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Measurement and Experimental Characterization of RSSI for Indoor WSN

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***Abstract*– The characteristics of RSSI shows that the received signal strength will decrease with increased distance but sometimes due to multipath effects there are variations and fluctuations in the received signal strengths. In order to analyse and evaluate signal measurements in an environment, it deem necessary to denote the pattern of the signal flow. This paper presents development of Received Signal Strength Indicator (RSSI) model of an indoor environment using TelosB sensor nodes. Real-time measurement of the RSSI was done extensively at the corridor of the first floor of Goddian Ezekwem building, faculty of Engineering Nnamdi Azikiwe University, Awka for several months. The average of the measurement was taken and used for the development of the RSSI model. Least Mean Square Error (LMSE) method of linear regression analysis was used to develop the model. The developed model was tested and the goodness of fit (R^2) of the model was determined to be 0.86. This confirmed that the model can be used to determine the RSSI at any given distance of an environment with similar radio characteristics.**

***Index Terms*– RSSI, WSN, TelosB and Sensor Nodes**

I. INTRODUCTION

RECENT advances in wireless communications and electronics have enabled the development of microsensors that can manage wireless communication. Wireless microsensor networks are autonomous networks for monitoring purposes, ranging from short-range as in monitoring [1] to wide-range environmental surveillance [2]. If a large number of sensors are deployed, wireless sensor networks can monitor large areas and be applied in a variety of fields. Sensor networks can also offer sensing data to context-aware applications that adapt to the user's circumstances in a ubiquitous computing environment. Sensor nodes can work autonomously to measure temperature, humidity, luminosity, and so on, if they are appropriately designed. Sensor nodes send sensing data to a sink node deployed for data collection. Wireless sensor nodes are deployed and arranged to form wireless sensor networks (WSNs).

A WSN can be generally described as a network of nodes that cooperatively sense and may control the environment enabling interaction between persons or computers and the surrounding environment [3]. Designing such a network and more specifically the protocols to support its functioning, is a challenging task. Despite the wide variety of applications, all sensors networks face similar constraints [4]. In the future, sensors will be cheaper and deployed everywhere; thus, user-location-dependent services and sensor locations will become more important. Although GPS (global positioning system) is a popular location estimation system, it does not work indoors because it uses signals from GPS satellites [5]. Using sensor networks instead of GPS makes indoor localization possible.

In wireless sensor networks, it is important to keep energy consumption low, so IEEE 802.11 [6] for wireless LANs, which was designed for high-power devices such as PCs, is not suitable for wireless sensor networks. This leads to the use of IEEE 802.15.4 [7] which is designed for low-rate wireless personal area networks This standard defines medium access control (MAC) and the physical layer (PHY) protocol for low-power devices. ZigBee [8], includes IEEE 802.15.4 for MAC and PHY, which is suitable for wireless sensor networks and is being offered in some products on the market.

In the experiment carried out, TelosB sensor nodes were used. The TelosB sensor node by crossbow is an IEEE 802.15.4/ Zigbee compliant node. The nodes are composed of four main units namely; the Chipcon CC2420 transceiver, the MSP430 microcontroller, the power section which consists of two AA (3V) batteries and the sensor section which consists of temperature (-40-123.8^{o}c), humidity (0-100%RH), visible light (320nm-730nm) sensors and slot for any two sensors of one's choice. The chipcon CC2420 transceiver operates at 2.4-2.4835GHz and has 250kbps data rates, RF power of -24 to 0dBm, receiver sensitivity of -90 to -94dBm. The MSP430 microcontroller has 16kbytes EEPROM, 48kbytes program flash memory, 12 bit ADC, 12 bit DAC and 10kbytes Ram. The TelosB sensor node has USB slot with which it is connected to computer/laptop for programming. It uses tinyOS operating system and runs only on window XP with cygwin. TinyOS 2.x has Java 1.5, cross compilers for MSP430 Platforms and TinyOS/NesC related tools. The codes were written, compiled and loaded into the node via USB. In this research work, the RSSI model of an indoor environment was developed based on extensive empirical study in an indoor environment.

