Climatic Parameters and Vegetation Effect on Wireless Routing Pattern in Greenhouse

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***Abstract*—One of the promising areas where wireless sensor network (WSN) application would be essential is in precision farming, especially those involving high value crops. Understanding the behavior of the signal propagates in such environment would be crucial in optimizing the wireless sensor nodes deployment. This paper discusses the experimental implementation of wireless sensor network in mango greenhouse and the effect of climatic parameters and vegetation on the routing pattern of the nodes. The results show that the number of hops increases as an effect of variation in climatic parameters. Nevertheless, the changes in temperature alone do not seem to affect the changes in the pattern of signals routed in the greenhouse significantly contrary to the changes in humidity level. As humidity level decreases, the number of signal routing increases, thus showing more chaotic routing pattern. The presence of vegetation around the nodes helps to preserve humidity level, thus increasees the creation of low cost path for signal to be undertaken, which in the end added to the number of signal hops.**

Index Terms–Greenhouse; Hop; Pattern; RSSI; WSN.

I. Introduction

Wireless sensor network has been intuitively deployed in many everyday applications for the betterment of human lives. The adoption of these applications is mainly driven by the technological advances made through in the area of miniaturization and communication protocols. Recent advances in wireless sensor networking technology have led to the development of low cost, low power, multifunctional sensor nodes. Each node consists of three sub-systems, which are the transducers/sensors, the processing system such as microcontroller, and the communication sub-system, which is RF chipset for establishing communication between neighbor nodes [1]. Wireless sensor networks have been used for extended variety of applications, including wireless data acquisition, machine monitoring and maintenance, smart building and highways, environmental monitoring, site security, automated on-site tracking of expensive materials, and safety management in many other areas [2]. One of the promising areas, where wireless sensor network (WSN) application would be essential, is precision farming, especially those involving high value crops. WSN technology has been applied in farmland environmental monitoring to provide better solution for information acquisition, transmission and analysis [3]. This application is also known as micro-climate monitoring, which is very important for precision farming. Liu and Ying [3] reported a greenhouse monitoring and control system using the Bluetooth technology, which involved a system collecting environmental data from a sensor network in a greenhouse and transmitted them to a central control system [4]. There have been other researches that discuss similar system for data collection [6]-[8]. In this paper, however, we discuss the implementation of wireless sensor network nodes in greenhouse and the effect of vegetation on the routing pattern of the nodes.

II. Literature Review

The application of WSN in data collection in agriculture has become very impactful to research communities. Until recently, most studies in WSN have focused on the devices [3], protocols [4]-[6] and the network architecture [7]. Although there have been some studies focusing on signal propagation, such as in [8]-[11], specific signal propagation analysis for WSN network deployment greenhouse has not be widely done. In a signal propagation analysis, simple channel models, such as the free space loss (FSL), given by Equation (1) is often used.

$$L_{FSL} = -27.56 + 20\log_{10}(d) + 20\log_{10}(f) \qquad (1)$$

The parameter f is the frequency in MHz; d is the distance between the isotropic transmitting and receiving antennas in meters.

The study reported in this paper used RSSI for estimating the signal strength received at the receiver given a certain value of transmitted signal. It has been reported in [11] that the RSSI can be predicted and modeled based on average signal strength over the distance of radius centered at the receiver. The model is given by Equation (2).

$$RSSI = -10nlog_{10}(d) + A \qquad (2)$$

where n is the signal propagation constant, d is the distance between transmitting and receiving antennas and A is the average of received signal strength at 1.5 m radius. Aside from these, the study monitored the hop pattern of signals from source nodes to various nodes before it was finally received at the base station. These hop characteristics developed into a route for each source node, and thus a routing pattern for the entire nodes was deployed in the greenhouse.

III. Experimental Monitoring

A. Environment Setup

The environment chosen was the inside of a greenhouse with mango trees. The mango trees were about 3.5 m in height and 1.5 m width. The greenhouse dimension was 60 m X 20 m X 20 m. The nodes positions inside the greenhouse was not done based on any requirement due to greenhouse or network, but rather due to the requirement to collect data for the vegetation experiment. The positions and nodes numbers are depicted in the diagram in Figure 1. The exact location in the greenhouse from top view is depicted in Figure 2.

