An Efficient Wireless Sensor Network for Precision Agriculture

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Abstract— **Wireless sensor network consists of many node with capability of sensing, computation, and wireless communications. The wireless sensor network technologies are increasingly being implemented for modern precision agriculture monitoring. The privileges of wireless sensor network in agriculture are for several causes: high performance, increase the production efficiency while decreasing cost, low-power consumption and collected distributed data.**

Keywords:wireless sensor network; precision agriculture; grid topology; random topology; Wi-Fi network

I. INTRODUCTION

Wireless sensor network (WSNs) are being used in a wide variety of critical applications such as military and healthcare applications, agriculture and industrial process monitoring. WSN is an intelligent private network made by a large number of sensor nodes which do specific function. Wireless transmission allows deploy the sensors at remote, dangerous, and hazardous location. WSN has several advantages including easy installation, cost-effectiveness, small size and low power consumption. In recent years, Agriculture faces many challenges, while humanity depends on agriculture and water for survival, so precision agriculture monitoring is critical and the demand for environmental monitoring and remote controlling in agriculture is rapidly growing. However, there have been few researches on the applications of WSN for agriculture. Miranda [1] used a closed-loop irrigation system and determined irrigation amount based on distributed soil water measurements. Shock [2] used radio transmission for soil moisture data from data loggers to a central computer logging site. Wall and King [3] explored designs for smart soil moisture sensors and sprinkler valve controllers to implement plug-and-play technology and proposed architectures of distributed sensor networks for site-specific irrigation automation. Hyun-Joong Kang [4] simulates the performance of sensor node running with low power operation in greenhouse environment to the impact of crop's growth when obstacle exists in inter-node's communication point. They found that different performance depends on the routing protocol. There are different simulation tools for Wireless Sensor Networks: e.g. OPNET, OMNET++, NS-2, J-SIM, SENSE TOSSIM and TYTHON [5, 6]. Here, we use OPNET simulation tools for implementing wireless sensor network. The objective of this paper is to report the design, construction, and testing of a distributed infield WSN, a remote monitoring control, and compare random and grid topologies.

This article is organized in the following way: In Section II, we have a brief overview of WSNs in precision agriculture; in Section III, we present the motivation for current work; in section IV, we identify the proposed methodology for this work; Section V presents the technical setting; In section VI, we discuss the results and challenges in the development of the application and, finally, Section VII conclude the paper.

II. WIRELESS SENSOR NETWORKS IN PRECISION AGRICULTUREE

The Wireless Sensor Networks consists of devices spread in an environment in order to monitor and manage it, based on the specific physical phenomena. Those small devices are called sensors [3, 4]. By using computer resources and appropriate technology, such activities are done automatically. Using WSN in Precision agriculture, we can make proper decision for each zone in the farm. Unlike traditional networks, which assume the user to be a human agent, WSN are centered in the physical environment, specially the data themselves [5]. The sensor nodes interact with the environment on which they are inserted, capturing information about it based on interesting physical phenomena and collaborating among themselves, helping to do tasks that need to be done in this method. In order to achieve these goals, the use of specific algorithms and communication protocols are essential, once the nodes are distributed in the environment and need to self configure the network and adapt themselves to it. These sensors can be programmed to record measures like temperature and humidity. All the data which are collected from the sensors, using a wireless multi-hop routing technology [6], end up in a sink node which transfers them to the end user through wireless network, internet or LAN [6,7], as it is shown in Fig. 1.

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The Precision farming system has the following parts:

- Sensing agricultural parameters.
- Identification of sensing location and data gathering.
- Transferring data from crop field to control station for decision making.
- Actuation and Control decision based on sensed data.