II. REVIEW OF RELATED WORKS

A lot of works have been done in WSN. Some of the works reviewed are listed in this paper.

In [9], the authors conducted an evaluation of RSSI and their preliminary results indicate that RSSI for a given link has very small variation over time. Their results also indicate that when the RSSI is above the sensitivity threshold which is about -87 dBm, the packet reception rate (PRR) is at least 85%. However, it was noticed that around this sensitivity threshold, the PRR is not correlated possibly due to variations in local phenomena such as noise. LQI, on the other hand, varies over a wider range over time for a given link. However, the mean LQI computed over many packets has a better correlation with PRR.

The performance of Rene motes which is based on TR1000 was analyzed by the authors in [10]. They showed that a simple algorithm such as flooding had significant complexity at large. This complexity was partly attributed to the link asymmetries and they suggested that these asymmetries were due to sensitivity mismatch at different nodes.

The authors in [11] measured packet delivery of Mica motes which is based on TR1000. It was observed that links with PRR of at least 95% had high RSSI from their measurements without any encoding.

In [12] the authors presented preliminary evaluation results for Telos motes which are based on CC2420. They suggested that the average LQI was a better indicator of PRR and that RSSI was a bad indicator. They believed that the correlation between RSSI, LQI and PRR may be more easily understood through plots of PRR against LQI and RSSI.

The authors in [13] examined the packet error rate and the received signal strength of received packets for a communication link between two underground sensors and between an underground sensor and an aboveground sensor. They found that the communication between two underground sensor nodes at the same depth is impossible. Hence, they focus on communication between one underground sensor node and one aboveground. However, the authors did not measure the path loss exponent which is useful to predict the signal propagation.

This paper presents an evaluation of the newer set of nodes called TelosB sensor node which is based on CC2420. The received signal strength obtained from real time experiment was analyzed and modeled.

III. EXPERIMENTAL METHODS

Extensive real-time experiments were conducted to determine the practical distance range of Wireless Sensor Nodes in an indoor environment in this paper. The aim of this work is to develop a model that can be used to predict the RSSI value at a given distance in an environment with similar radio characteristics as the one used in this work. Crossbow TelosB sensor node from Texas Instrument which has Chipcon CC2420 radio chip as the transceiver was used in the experiment. CC2420 uses an encoding scheme that encodes 32 chips for a symbol of 4 bits. This encoded data is then offset quadrature phase shift keying (OQPSK) modulated. CC2420 provides two useful measurements: RSSI and LQI. RSSI is the estimate of the signal power and is calculated over 8 symbol periods and stored in the RSSI VAL register. Chipcon specifies the following formula to compute the received signal power (P) in dBm [14]:

$$P = RSSI\_VAL + RSSI\_OFFSET \qquad (1)$$

Where RSSI OFFSET is about -45. LQI can be viewed as chip error rate and is calculated over 8 bits following the start frame delimiter (SFD). LQI values are usually between 110 and 50, and correspond to maximum and minimum quality frames respectively.

A) Experimental Setup

A test bed of WSN comprising of four TelosB sensor nodes was built at the Faculty of Engineering, Nnamdi Azikiwe University, Awka. The sensor nodes were placed at different angles in order to get all round measurement. The set up is shown in Fig. 1. The sensor nodes were programmed with NesC programming language.

Fig. 1: Pictorial representation of the experimental testbed

Programs written in NesC were used to convert the readings from the sensor nodes direct to actual values. The program for the collection of data and graphical user interface display of the sensor node was written in Java language. The program displays the data received and also shows graphical relationship of the sensor node for voltage, temperature, light intensity, humidity. The graphical display has options for save data, clear data, start monitoring and stop monitoring. The nodes were programmed to send data every 5 seconds. The data collected nine months was averaged and used for analysis. One of the sensor nodes was attached to the laptop through a USB cable and was used as the sink. The remaining three sensor nodes were placed at 0^0, 90^0, 180^0 from the sink at the same distances while taking the measurements. The measurements were taken from 1m to 7m distance at the interval of 1m. The mean of the RSSI value obtained at a given distance was calculated.

