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Location Estimation using RSS Technique of ZigBee Module

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Abstract:

The Received Signal Strength (RSS), which could be acquired at the time upon receiving a packet in most standard RF wireless sensor, could be use to estimate location for wireless device. In this paper, experiments have been conducted on Texas Instruments IEEE 802.15.4 / ZigBee CC2431 sensor module to evaluate the reliability and accuracy of using RSS approach for localization algorithm development in an indoor environment.

Keywords

Received Signal Strength, Localization, Wireless Sensor Network, ZigBee

1. Introduction

Increment of on-field industrial and consumer wireless devices deployment has become a trend for next coming years. The ability of these wireless sensor devices to identify its own location could contribute to the development of various useful monitoring, control and location-based applications [1]. Wireless sensor devices have advantages of low cost, low power utilization and can be deployed in short period. Since signal attenuation strength is falls off with distance, the Received Signal Strength Indicator (RSSI) measured at the receiver can be use to estimate distance between transmitter. This paper studied the Received Signal Strength (RSS) empirically in indoor environment, to access the accuracy of RSS to be used in further wireless sensor nodes localization algorithm development.

The rest of the paper is organized as follow: Section 2 discusses the background and related work. Section 3 focuses on signal propagation model use in RSS measurement. Section 4 describes experiments and discussed on the result. Section 5 concludes the findings.

2. Related Work

All wireless sensor IC chips nowadays have built-in RF signal receiving quality measurement mechanism. This major advantage provides a great opportunity for creating location-based software application without additional hardware cost.

Wireless sensor network localization measurement method typically based on Received Signal Strength (RSS), Time of Arrival (TOA), Time Difference on Arrival (TDOA), Angle of Arrival (AOA) [1, 6, 8, 13, 16] and Link Quality Indicator (LQI) [7]. RSS gain more popularity as it does not involve complex software algorithm, hence will not incur excessive MCU power consumption, memory space or bandwidth, enable the wireless sensor device to operate for long hours or months duration on battery.

The 802.11 WLAN [3, 4] and IEEE 802.15.4 / ZigBee [2, 5, 6, 7] were among the popular wireless standard used to study RSS in localization algorithm research. Stoyanova *et al*.[2] assessed factors that could affect RSS accuracy using the *Tmote* Sky ZigBee module. Multiple impact factors such as, RF operating frequencies, distance between transmitter and receiver, antenna height from ground, antenna orientation, and specific environment scenario was evaluated on RSS at outdoor environment.

Patwari *et al.* [1] explained that, RSS major error source, and presented statistical model for RSS, TOA, and AOA, on cooperative localization research. In an indoor environment, Elnahrawy *et al.* [3] presented the constraint of localization algorithm precision on WLAN standard using wireless access point.

Grossmann *et al*. [7] discussed factors that affect RSSI accuracy and introduce Weighted Centroid Localization (WCL) algorithm for localization. Huang *et al.* [4] has implemented two phase localization algorithm, which consists of region partitioning and localization refining, based on RSSI on Texas Instruments CC2430. Kalman filtering approach is simulated by Bhuvaneswari *et al*. [5] to increase the accuracy of localization based on RSS measurement.

In order to fulfill our research on swarm robotics agent localization algorithm development application scenario [17, 18], we are focusing our study on the measurement of RSS variability for distance in the range of 1 to 10 m, in an indoor environment and effect of receiver position in corresponding to transmitter.

3. Received signal strength value acquisition

The CC2431 IC from Texas Instruments was selected as the testing platform. CC2431 is a 2.4 GHz IEEE802.15.4 / ZigBee System-on-Chip (SoC) IC chip. The CC2431 does not publish RSS value directly. Instead, the RSS value is measured internally and published as Received Signal Strength Indicator (RSSI). After loaded in the ZigBee protocol stack (Z-Stack) from Texas Instruments to the CC2431 Evaluation Module (EM), firmware can access the value from the RSSI register in CC2431.

3.1. Signal Propagation Model

The path loss log-normal shadowing statistical model **eq. (1)** is used to model distance estimation between two nodes based on the measurement RSS, which is randomness to various deployment environments and distributed characteristic.

$$P_r(d)[dBm] = P_0 - 10n\log_{10}\left(\frac{d}{d_0}\right) + X_\sigma \quad (1)$$

Where $P_r(d)$ is received power; P_0 is the received power at a point with reference distance d_0; n is the path loss exponent that measures the rate the RSS decreases with distance; X_σ is a Gaussian random variable with zero mean and standard deviation σ, which accounts for the random effect of shadowing.

