Effect of Distance and Antenna on Received Signal Strength in Wireless Sensor Network Using XbeeS2B Radios - A Case Study

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Abstract

Today, through the monitoring of agronomic variables, the wireless sensor networks are playing an increasingly important role in precision measurement. Among the emerging technologies used to develop prototypes related to wireless sensor network, we find the Arduino platform and XBee radio modules from the DIGI Company. However data collection and monitoring is possible without use of Arduino platform also. We can simply use Xbee radios and processing can be done with Java, which is cost effective and more flexible set up. For any effective and efficient result of measurement in wireless sensor network, it is necessary to study about the strength of received signal from a remote place.In this article, based on field tests, we conducted and studied comparative analysis of received strength signal intensity levels with reference to distance between Xbee S2B radios and presence/absence of antenna. Experiment was conducted for two XBee radios only, one as coordinator and another as router.

Keywords — *XBee, wireless sensor network, received strength, signal intensity level*

I. INTRODUCTION

Wireless sensor networks are often seen as an alternative to their wired counterparts. Xbee radios are a market standard in creating wireless sensor networks. The Xbee radios are scalable, flexible and easy to use. A lot of research in this field has shown that to measure the parameters of remote locations, the traditional wired systems fail [1]. Wireless sensor networks have a number of advantages over wired industrial monitoring and control systems; such as self-organization, flexibility and ease of deployment [2]. Wireless sensor networks can be used for remote sensing, industrial and domestic automation, control applications [3].

Wireless sensor networks are composed of a number of remote sensor nodes and a single control node. These wireless sensor network nodes are capable of sensing, actuating and relaying the collected information [4], [5]. Received Signal Strength Indicator (RSSI) is a measurement of the power present in a received radio signal[6].RSSI is usually invisible to a user of a receiving device. However, because signal strength can vary greatly and affect functionality in wireless networking, IEEE 802.11 devices often make the measurement available to users.

As early as 2000, researchers were able to use RSSI for coarse-grained location estimates [7]. More recent work was able to reproduce these results using more advanced techniques [8]. Nevertheless, RSSI does not always provide measurements that are sufficiently accurate to properly determine the location [9]. However, RSSI still represents the most feasible indicator for localization purposes as it is available in almost all wireless nodes and it does not need any additional hardware requirements [10].

Each XBee module has the capability to directly gather sensor data and transmit it without the use of an external microcontroller known as XBee direct. This offers many advantages. By excluding the external microcontroller, the overall size of the project can be reduced. This is essential when creating sensors that need to be inconspicuous. By using XBee alone, it can minimize weight which is an important factor for systems such as Body Sensor Networks or wearables[11].

In this paper we have studied the effect of distance between local radio (Coordinator) and remote radio (Router) and also the effect of presence/absence of antenna has been monitored.

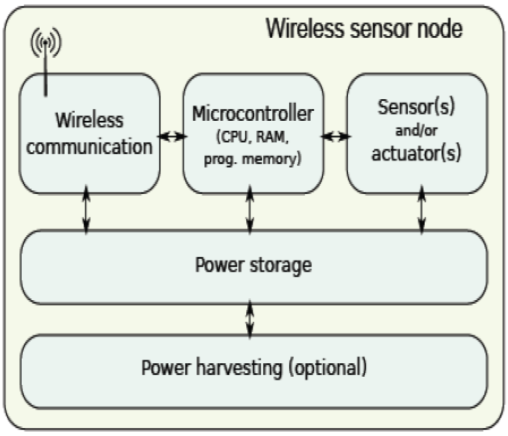


Fig. 1: Hardware components of Wireless Sensor Node

The outline of this paper is as follows. In Section II we have briefly discussed about the Experimental Set Up. Software and Hardware components are described in Section III and IV respectively. Section V is about RSSI Measurement. Observation and Result are mentioned in Section VI. Conclusions are shown in Section VIIand references are mentioned in Section VIII.

II. EXPERIMENTAL SETUP

For our experiments, we used XBee Series 2, 2mW modules from Digi International, model XB24-ZB. Each module is equipped with an antenna. We build single-hop and multihop wireless sensor networks where each node consists of XBee module. For programming each node, we used X-CTU, free software provided by Digi International. With this software,the user is able to update the parameters, upgrade thefirmware and perform communication testing easily. Communication with XBee modules is done via XBee Interface board connected using a USB cable to a personal computer (PC) as shown in Fig. 2 & 3. All the nodes were configured to use the same Personal Area Network (PAN) ID with a baud rate of 115200bps.(Fig. 4 & 5) XBee S2 B radio offers transmission range of 200 m in outdoor.