IV. RESULT ANALYSIS AND DISCUSSION

Table 1 shows the RSSI values of the nodes as were obtained from measurement testbed. The RSSI values of the sensor nodes against distances are shown in a bar chart plotted in excel worksheet in Fig. 2. Also Matlab software tool was used to show the relationship between RSSI and distance of the measured data. It was observed that RSSI decreases as the distance increases, although, there are some exceptions which may be due to line of sight measurements or multipath effects. Fig. 3 and Fig. 4 plotted in Matlab show the RSSI of the 3 nodes and the RSSI of the 3 nodes and their average in the testbed environment respectively.

Table 1: RSSI values of the 3 nodes and their average of the testbed

Distance (m)	RSSI (dBm) for node ID 301	RSSI (dBm) for node ID 302	RSSI (dBm) for node ID 303	RSSI (dBm) of the 3 nodes
1	-44.6	-52.0	-38.1	-44.90
2	-58.5	-57.3	-53.25	-56.53
3	-74.1	-60.4	-56.5	-63.67
4	-57.0	-67.7	-59.8	-61.50
5	-68.5	-57.7	-62.3	-62.83
6	-70.2	-64.0	-60.0	-64.73
7	-57.3	-72.5	-58.7	-62.83

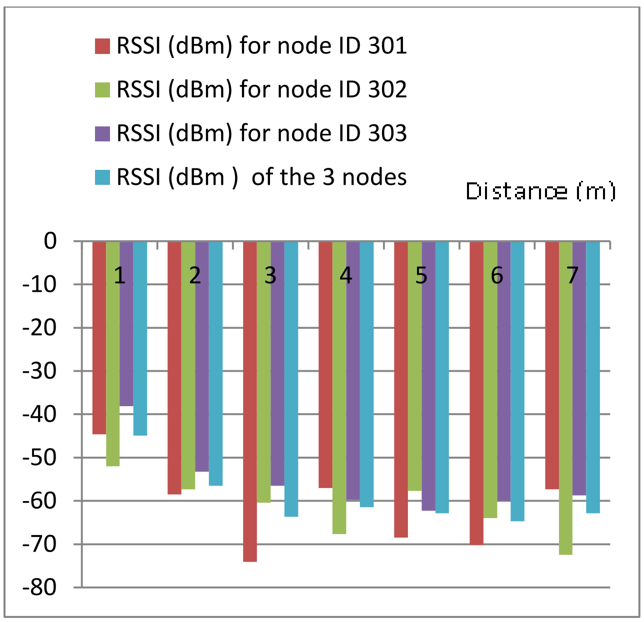

Fig. 2: Bar Chart of the mean RSSI of the three sensor nodes and average

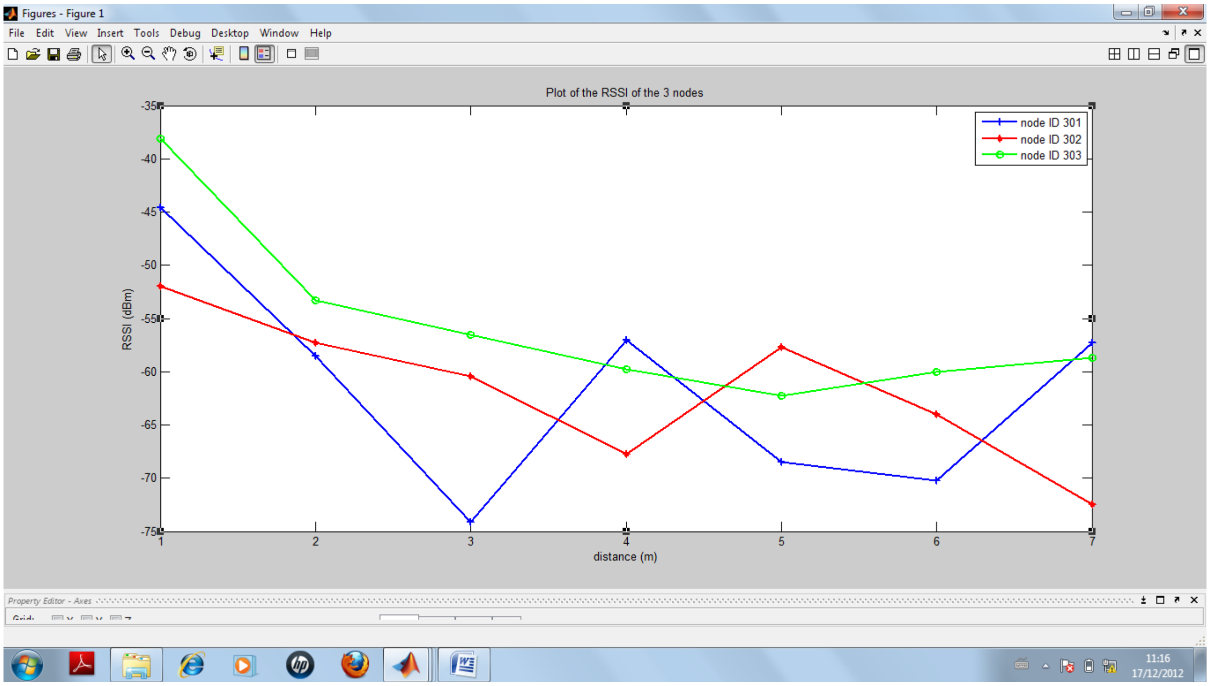