For CC2431, the RSS is converted to RSSI and it is modeled based on the simplified log-normal shadowing model, as **eq. (2)** below.

$$RSSI = -(10n\log_{10} d + A) \quad (2)$$

Refer **eq. (2)**, n is path loss exponent; d is distance between transmitter and receiver; A is received signal strength at a distance of 1 meter.

The RSS is measured by CC2431 each time a packet is received and stored in RSSI register based on (2). The RSSI value read out need to be added an offset of -45 as specified in CC2431 data sheet to convert to RSS, as **eq. (3)** below. The offset may vary according to antenna configuration.

$$RSS[dBm] = RSSI + RSSI\_OFFSET \quad (3)$$

4. Experiments and Results

4.1. Experimental Setup

Experimental setup 1, illustrated in **Fig. 1** is performed in an indoor environment with area of 12 m × 8 m. CC2431 Evaluation Module (EM) with external swivel antenna is used as transmitter and receiver to perform the RSSI measurement. The CC2431 EM was positioned at top of pole with height of 0.8 m from ground. The experiment has been tested on distance between transmitter and receiver from 1 m to 10 m.

Experimental setup 2, illustrated in **Fig. 2** is conducted in an indoor environment to study RSSI measured at 1 m distance between the transmitter and receiver. The receiver is placed at position P1, P2, P3, and P4 each a time. Both the transmitter and receiver are positioned at the top of a pole, which is 0.8 m from the ground.

Both experiments were conducted based on the following procedure: The transmitter send a packet with 30 bytes of constant data every 100 msec. The receiver will receive 200 packets/samples and embedded the measured RSSI, then send to a laptop computer via USB cable for data collection.

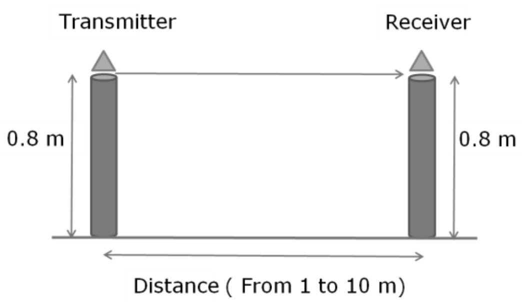

Figure 1: Experiment setup 1

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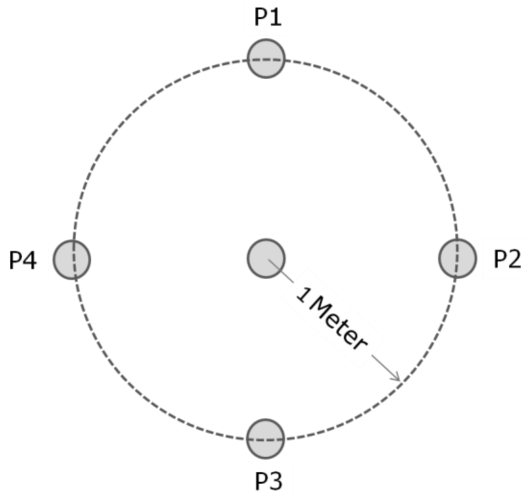


Figure 2: Experiment setup 2

4.2. Effect of variant receiver node on RSSI

The minimum, maximum and average of RSSI results are shown in **Fig. 3**, **Fig 4** & **Fig. 5**. The RSSI was measured for 5 receiver nodes in distance from 1 to 10 m. Node 2 recorded the highest variability of RSSI value at distance of 3 m. At distance of 4 m, node 4 and 5 recorded highest RSSI range of 15. Range between minimum and maximum RSSI increase after 2 m, which could cause by wall reflection, multipath fading effect, *etc*.

Figure 4 illustrates the average RSSI result in distance from 1 to 4 m, and **Fig. 5** depicts the average distance from 5 to 10 m for 5 receiver nodes. Overall, node 4 has lowest average RSSI value. Node 3 has highest average RSSI value. We also have noticed that the relationship between RSSI versus distance is not linear in actual environment, and it is highly affected by surrounding factors.

