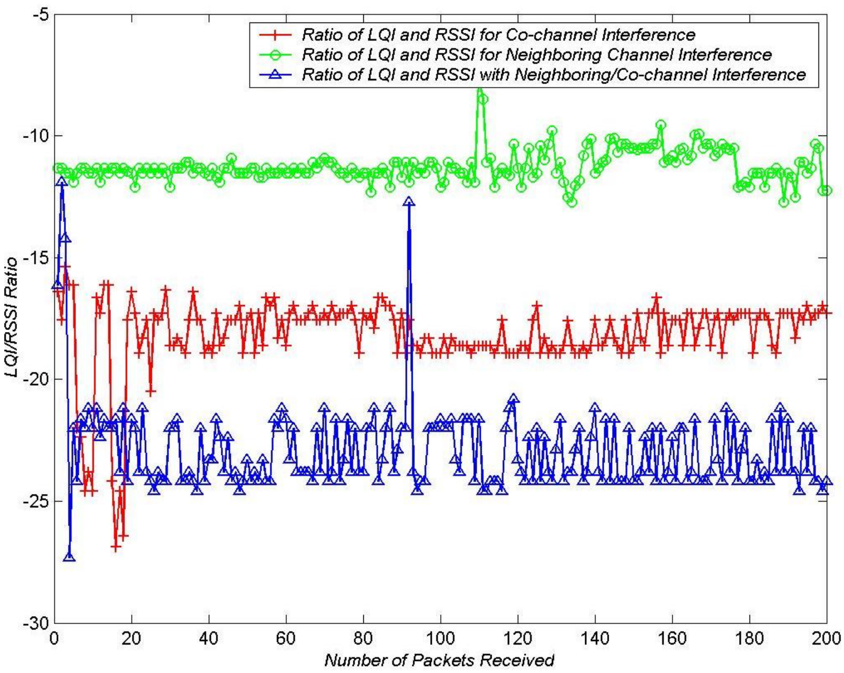

Fig. 4 Number of packets received versus ratio of LQI/RSSI

V. CONCLUSION

The series of experiments for the study of impact of RSSI and LQI and their dependencies in presence of co-channel and neighboring channel interference was carried out for different scenarios. Based on the measurements, the analysis was carried out and it is shown that variation in RSSI with co-channel interference is higher than its values without the interference. Changes in RSSI are also abrupt because of addition of comparatively higher interference power. LQI variation is in good agreement with the variation in the RSSI. The results indicate that RSSI can be also used for determining the link quality subject to limited and controlled interference.

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