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Performance Analysis of Different WSN Based Systems in Precision Farming

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ABSTRACT

Development in Wireless Sensor Networks (WSNs) has been a boon to Precision Farming (PF) worldwide. Its immense potential has attracted the attention of researchers in recent years. The sensor nodes, forming the basic blocks of WSNs, along with advanced Wireless Technologies (WTs) help in collecting, storing and sharing various sensed agricultural parameters, thereby enabling control over inputs. It thus helps in resource conservation and is economical. This paper discusses some of the practical challenges facing the precise functioning and implementation of the WSNs. It attempts to give an overview of certain existing WSN systems that utilize different Wireless Technologies (Bluetooth (BT), Wi-Fi, Zigbee and RF) to monitor field parameters such as, irrigation, temperature variation, nutrient and moisture content and pH level of soil for wide and short ranges. The systems are then compared to arrive at an efficient and farmer-friendly system for implementation and also to look at specific areas in the systems that need research to enhance efficiency.

Keywords – **Bluetooth, Precision farming, RF, Wi-Fi, Wireless Sensor Networks (WSNs), Zigbee**

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I. INTRODUCTION

Agriculture is unquestionably the largest means of occupation provider in India, majorly in the vast rural areas, contributing a remarkable figure to the Gross Domestic Product (GDP).Hence its slow growth is a major concern. Grandeffortsfor sustainable agriculture have been focused on the development of effective technological practices that allow not only to optimize costs but also to minimize possible negative environmental impacts through appropriate and regulated fertilization and irrigation practices. Popularly termed 'Precision Farming'(PF), it is the latest practice being adopted in several nations across the globe.

Precision Farming is a management concept, which involves observing and responding to variations within a field. Presently, precision farming is about entire farm management with the goal of optimizing returns on inputs while conserving resources. It relies on latest wireless technologies like Wi-Fi, BT, RF, Zigbee, etc., information technology, and geospatial tools. Wireless sensor networks form the basis for the modern precision farming. Mainly consisting of specialized transducers for monitoring and recording conditions at various locations with communication infrastructure, it helps in data collection, monitoring in harshconditions, precise irrigation and fertilizer supply for efficient crop production while reducing cost and assisting farmers in real time data gathering. Commonly monitored parameters for the purpose include temperature, pH, organic content and moisture level of soil, wind direction, concentrations of chemicals and amount of pollutants.

The PF farming system has the following steps:

- Sensing agricultural parameters.
- Recognition of sensing location and data collection.
- Data is transferred from crop field to control station for further action.
- Initiation and Control decision based on the sensed data.[1]

A wireless sensor network with sensor nodes spread throughout the field can collect and impart soil data to the information processing center at regular intervals. All the data that is collected from the sensors using a wireless multi-hop routing technology ends up in a sink node, which transfers them to the user via wireless network, Internet or LAN. This data is used as inputs to the modeling software(s) to determine the required amount of the agricultural inputs (fertilizers, irrigation, etc.) required in various locations and at distinct times in the field [1].

The WSN system requires a unified control unit with a user interface, communication units and routers, power elements and most importantly – the sensors. The Wireless

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sensor network has a large number of sensor nodes, which consist of sensing, processing, transmitting and memory, and power units. Figure 1 depicts the components of the sensor node. It also contains position-finding equipment rarely which is not shown in the figure 1. The basic unit of wireless sensor networks is a sensor node. It further has base stations, communication systems, Internet access and a structure for monitoring hardware and software system. A base station is capable of connecting the sensors to an existing communicating network [2] (wireless) or to the Internet where a user can have access to the reported data.

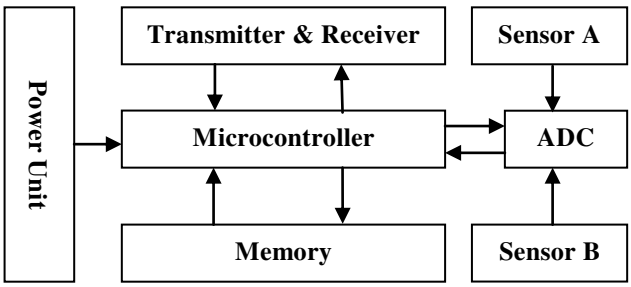

Figure 1: Wireless Sensor Node

An Operating System, Sensor Module, Mobilizing Module, Location and navigation module, Antenna and Communication Module together make the software of a senor node [2].

The objective of this paper is to report some of the WSN systems that along with advanced wireless communication hubs work to serve the purpose of PF. Further, we compare them to analyze and conclude on a system with efficiency for experimenting.