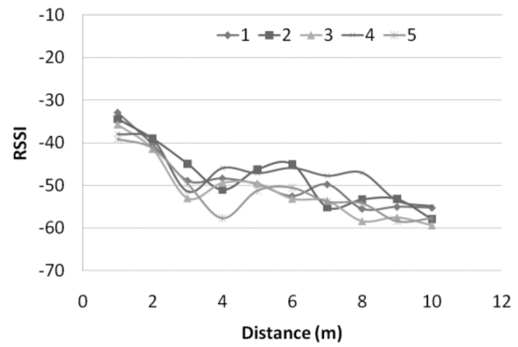
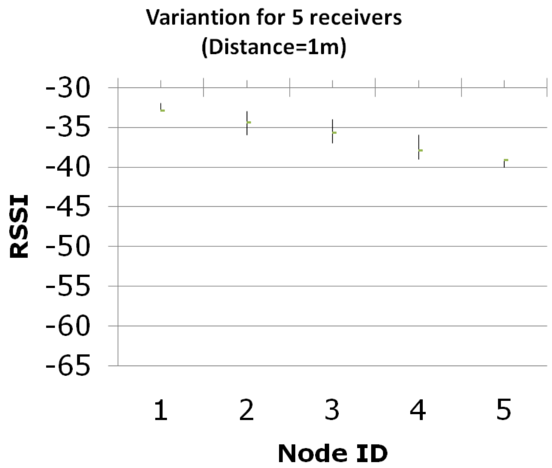
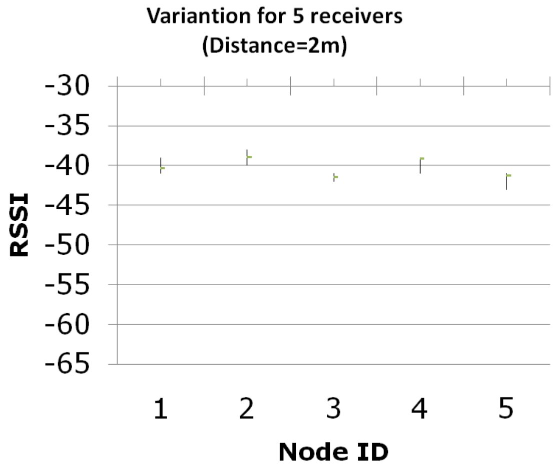


Figure 3: Average RSSI for 5 receivers





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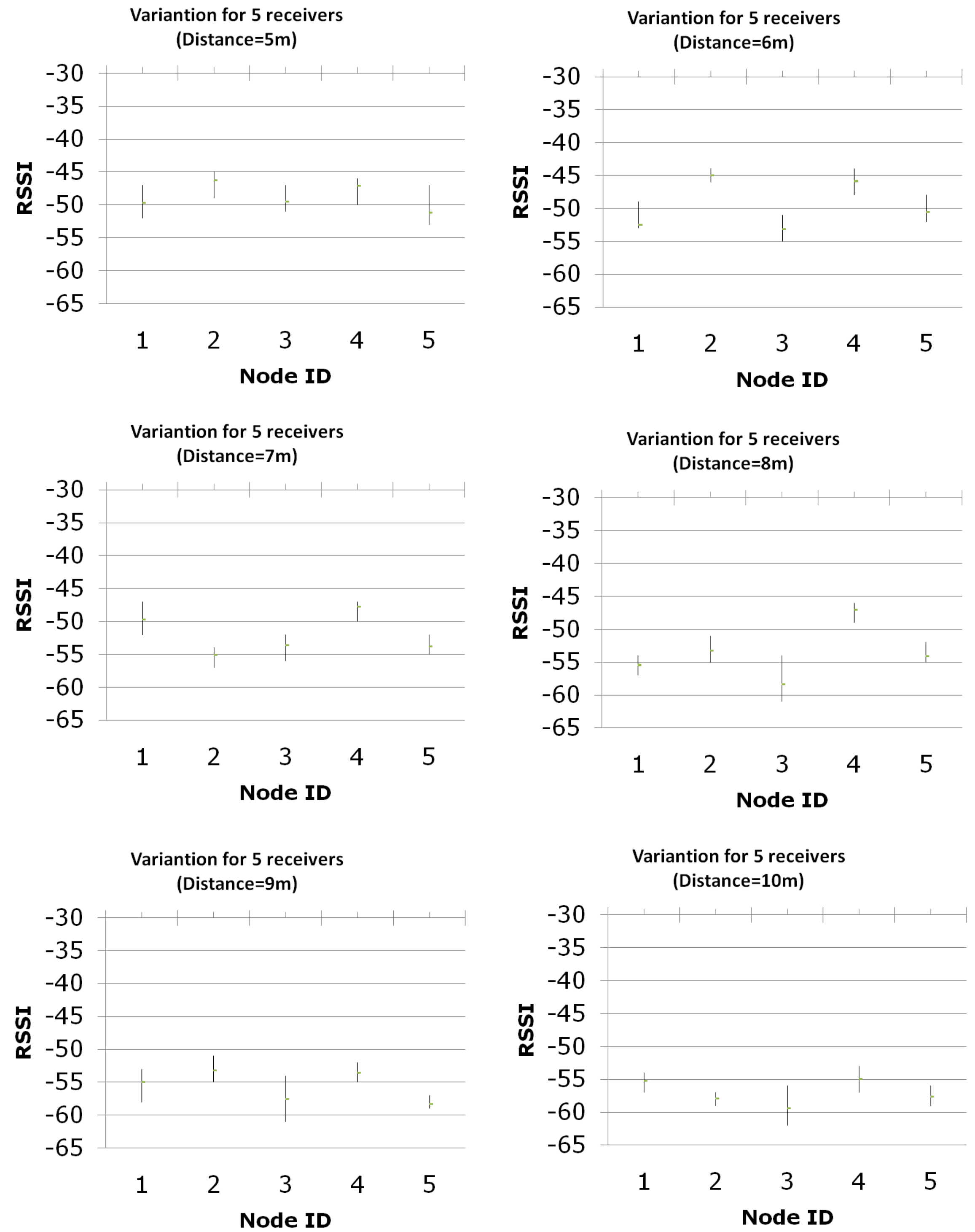

