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A Modelof Real-Time Outdoor Wireless Monitoring

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Abstract:- This paper presents development of Received Signal Strength Indicator (RSSI) model of an outdoor environment using TelosB sensor nodes. Extensive real-time measurement of the RSSI was done at the library field of 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 0.83. This confirmed that the model can be used to determine the RSSI at any given distance of an environment with similar radio characteristics.

Keywords:- RSSI, WSN, TelosB, Sensor nodes.

I. INTRODUCTION

Since the start of the third Millennium, wireless sensor networks (WSNs) generated an increasing interest from industrial and research perspectives [1, 2]. 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]. A large number of such sensors can be deployed in an area to achieve an overall sensing objective. In addition to sensing and collecting data, these sensors are also equipped with processing capabilities to deduce how to route the data packets through the neighbours to an Internet-connected base station or sink. The wireless sensor nodes are usually battery powered or have energy harvesting units built in them to prolong their lifetime. The sensing circuitry measures ambient condition related to the environment surrounding the sensor and transforms these into an electric signal. Processing such a signal reveals some properties about objects located and/or events happening in the vicinity of the sensor. The sensor sends the collected data through a radio transceiver to the sink either directly or through a gateway. The decrease in the size and cost of these sensors, resulting from technological advances, has fuelled interests in the possible use of large set of disposable unattended sensors. Such interests have motivated intensive research in the past few years addressing the potential of collaboration among sensors in data gathering and processing and the coordination and management of the sensing activity and data flow to the sink. A natural architecture for such collaborative distributed sensors is a network with wireless links that can be formed among the sensors in an ad hoc manner.
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 ones choice. The chipcon CC2420 transceiver operates at 2.4-2.4835GHz, has 250kbps data rates, RF power of -24 to 0dBm, receive 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 written were compiled and loaded into the node via USB. In this paper, the RSSI model of an outdoor environment is developed based on extensive empirical study in an open field.

II. RSSI MODEL

Received Signal Strength Indicator (RSSI) measures the strength of the radio signal received. The characteristics of RSSI, shows that the received signal strength will decrease with increased distance as shown by equation 1, [4]

$$RSSI = -(10n\log d + A) \qquad (1)$$

Where n is the path loss exponent, d is distance from sender to receiver, A is received signal strength at a reference distance.

In embedded devices like wireless sensor nodes, the received signal strength is converted to a received signal strength indicator (RSSI) which is defined as a ratio of the received power to the reference power (P_{ref}). Typically, the reference power represents an absolute value of P_{ref} = ImW. An increasing received power results in a rising RSSI.

$$RSSI = 10\log\frac{P_r}{P_{ref}}\left[RSSI\right](dBm) \qquad (2)$$

The specific point in a system where position estimates are calculated is an important design parameter. For environmental changes the log model also will change. So using a scaling factor for adjusting the log model with the measured data, the basic RSSI log model equation changes to

$$RSSI = -[10n\log_{10}(sd+1) + A] \qquad (3)$$

where s = scaling factor.

$$n = \frac{RSSI + A}{-10\log_{10}(sd+1)} \qquad (4)$$

$$d = 10^{\frac{[\frac{RSSI+A}{-10n}]-1}{s}} \qquad (5)$$

RSSI model is very important because RSSI measurements are applied in many areas such as estimation of the position of targets in an observation area, determination of Link Quality of a testbed environment, development of routing algorithms, characterization of environments and determination of the energy spent by the sensor nodes in communicating to each other.

The authors in [5] described an enhancement method for location estimation based on RSSI-values and extended Kalman filter, using per-calibration measurements. However they support their system with a standard wireless local area network over the 2.4GHz frequency band. The authors in [6] also described localization in a WSN using RSSI as the underlying model. However, their major focus has to quantify distance estimation errors across multiple environments. In [7], the authors derived the Cramer-Rao Bound (CRB) for location estimation using RSS and Time Of Arrival (TOA) relative localization techniques. Their testbed developed at Motorola Labs consisted of 12 prototype peer-to-peer wireless sensor devices with RSS measurement capabilities. They concluded that despite the reputation of RSS as a coarse localization model, it can nevertheless achieve an accuracy of about 1m RMS in a real testbed environment. The authors in [8,9] discussed the characterization of an environment using RSSI in WSNs. The energy model of WSNs in terms of the distance and pathloss exponent was described by authors in [10,11]. In [12,13], the authors showed how RSSI can be used in developing routing protocols in WSNs. This paper presents the development of RSSI model using Least Mean Square Error (LMSE) method of linear regression analysis.