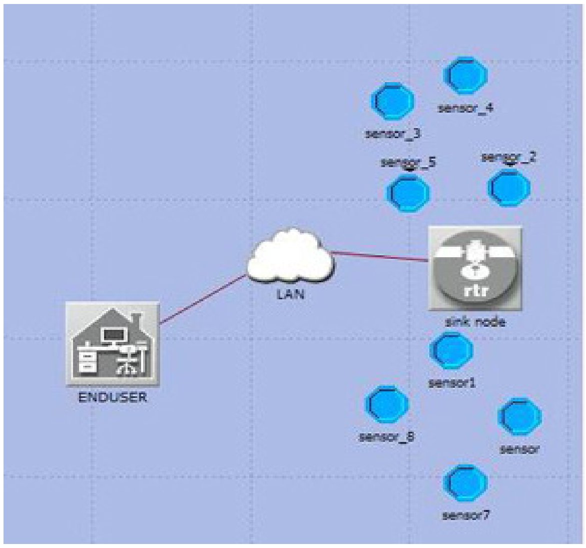

Fig. 1. Wireless Sensor Network

III. MOTIVATION FOR CURRENT WORK

In the past few years, new trends have appeared in the agricultural sector. Precision agriculture concentrates on providing the means for monitoring, determining and managing agricultural practices. It covers a wide range of agricultural involves from daily herd management through horticulture to field crop production [8-10]. It relates as well pre- and post-production aspects of agricultural enterprises. Many topologies for WSNs have been developed but most of them do not take into consideration the limited power resources for sensor nodes. This is a main drawback in most topologies where they should choose the sensing place based on the supposition. More over the use of appropriate topology depending on the field conditions, water control, the optimum quantity of topology and spending less money on agriculture scientists and consulting firms are factors that WSN has a direct impact. Wireless sensors operate on limited power sources. Therefore, their main focus is on power conservation through appropriate optimization of communication and operation management.

IV. THE PROPOSE METHODOLOGY

In this paper, we propose two topologies for precision agriculture. In the first one, each sensor node is placed at the corner of each grid. In the second topology, nodes are placed at the random position. Finally, we compare two models and choose the appropriate topology. The topology should guarantee QoS while taking into consideration the limited power and optimization of communication.

The size of the zones depends on the ability of the agronomist to differentiate them according to measurements. So, there is no rule to define the scale of a zone. Hence, the form of the zones depends on which characteristic the agronomists' measure and form the variability in the zones and it is related to product type [11]. However, generally the zones should be clearly detected. In this case, we consider 4 hectare for both topologies with 24 wireless sensor nodes distributed.

The aforesaid approach is practical for the separation of field in management also, monitoring areas, in order to avoid the node placement in grid placement, random placement. An appropriate number of sensors which will completely cover the areas completely .Therefore, the aspect of data are placed so that a complete picture of the total field is received. For our proposed model, we used 24 WSN under Wi-Fi network with specific properties .The properties are shown in Table I. Moreover, we illustrated properties antenna which we use in Table II.

Simulations are done using the two following network topologies as shown in Figs. 2, 3

- A grid topology of 24 sensors with 16m vertical and horizontal distance each. Moreover, we use 6 access points that is played role as sink node. First, each of sensors communicates with sink node through wireless network (as we mentioned before Wi-Fi network). After that, sink node should transfer real time data to the base station. In addition, we connect each of accesses point to the server using wire and 2 routers.
- A random topology of 24 sensors that is distribution in the felid with unplanned distance among sensors

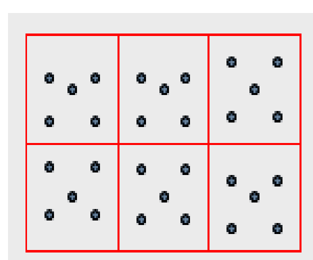

Fig. 2. Grid topology

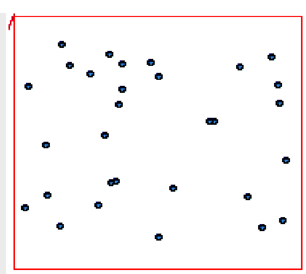

Fig. 3. Random topology

TABLE I. Sensor Properties

SENSOR SPECIFICATION	*Model*	*Protocol*	*Frequency*	*Tx power*	*Sensitivity*	*Range*
	WI-FI	IEEE 802.11b	2.4GHZ	100mw	-20dbm	500m

TABLE II. Antenna Properties

ANTENNA SPECIFICATION	*Type*	*Gain*	*Dimensions*
	Omni directional	5dbi	224*22 mm

The coverage distance for each node depends on the type of node and RF technology. The nodes were not put at the maximum coverage distance because of power efficiency. The medium distance of 10m between sensors which result a high possibility of communication between them (the Signal-to-Noise ratio was above a certain threshold). Clearly there is a trade-off among the number of nodes used (lower cost) and the network strength.

A key feature in the design of the network is to consider factors such as distributing, the absorption and being undermined of the signal that rely each time on the type of the cultivation, the height of leafage as also hillocks and pieces of machinery in the field, and lastly the sources of electric noise such as high voltage cables. Other factors are still the technology of sensors used such as power sensitivity, TX power, the height of antenna and real climatic conditions that surpass in the field.

One disadvantage of the proposed topology is that for specific nodes (access point) used wire for connecting to the server so it's costly

V. TECHNICAL SETTING

Since a variety of topologies for wireless sensor network has been developed and each topology has its own scenario, it is hard to compare all of these topologies. We use OPNET to deal with the challenges of comparing different topologies.