In this system, we have 2 Xbee radio modules – coordinator and router modules. The Coordinator module is configured to work in API mode. The router Xbee is configured to work in AT mode. For our application, we do not need to program the router Xbee in API mode. When performing API-AT communication, the data from the AT module is read at API frame 19 by the API module. Even if we configure both radio modules in API mode, the router would still have to make use of API frame 19 to send its sensor data. The router module is placed at a remote location from the coordinator radio module. The coordinator radio module is connected to a USB Xbee explorer. The Xbee explorer is connected to the PC via a COM port.

For initialization, the Xbee modules were configured using XCTU software provided by Digi. One of them is configured as a coordinator, while the other is configured as a router.

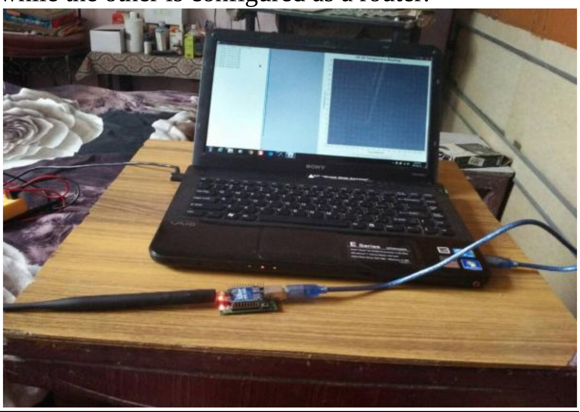


Fig. 2 Experimental Setup of the Coordinator Xbee

Fig. 3 Experimental Setup of the Router Xbee

III. SOFTWARE COMPONENT

A. XCTU

XCTU is a free multi-platform application that enables developers to interact with Digi RF modules through a simple-to-use graphical interface. It includes new tools that make it very easy to set up, configure and test Xbee RF modules. It is needed to configure the Xbee radio modules for initial use.

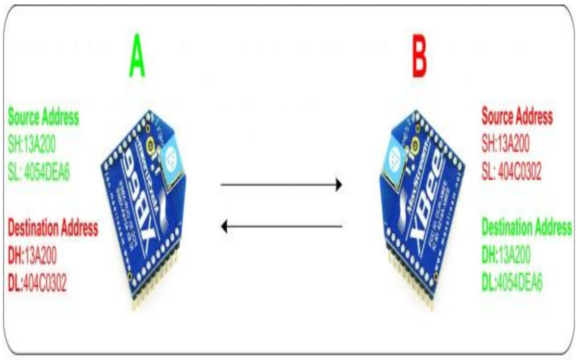


Fig.4 Configuration of Xbee parameters

The basic requirement to configure the two Xbee pro modems (one at coordinator end and other at receiver end) is that

(i) PAN ID of both should be same.

(ii) Both should be in AT/API command mode.

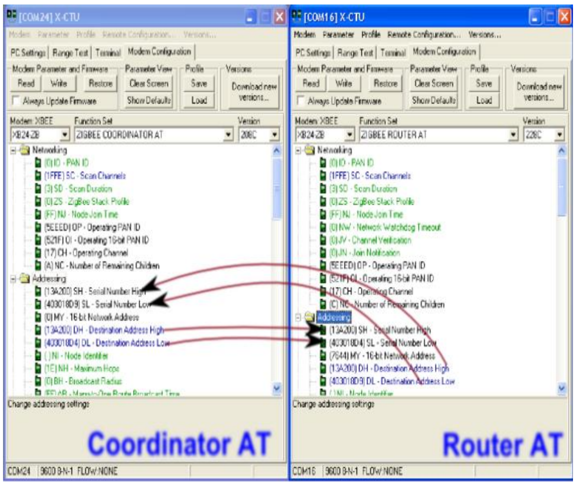


Fig. 5. ConfiguringXbees using XCTU software.

IV. HARDWARE COMPONENTS

A. Xbee S2B radio module

The Xbee radio modules are low-cost, low-power radio modules. They are often used to create wireless sensor networks. They require minimal power and provide reliable delivery of data between remote devices. They operate within the ISM 2.4 GHz frequency band.