Fig. 3: A graph of RSSI (dBm) against distance of the 3 nodes of the testbed

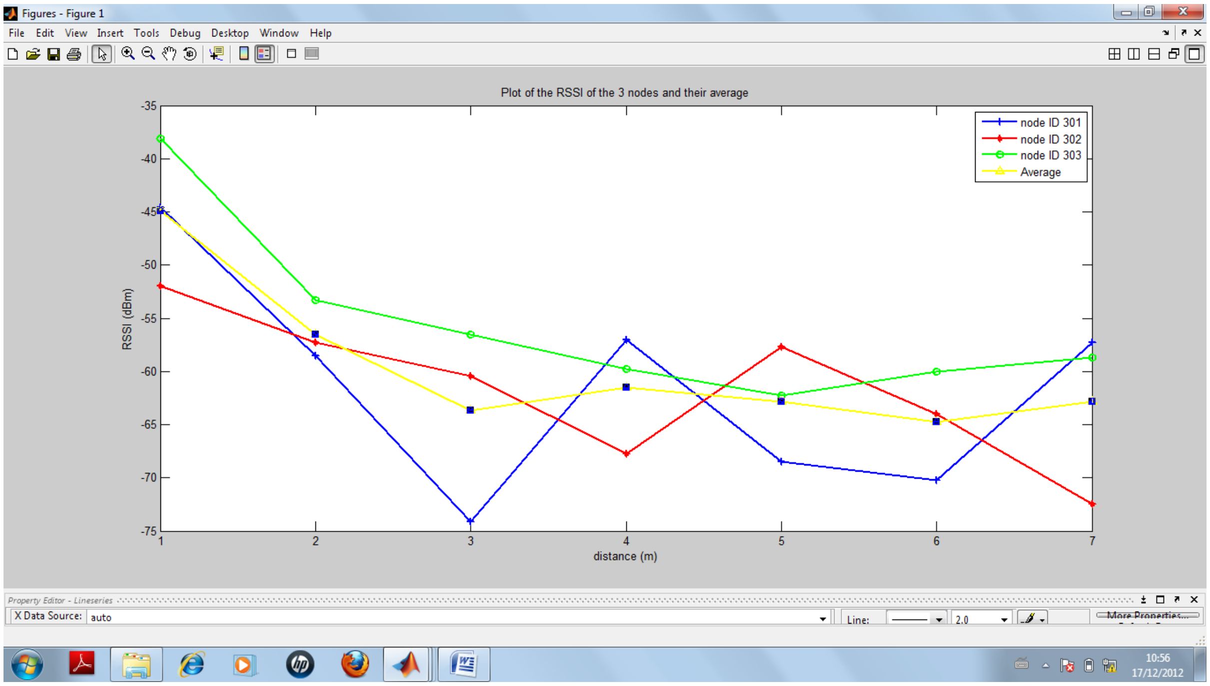

Fig. 4: A graph of RSSI (dBm) against distance of the 3 nodes and their average of the testbed

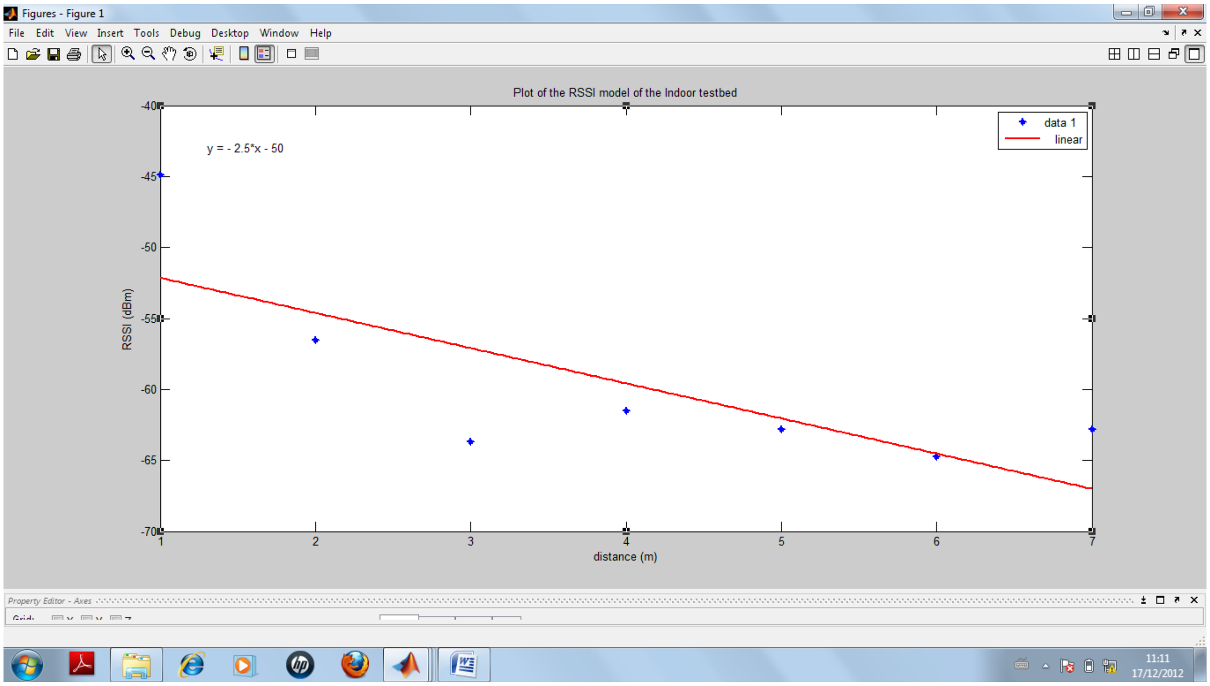

Fig. 5: Plot of the model of the RSSI of the testbed

A model equation of RSSI of the testbed was developed by finding the least mean square error line of the measured points. The plot is shown in Fig. 5.

The equation of the model is shown in equation 2:

$$RSSI = -2.5 * d - 50 \qquad (2)$$

Where *d* is the distance.