In our research, access point is placed on the middle of each cell of the farm zone as shown in Fig. 4 for grid topology. In this model, sensor nodes which are on the left and right side of the road will sense agriculture parameters and forward those to the base station every 15 minute, which are indicated by red arrows in Fig. 4. In this topology we divided our field to the 6 zones, and 4 sensors are located in each section. Therefore, we have 24 sensors with 16m of vertical and horizontal distance between them.

We use different range of IP addresses for connecting an access point to the routers and base station. In addition, each of sensors has a specific IP for delivering the information to the sink node; hence, monitoring system with this feature is controlled and managed each sensor area with a specific function. Also, in the base station, end-to-end delay for each node is monitored.

We have another topology which is random topology. It has the same setting like grid topology. In this model, sensors and access points are distributed in an unexpected situation as shown in Fig. 5.

Here, for both topologies, we consider the same technical setting for sensors which are shown in table I, II. Number of access point is an important factor in this project; therefore it is given by equation 1. We use this number of access points to cover the whole area. *f* is frequency in MHz and *d* is distance in Km in equation 1. Therefore, FSPL[3] is:

$$FSPL(db)=20log_{10}(20)+20log_{10}(f)+32.45 \qquad (1)$$

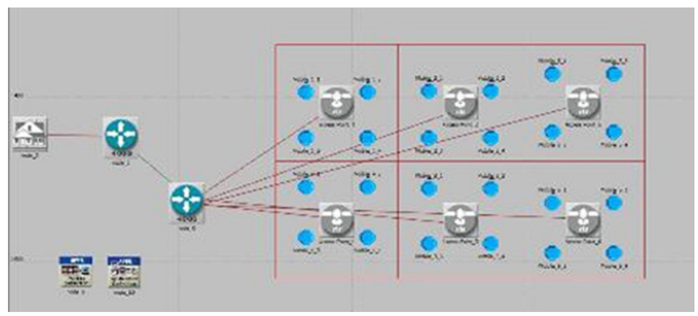

Fig. 4. Grid topology

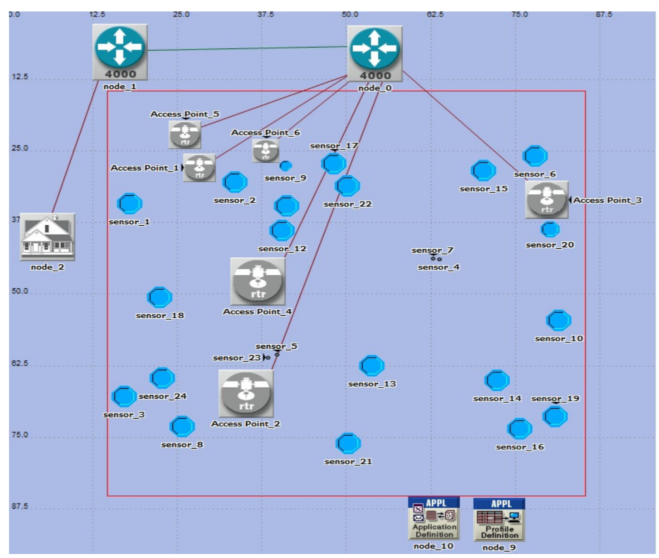

Fig. 5. Random topology

[3] Path Loss in Free Space

VI. SIMULATION RESULTS

We consider a set of performance metrics for comparing different topologies, including *delay, throughput*, and *load*. The simulation time is 300 seconds. Some definitions of the metrics are:

- Throughput: Number of messages are received per second. The throughput of the network is the sum of the throughputs of all the destinations.
- Delay: Time to send a message from source to destination. For any destination, if n packets have arrived, delay for that destination is given by equation 2. Where di is the delay of the ith packet. Network delay is. Averaged by the number of destinations.

$$Delay = \sum_{i=1}^{n} \frac{di}{n} \qquad (2)$$

- Load: Number of packets that can be sent by the network at one time.

Figures 6, 7 and 8 show the results. Delay in grid case is much less than delay in random topology as shown in Fig. 6. We have calculated the average network delay using the simulation for the two cases. It is 0.001sec for the grid and 9sec for the random topology. In grid, delay is decreased by approximately 75%.