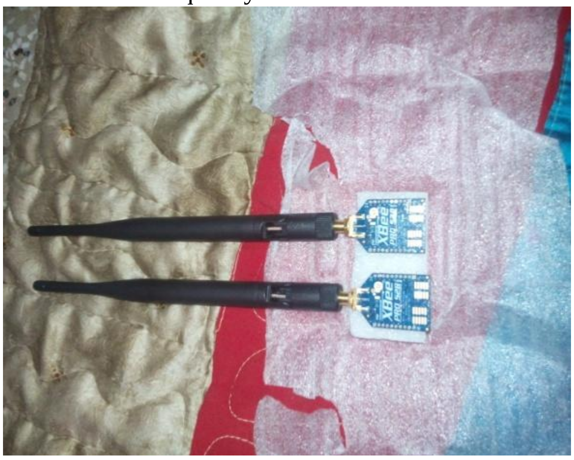


Fig. 6Xbee S2B Radios

B. Xbee USB Explorer

The Xbee USB explorer is a USB to Serial base unit for the Xbee radio modules made by Digi.It has a USB-to-Serial convertor, reset button and a voltage regulator to supply the Xbee. It has 4 indicator LEDs for Rx, Tx, RSSI and power. It also has a break out for the pins of the Xbee which make it easy to interface with the IO lines on the Xbee.

Fig. 7Xbee USB Explorer

V. RSSI MEASUREMENT

Received signal strength indicator (RSSI) is the signal strength level of a wireless device measured in –dBm of the last received packet [12]. The main idea behind the RSS system is that the detected signal strength value decays with the distance travelled. In free space, the RSS degrades with the square of the distance from the sender [13]. Using the Friis transmission equation, the ratio of the received power P_R *to* the transmission power $P_T$can be expressed as:

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi R)^2}$$

Where, G_T, $G_R$are gain of transmitter and gain of receiver respectively.λ is a wavelength, and $R$is the distance between thesender and receiver. It can be seen that the larger the wavelengthof the propagating wave the less susceptible it is topath loss. The received signal strength is converted to RSSI which can be defined as the ratio of the received power $P_R$to the reference PowerP_{Ref}which can be defined as the ratio of the received power P_R *to* reference power $P_{Ref.}$

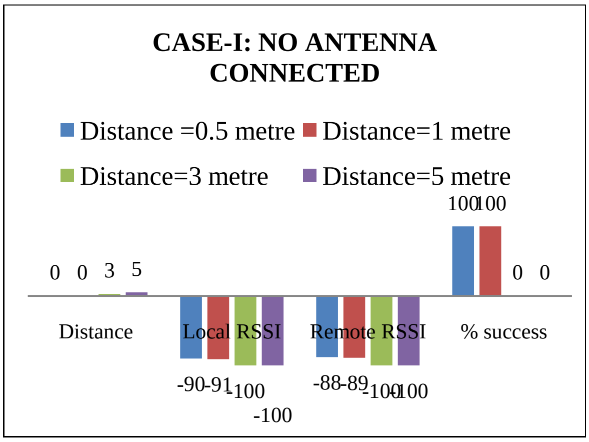
RSSI= 10 log (P_R/P_{Ref}).

VI. OBSERVATION AND RESULT

We observed the four cases for Xbee S2B Radio and monitored the effect of distance and presence/absence of antenna on 'Local RSSI & Remote RSSI' and also on % Success.

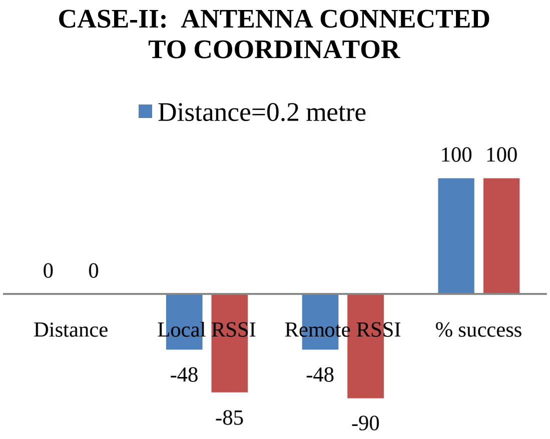
CASE-I: NO ANTENNA CONNECTED

Distance	Local RSSI	Remote RSSI	% success
0.5 meter	-90	-88	100
1 meter	-91	-89	100
3	-100	-100	0
5	-100	-100	0