This article is organized in this way: In Section II, various design challenges encountered during implementation are discussed; in section III, we present certain wireless systems that are currently employed in Precision Farming; in section IV, presentation of comparison of the different systems can be seen for several parameters for efficiency analysis; section V we look at some specific areas in the described systems which need research for efficient practical implementation in future, and finally section VI concludes the paper.

II. DESIGN CHALLENGES AND ISSUES

Precision farming includes application of technology on agricultural fields. Though it is considered as an efficient farming, there are certain challenges while implementing precision agriculture. Few challenges are listed below:

- Precision farming technology has the potential to improve production efficiency but adds difficulty to the decision making processes since the information to be processed is large in amount [3].

- Precision farming is capital intensive rather than labor intensive. Due to the cost of technology farmers are reluctant to get into Precision Farming. Specific tools for Precision Farming are costly and the economic benefits are not clear [3].

- The bit rate error (BRE) decreases as signal noise ratio (SNR) increases. This trend is seen in all the wireless technologies but ZIGBEE shows a prompt decrease of BER even for less SNR. This shows that even in the presence of high noise strength almost equal to the signal strength; the system can trace the required signal eliminating the errors. This gives a very robust performance [4].

- The energy issue is unlikely to be solved soon due to slow improvement in developing battery capacity which automatically affects the power supply required for sensor nodes.

- In many cases, sensor data must be delivered within time limits so that appropriate decisions and actions are taken [5].

- Since sensor nodes are not reliable and subject to failure, the background noise distorts the single sensing readings and cause false alarms. In order to avoid this multiple sensors should be used in same area [5].

III. EXISTING WIRELESS SYSTEMS IN PRECISION FARMING

Wireless communication brings significant changes to data networking, making integrated networks a reality. It takes any type of wireless network whose interconnection between nodes is implemented without using cables. Different types of wireless technologies are used, each one having advantages and disadvantages. But, the maximum use is of wireless local area networks (WLANs) based on IEEE standards. However, these networks are not for connecting devices that are small and run on batteries. Some alternative technologies are explored and briefly explained below.

3.1. BLUETOOTH TECHNOLOGY

Bluetooth (IEEE 802.15.1) is considered as one of the suitable technologies for WSNs and especially in cases where the WSN is composed of a relatively less number of sensors and covers small areas, personal area networks (PAN). BT wireless technology is a low-cost, low power; short-range (10-100m) radio technology.

In a Bluetooth based system, the various sensors via a microcontroller are connected to a Bluetooth module. BT consists of the Network layer that provides a packet delivery service, capable of releasing data across the network. Then is the application layer, where information is received and compared. Next layer is the control layer,

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which gathers the agro climate data from the sensors (temperature, pH, and humidity, light) with management models and makes suitable decisions for the control of the agricultural environment. This layer is composed of the Control Unit, which gathers and stores in a local database all the agro climate information collected from the sensors. Thus the information is interfaced to the user. It uses 868 and 915MHz and 2.4GHz radio bands to communicate at 1Mbps between up to seven devices. [6], [7] and [8].

The replacement of regular cable networks can introduce several advantages. Firstly, cable exclusion enables stations' mobility. Another advantage is that the networking becomes faster and easier.

3.2. ZIGBEE TECHNOLOGY

Zigbee (IEEE 802.15.4), a wireless networking standard is used for sensor applications and remote control and can be used in rough radio environments and isolated locations, where comparatively low level of information throughput is needed with low power consumption. Having frequency band of 2.4GHz, 915MHz for North America and 868 MHz for Europe, therefore it works worldwide with 250 kbps data rates. It is highly reliable in congested environments [9] and [10].

The zigbee based sensor node also consists of a microcontroller to function as an end device, router or coordinating sensor node, which is capable of being reprogrammed. As an end device sensor node, it can only interact with the router or coordinator to pass the data from the sensor. The sensor node acts as a router and routes the data from other routers to the coordinator or to other routers, which are closer to the coordinator. The coordinator sets the channel for the network to use. The base station also with the same zigbee module is responsible for data collection from the sensor nodes. It is sent to the user via a RS232 protocol [11].

As the duty cycle is very small, to send and receive messages with low power consumption, two 1.5 V batteries can be used to support for six months to two years. It achieves energy saving effect and provides a rich application space [9].

3.3. WI-FI TECHNOLOGY

Wi-Fi (Wireless Fidelity) is a wireless technology, which uses radio frequency to transmit data via air. Wi-Fi has data rate of 1 mbps to 2mbps and transmits information in the frequency band of 2.4 GHz. It utilizes frequency division multiplexing technique and the range is 40-300 feet [12].