III. RESEARCH METHODOLOGY

In this work extensive real-time experiments were conducted to determine the practical distance range of Wireless Sensor Nodes in an outdoor environment. The aim of this work is to predict the RSSI value at a given distance in an environment with similar radio characteristics as the one used in the work. The development kit used is Crossbow TelosB sensor node from Texas Instrument which have Chipcon CC2420 transceiver- an IEEE 802.15.4 radio with a built in 2.4 GHz antenna as the communication unit. The transceiver has built-in RSSI providing a digital value that can be read from the 8 bit, signed 2's complement RSSI.RSSI_VAL register. The RSSI value is always averaged over 8 symbol periods (128μs), in accordance with [14]. The RSSI_VALID status bit indicates when the RSSI value is valid, meaning that the receiver has been enabled for at least 8 symbol periods.

The experimental setup consist of four Crossbow TelosB sensor nodes programmed with NesC programming language is shown in figure1.

Fig. 1 shows pictorial representation of the experimental tesebed.

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 as shown in figure 2.

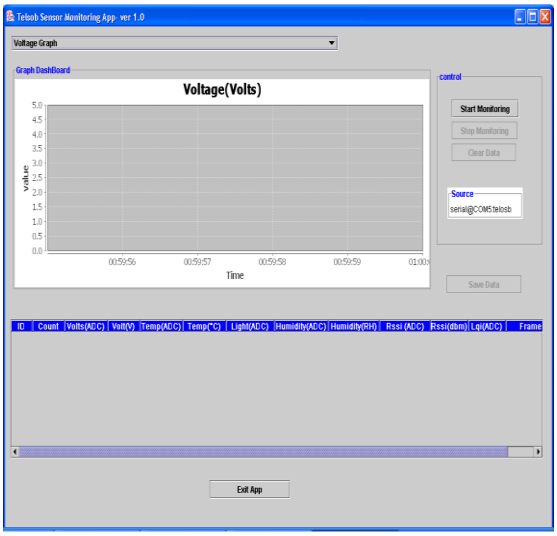

Fig 2: Run SensorRouterApp screen

The nodes are programmed to send data every 5 seconds. The data collected over a long period of time 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 5m to 60m distance at the interval of 5m. At each distance readings were taken for 2 minutes giving a total of about 20 readings for every distance. The mean of the RSSI value obtained at a given distance was calculated and variance and the standard error of the mean were determined.

In the experiment, the RSSI value is an average of the received signal strength at the packets arrival time. RSSI is the estimate of the signal power and is calculated over 8 symbol periods and stored in the RSSI_VAL register. Chipcon [15] specifies the following formula to compute the received signal power (P) in dBm.

$$P = RSSI\_VAL + RSSI\_OFFSET \qquad (6)$$

where $RSSI - OFFSET$ is about – 45.

Tables 1 shows the mean RSSI values of the nodes from measurement testbeds (outdoor environment).

Table 1 RSSI values against distance of the testbed

Distance (m)	RSSI (dBm) for node ID 301	RSSI (dBm) for node ID 302	RSSI (dBm) for node ID 303	Ave. RSSI (dBm) of the 3 nodes
1	-40.7	-46	-44.8	-43.83
5	-61.4	-64.1	-62.3	-62.60
10	-68.1	-69.6	-65.8	-67.83
15	-82.4	-75.9	-74.7	-77.67
20	-80.3	-77.7	-81.9	-79.97
25	-77.6	-88.5	-81.3	-82.47
30	-81.5	-88.5	-89.5	-86.50
35	-88.7	-89.2	-84.7	-87.53
40	-75.8	-88.2	-86.3	-83.40
45	-82.3	-91.8	-85.5	-86.53
50	-84.7	-91.8	-92.2	-89.57

55	-78.8	-88.8	-89.3	-85.63
60	-92.2	-92.43	-92.3	-92.3

IV. RESULT ANALYSIS

From the data obtained graphs were plotted to show the relationship between RSSI and distance of the measurements. A bar chart showing the mean values of the RSSI of the three sensor nodes and their average at various distances of the measurement were drawn. Also, the average value of the RSSI of the three sensor nodes and their average was plotted against distance in matlab. Least Mean Square Error method of Linear Regression Analysis was used to develop a model of the testbed environment.