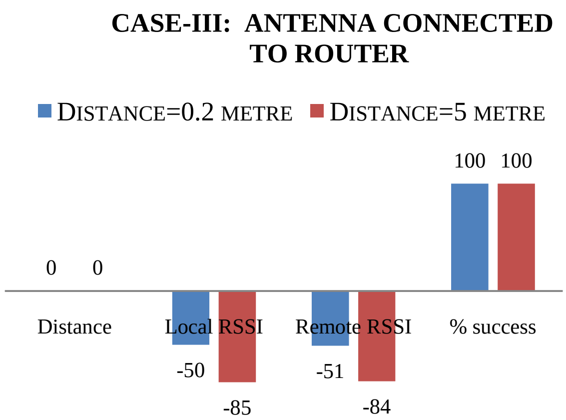
CASE-II: ANTENNA CONNECTED TO COORDINATOR

Distance	Local RSSI	Remote RSSI	% success
0.2 metre	-48	-48	100
5 metre	-85	-90	100



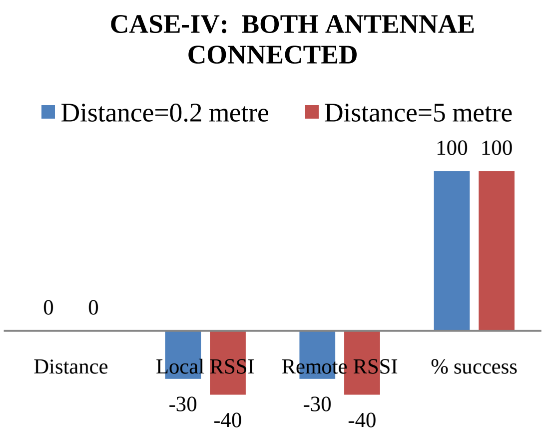
CASE-III: ANTENNA CONNECTED TO ROUTER

Distance	Local RSSI	Remote RSSI	% success
0.2 metre	-50	-51	100
5 metre	-85	-84	100



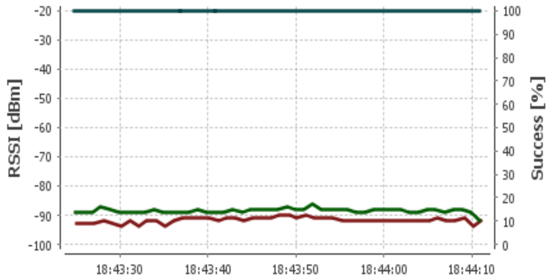
CASE-IV: BOTH ANTENNAE CONNECTED

Distance	Local RSSI	Remote RSSI	% success
0.2 metre	-30	-30	100
5 metre	-40	-40	100