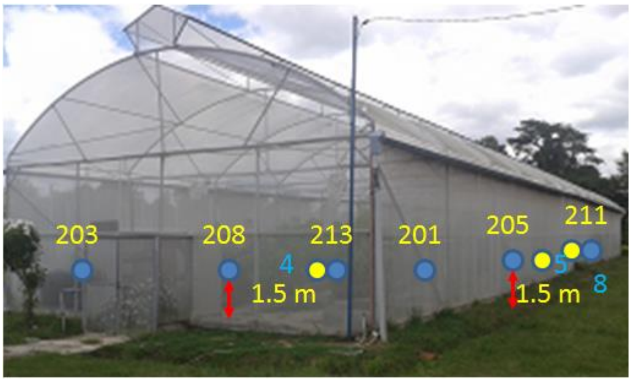

Figure 1: Diagram showing greenhouse with node position side view

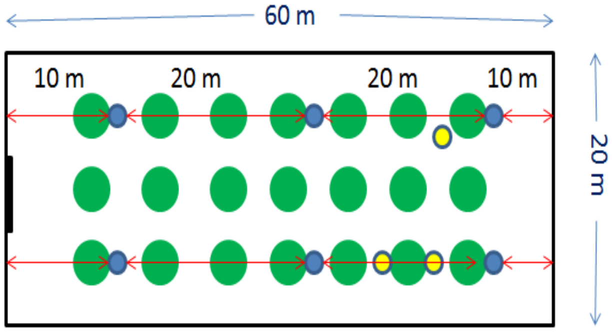

Figure 2: Diagram showing nodes position among the vegetation in greenhouse from top view

The deployment utilized six IRIS nodes and three EKO nodes, both of nodes are from MEMSIC. The nodes were positioned at specific locations in the greenhouse. The nodes in blue color shown in Figure 1 are IRIS nodes and they were numbered as 203, 208, 213, 201, 205 and 211. The first three nodes were positioned at left hand side of the greenhouse as depicted in upper section in Figure 2, while the remaining three nodes were positioned on the right side of the greenhouse as depicted in the lower section of Figure 2. Meanwhile, there were three EKO nodes deployed in the greenhouse as well and numbered 4, 5, and 8. They are marked as yellow circles in Figure 1 and Figure 2.

All the nodes were positioned at 1.5 m from ground as shown in Figure 1, which is essentially in the middle of the trees in the greenhouse. The purpose of this positioning is to evaluate the effect of trees and their vegetation on signal propagation of the nodes, which was analyzed from the routing pattern of the signals.

B. Equipment Used

This study has been performed using MEMSIC manufactured nodes, known as IRIS and EKO, which are ZIGBEE/IEEE802.15.4 compliant. The nodes transmitted in the 2.4 GHz – 2.5 GHz range ISM band. The IRIS nodes used supply voltage of 4.5 V and utilized Omni-directional 3 dBi antenna, while EKO nodes used 8 dBi antennas. Additionally, EKO nodes were running on battery and assisted by solar panels, thus making it capable of operating without having to replace the battery. The transmit power for all the nodes was 0 dBm or 1 mW. The noise floor for these nodes was at -90 dBm. Furthermore, both IRIS and EKO nodes were designed to use Moteworks^{TM} platform from MEMSIC, which govern the routing protocol for the nodes in wireless sensor networks. The protocol ensures reliable ad-hoc mesh networking, which focus on low power operation.

Additionally, in order to understand the effect of temperature and humidity on signal propagation, which would be observed through routing pattern, temperature and humidity sensors were placed in the greenhouse at 1.5 m height. Data from these sensors as well as routing pattern measurement throughout the day were then observed and analyzed.

IV. Results and Discussions

A. RSSI values measurement

This section discusses the results obtained in signal routing measurement in the greenhouse at 1.5 m antenna height. The results are shown as a routing pattern under the influence of temperature and humidity.

A fixed node was selected and all nodes to which the data hop were identified and RSSI value for each hop was collected. Figure 3 shows the routing pattern for node 205, which is at 1.5 m from the ground. These RSSI data showed the network routing as a result of changes in climatic condition throughout the day. In Figure 3, it is observed that the network was maintaining the RSSI to be well above -90 dBm by routing the data to multiple nodes around the greenhouse. In the early morning from 12 am to about 9 am, the amount of variation in routing pattern was less compared to after 9.30 am to about 9 pm. The data from node 205 hop and stayed at the node for a little bit longer. Additionally, data were routed directly to gateway (node 0 outside the greenhouse) from node 205 more often than during other times. There have also been some reports from other researchers on the effect of temperature and humidity on wireless signal strength in outdoor environment similar to what we observed in this study [8], [12].

However, after 9.30 am onwards to 7 pm, the routing pattern started to show some turbulent, with the signals moved from one node to the other more abruptly. The RSSI values shifted from very low at -85 to around -40 dBm in those few hours. Afterwards, the pattern of staying longer on one node took over and in many occasions, data hop directly to gateway. It was also observed that around 9.30 am to 7 pm, the routing preference were EKO nodes. Aside from these, it was also observed that anytime the RSSI values dropped to below -80 dBm, the routing went to EKO nodes instead of IRIS.