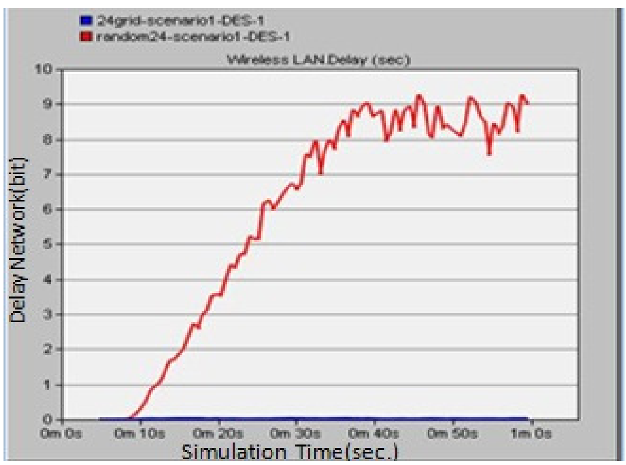

Fig. 6. Delay for both networks

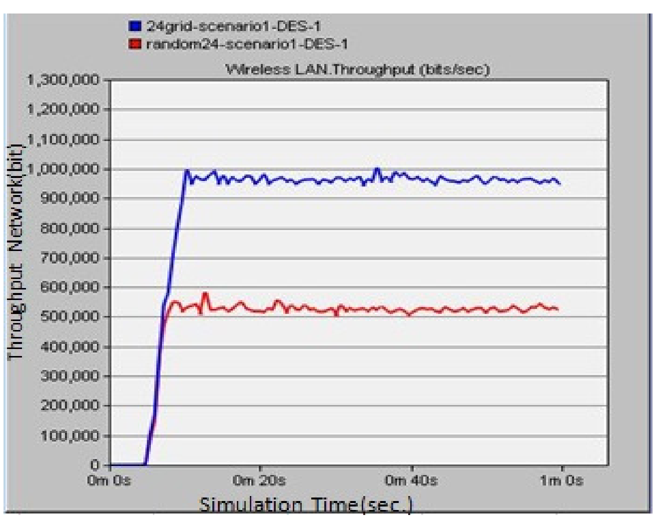

Fig. 7. Throughput for both networks

Random topology throughput is lower than that in grid as shown in Fig. 7, because in grid topology the total packets sent to the destination (implying that we consider 100% delivery rate) are much more than the packets sent by sources in the random topology.

In grid topology, load for a long portion of simulation time is increasing as is shown in Fig. 8. This means that more packets are likely to be delivered to the destination through the network. Approximately after 20 seconds in grid topology, the load is near 85%. On the other hand, in random topology, we observe that not only load is on average constant, but it has converged approximately to 35%. The maximum difference in load measurements in both topologies reaches about 50%.

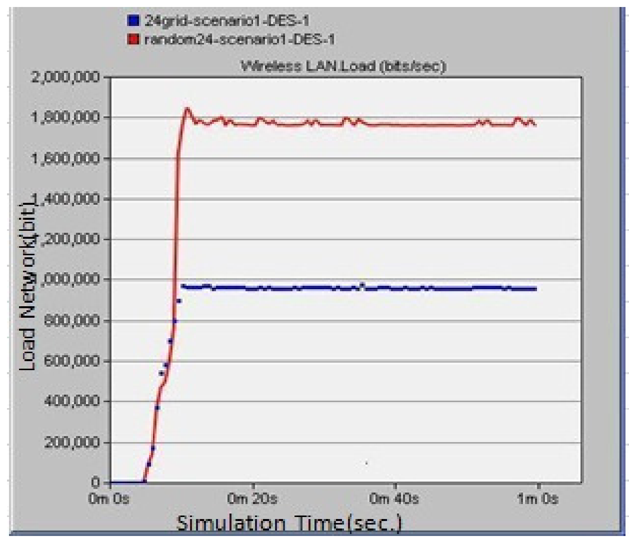

Fig. 8. Load for both networks

VII. CONCLUSIONS

Precision agriculture and WSN applications combine an exciting new area of research that will greatly improve quality in agricultural production, precision irrigation. There are potential applications of Wi-Fi wireless sensor network technology in agricultural systems such as real time field monitoring, automated irrigation control, monitoring, and remote operation of field machinery. In this paper, we proposed two topologies of wireless sensor network for automatic monitoring in precision agriculture. In first topology, each sensor node is placed at the corner of each grid. In the second one, nodes are placed at the random position. These topologies were evaluated using OPNET Modeler. In our model, the sensor nodes collect the data such as water-level, gate position, rainfall and soil moisture. The real-time data is transferred to the sink node via Wi-Fi. The information center stores and processes the data. We use a set of performance metrics for comparing the topologies, including delay, throughput and load.

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