Figure 5: Average RSSI for 5 receivers (top-left at 5 m | top-right at 6 m | middle-left at 7 m | middle-right at 8 m | bottom-left at 9 m | bottom right at 10 m)

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4.3. Effect of receiver node position on RSS

Figure 6 shows result of the RSSI measured when the receiver node is located at position P1, P2, P3, and P4 at experimental setup 2. Node 3 has smallest variability, but node 4 has largest variability, in term of RSSI value measured. Basically, this explained that the antenna used is not isotropic. This implies that an average value will need to be calculated for parameter A, RSS at distance of 1 m from transmitter, in (2).

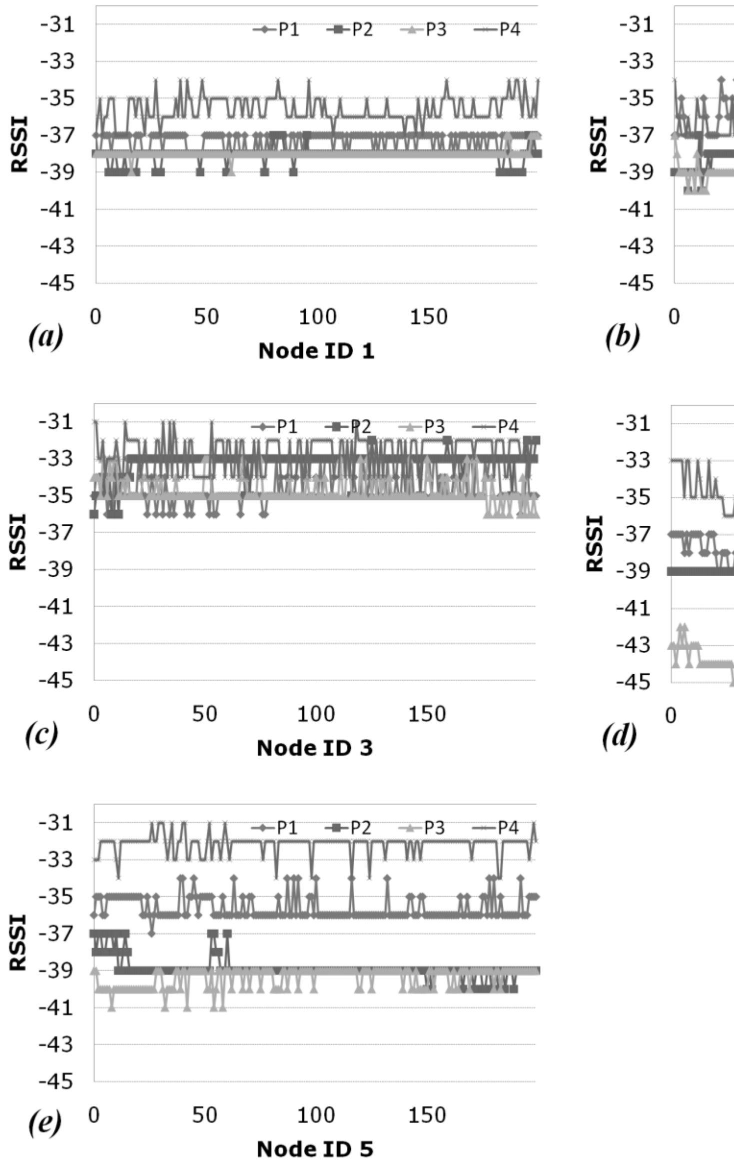

Figure 6: RSSI at different node position (top-left is Node ID 1 | to
Node ID 3 | middle-right is Node ID 4 | bottom-left is Node ID 5)

5. Conclusion

Using RSS for distance estimation was simple to be implemented and cost effective. Indeed, the irregularity RSS measurement result can be fine tune further with integration of additional filter algorithm. Averaging the RSSI value measured was the simplest method to increase RSSI accuracy. If advanced statistical filter is going to be implemented, we need to carefully investigate the impact of the algorithm towards the resource consumption of the wireless sensor device.

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