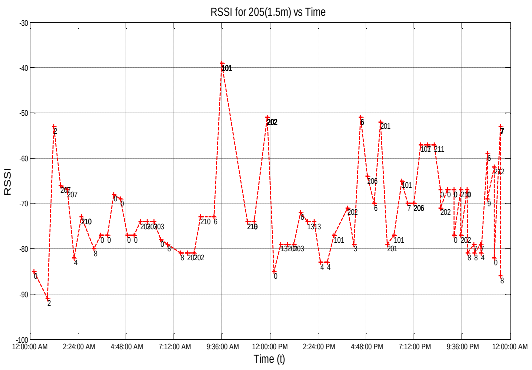

Figure 3: RSSI variation over time of the day for node 205 which hop to multiple nodes in the greenhouse

B. Climatic Data for the Greenhouse

The climatic data collected were temperatures and humidity for the identified nodes in the greenhouse under study. The data are as depicted in figures below.

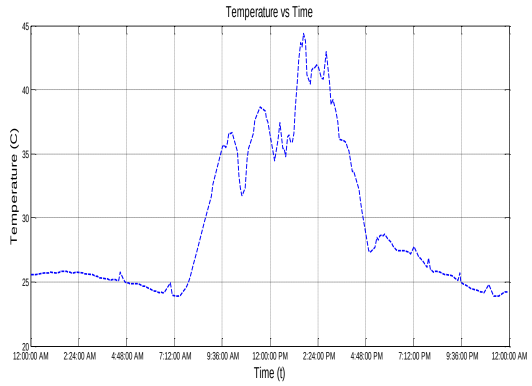

Figure 4: Temperature variation over time of the day for node 205

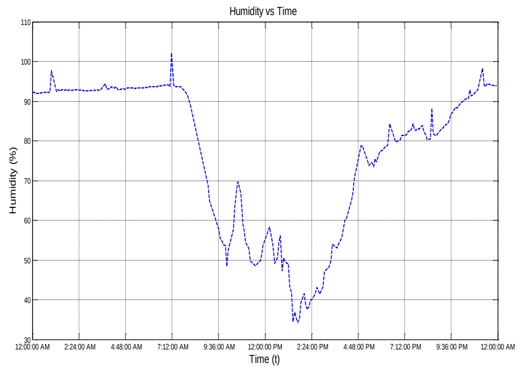

Figure 5: Humidity variation over time of the day for node 205

Figure 4 shows the temperature variation in a day for node 205 at 1.5m height. In the morning, the temperature was almost constant; however, the reading changed as the day progressed. It was observed that the node temperature increased significantly from 7.30 AM to 9.30 AM. There were variations in temperature although it was still on the increasing trend from 9.30 AM to 2.00 PM. This corresponded to the high variation in the routing pattern observed in the greenhouse. The sudden increase in temperature caused signals to hop on multiple nodes in greenhouse. Although the temperature showed a significant drop after 2.30 PM, the intense routing pattern was still observed on node 205.

Figure 5 shows the humidity variation in a day for node 205 at 1.5m height in a greenhouse. From the result, it is observed that high humidity in the greenhouse started to deteriorate after 7.30 AM onward as the temperature of the day rised. Interestingly, sudden decrease in humidity in the greenhouse showed a lower rate of signal hop among multiple nodes. For example, from 9.30 AM to 12.00 PM, there were only two hops observed in the period of 2.5 hours compared to six hops observed from 2.00 AM to 4.30 AM. As the humidity level started to increase gradually from 2.30 PM onward, the number of hops seem to increase as well. In addition to that, the close proximity between the node and vegetation around it has increased the overall number of hops as the signal scrambled around to find lower cost path. The presence of higher humidity around the vegetation has increased the possible lower cost path for signals to choose from, thus increases the routing pattern.

V. Conclusion

This paper presented a wireless propagation study performed in a greenhouse. The study involved observing the number of hops and pattern for node around vegetation. The results show that routing pattern increases when there is a variation in climatic parameters. However, the changes in the temperature do not seem to affect the routing or number of hops of the signals in the greenhouse.

On the other hand, changes in the humidity level affect the routing pattern significantly in greenhouse. As the humidity level decreases, the number of hops increases significantly, thus showing more chaotic pattern. However, as the humidity level decreases, the number of hops decreases. The presence of vegetation around the node helps preserve the humidity level, thus increases the creation of low cost path for signal to be undertaken.

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