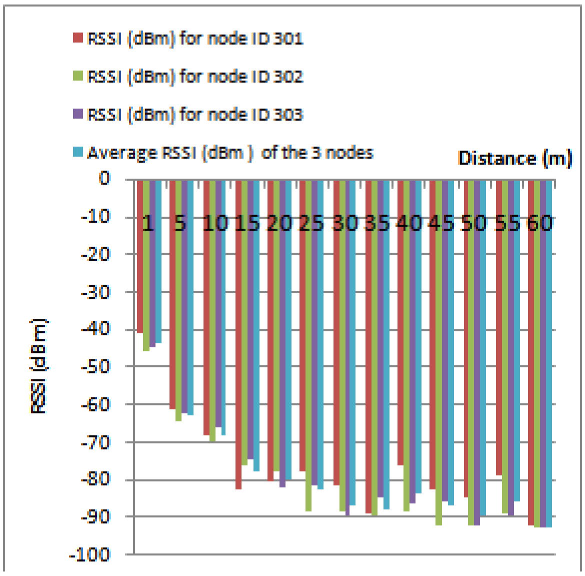

Fig 3: Bar chart showing the mean RSSI of the three sensor nodes and their average

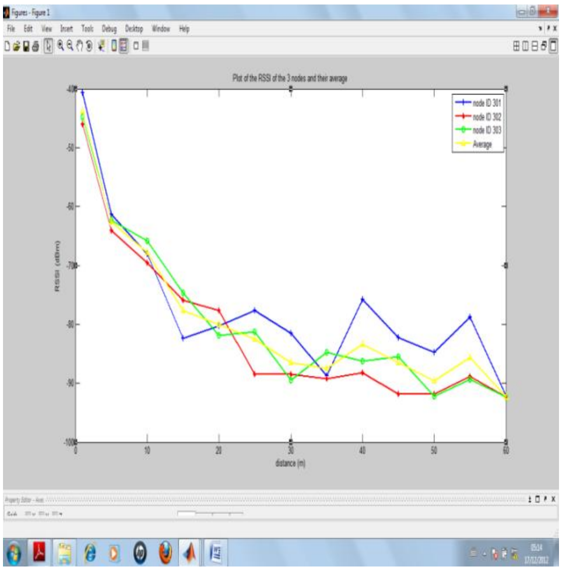

Figure 4: Plot of RSSI of the three nodes and their average against distance

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

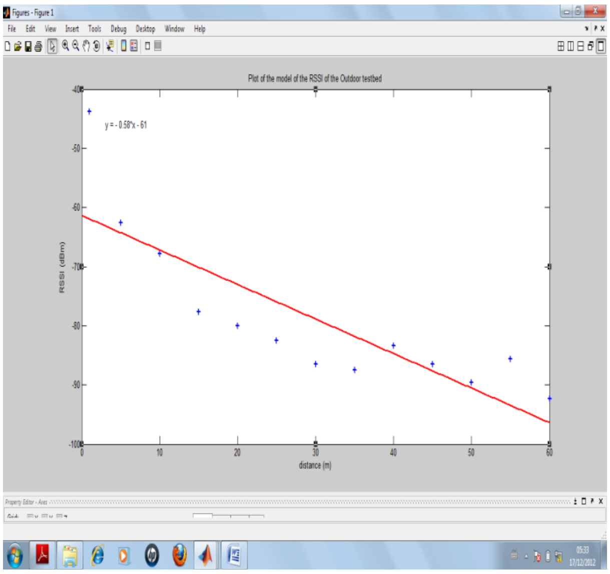

Figure 5: Plot of the developed model of the RSSI of the testbed environment

The *RSSI* developed model of the testbed environment follows the trend given by equation 7.

$$RSSI = -0.58 * d - 61 \qquad (7)$$

Where *d* is the distance.
The goodness of fit (R^2) of the RSSI model developed for the testbed environment was tested and found to be 0.83.

V. CONCLUSION

From the graphs, 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. The RSSI at any known distances can be calculated using the developed model of equation 7 for the outdoor environment. The goodness of fit (R^2) of the developed RSSI model was 0.83 which shows 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 7 for the outdoor testbed.

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