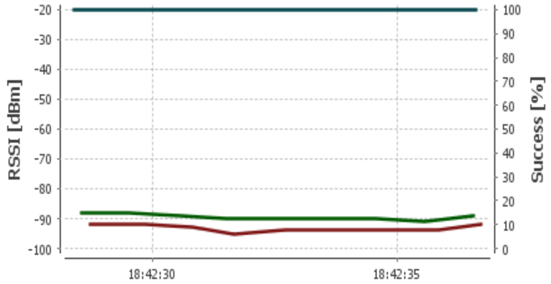


CASE 1- NO ANTENNA CONNECTED

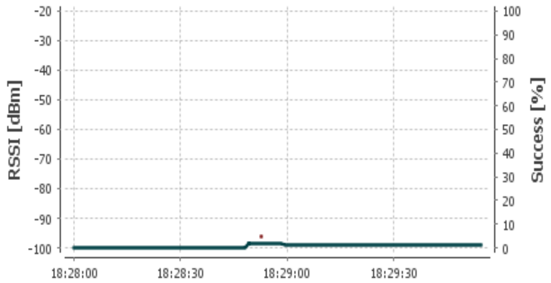
(i) DISTANCE - 0.5 M



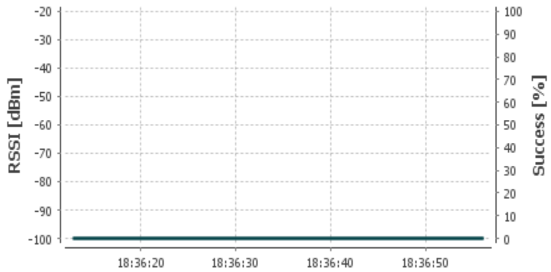
(ii) DISTANCE - 1 M



(iii) DISTANCE - 3 M

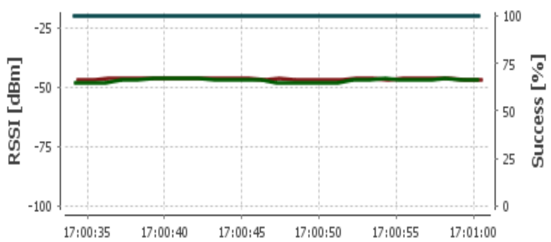


(iv) DISTANCE – 5 M

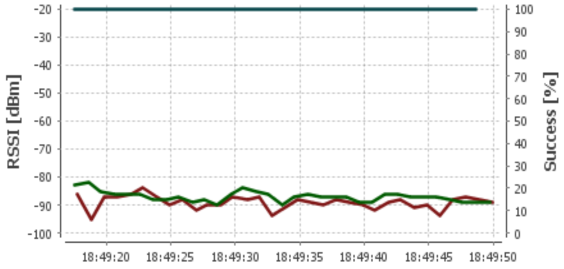


CASE2-ANTENNA CONNECTED TO COORDINATOR

(i) DISTANCE – 0.2 M

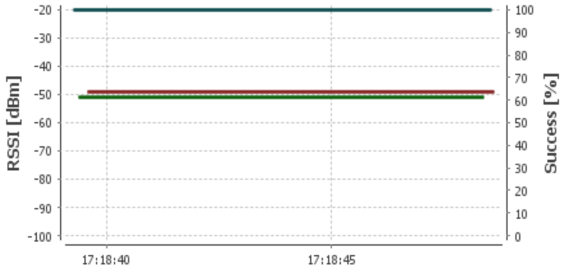


(ii) DISTANCE – 5M

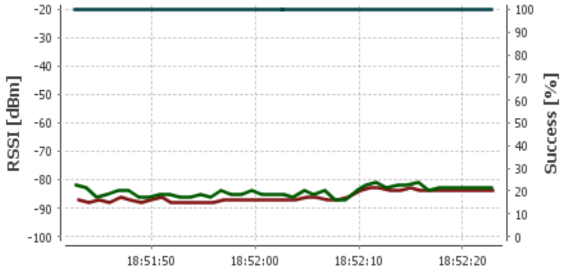


CASE-3 ANTENNA CONNECTED TO ROUTER

(i) DISTANCE-0.2

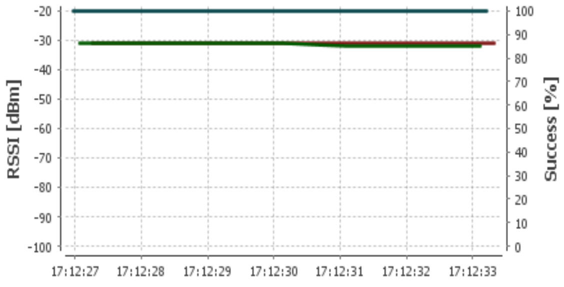


(ii) DISTANCE-5



CASE-4 BOTH ANTENNAE CONNECTED

(i) DISTANCE -0.2M



(ii) DISTANCE- 5M

VII. CONCLUSION

1. In case of without antenna the Success rate is 100% only upto 1(one)meter of distance and Received Signal Strength ia almost same as the Strength of Remote Signal. For distance more than one meter the Success rate is Zero and Strength is almost negligible.
2. When the antenna is connected to either to Coordinator or Router, although the Success is 100% but the Signal Strength is drastically reduced(-80 to -90) for large distances greater than 5(five) meter.
3. When both the antennae connected to Router and Coordinator the Success rate is 100% both for distances of 0.2 meter and 5 meters and the Received Signal Strength is far better than as mentioned above in S.No.(2).However as the distance is increased the Received Signal Strength is reduced in comparison to distance of 0.2 meter.

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