The goodness of fit (R^2) of the Received Signal Strength Indicator (RSSI) model developed for the indoor testbed was tested and found to be 0.86. This confirms that the model can generally be applied in RSSI determination of an environment with similar radio characteristics. Therefore, the RSSI at any known distance can be calculated using the developed model of equation 2 for the indoor testbed. The screen shot of the statistical data determined is shown in Fig. 6.

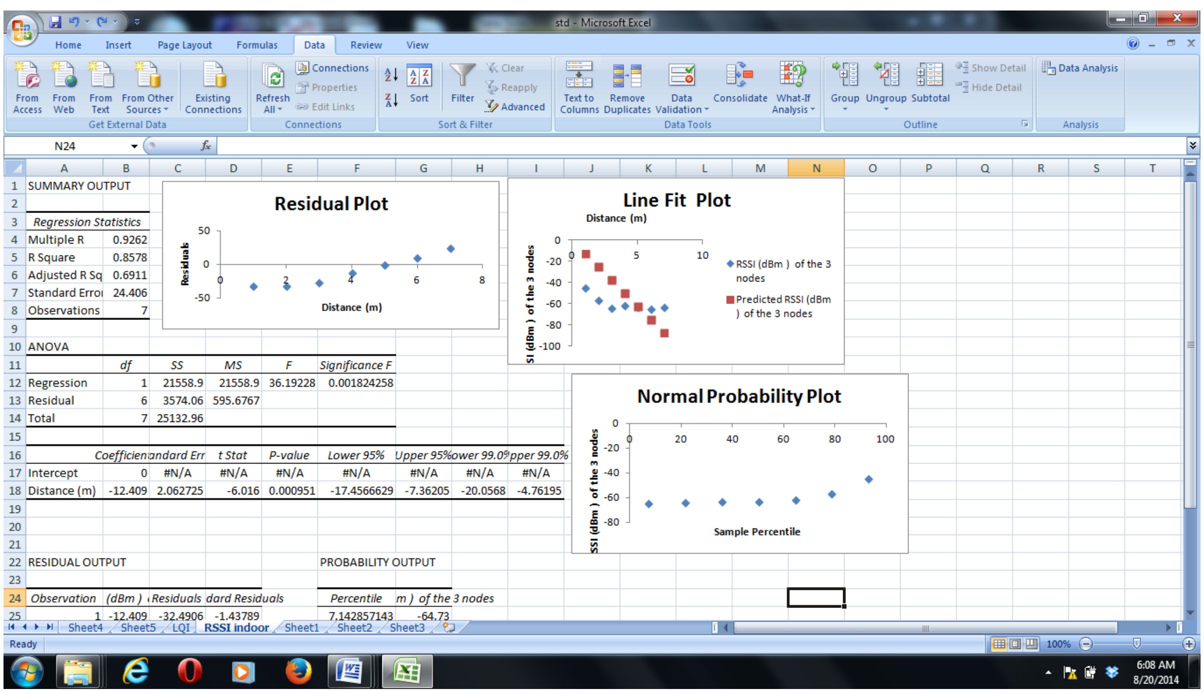

Fig. 6: Screen shot excel worksheet showing the data analysis

V. CONCLUSION

RSSI of wireless sensor nodes in an indoor environment was analyzed and modelled. The modelling was achieved using least mean square error method of linear Regression Analysis. The goodness of fit (R^2) of the model was found to be 0.86. This shows that the model is good and can be applied to an area with similar radio characteristics. It was also found that the experimental distance range of TelosB sensor nodes from the developed model is about 16m. This is so because at 16m, the RSSI is about -90dBm which is the range of the receiver sensitivity of the TelosB sensor node. However, the Data sheet of CC2420 gives the distance range as 20-30m in indoor environment. The reduction in the distance range of the sensor node can be attributed to the radio characteristics of the environment of the testbed. This implies that the model holds and can be applied only to the testbed and any environment with similar radio characteristics.

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