A chosen Wi-Fi module is connected to various sensors in the field with analogue outputs via a multiplexer. The multiplexer channels can be selected based on the General Input/output (GPIO) on the WSN module or only on the GPIO output values. At user-defined intervals, the signals are measured, transferred and recorded into the server on the network. The standard wireless router connects the server to the network. Thus the server can be run on a Wi-Fi enabled system in the field. The system usually takes 3-3.6V DC supply along with two ADC and four primary GPIOs. Triggered measurements of ADCs along with any GPIO values programmed as inputs are transferred to the server. The data of various parameters namely temperature, pressure, humidity, pH etc., is collected by the sensors. Then the sensor nodes send the data to the base station via a sink node. The farmer can access the data through user interface [13].

Also it is user-friendly for an Indian farmer. With moderate cost, serving large number of nodes with the flexibility of mobility, it can be a sought after alternative.

3.4. RF TECHNOLOGY

An **RF module** (radio frequency) is an electronic device used to transmit and receive radio signals between two devices (Sensor nodes). The module interacts with sensor nodes, thus transmitting the sensed parameters (temperature, moisture). An RF module are mostly interfaced with a micro controller and works freely at 433/868/915 MHz frequency and has about 400 m range.

It basically consists of transmitter and receiver .The transmitter, a small PCB assembly is able to transmit and modulate a radio wave. Energy flows as current in conductors, changes to waves to travel in air and reaches receiver to as current to move along conductor. The transmitter circuit is used for low power, low voltage wireless application. The receiver circuit is also a single-chip receiver module. It also uses very low power and voltage levels for functioning. It's sensitive to signals it receives and demodulates it. A LCD attached, helps in conveying field data [14].

However, the entire functioning is controlled by programming microcontrollers at field and central station in a field for transmitter and receiver respectively [14].

The figures shown next summarize the functioning of the various technologies used. Figure 2 for the functioning while figure 3 gives diagrammatic representation of the technologies used.

The comparison table, Table 1 below compares the different systems for various parameters.

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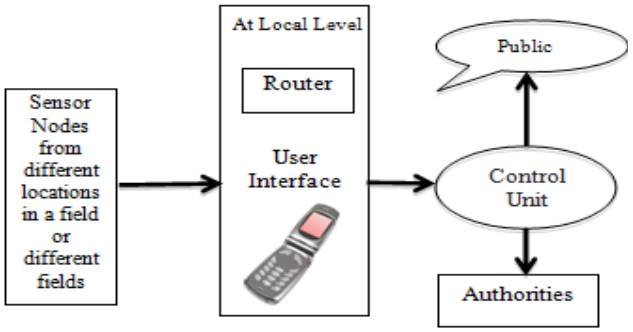

Figure 2: Representation of overall functioning of the system using different wireless technologies

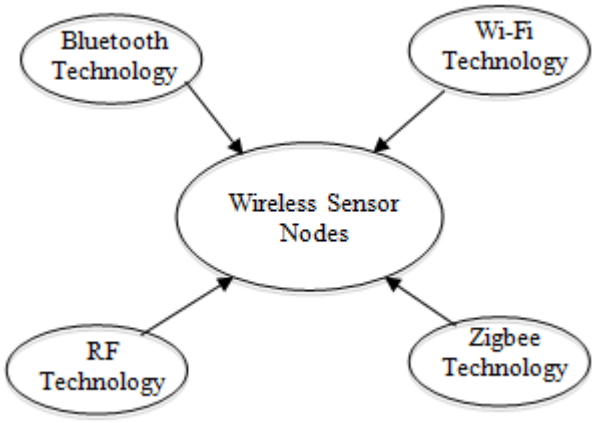

Figure 3: Diagrammatic representation of the wireless technologies

IV. COMPARISON OF THE SYSTEMS

Table 1: Comparison of different Systems used in Precision Farming

System	Technology Used	Sensors Used	Frequency Band	Range (m)	Battery Life	Cost	Power Consumption	Comments
Precision Agriculture Using Zigbee	Zigbee [3]	Temperature, Humidity	868 MHz 902 – 928 MHz 2.4 GHz	50 m	Greater than one year	Low	Low	Parameters are monitored and sent to the base station using zigbee protocol
System for monitoring the agriculture environment	Bluetooth[4]	Temperature, Relative, Humidity, Soil Moisture PH, Light	2.4 GHz	10 m	1 Week	Low	Low	Since its communication range is low, it can be used in greenhouse application due to relative low distance inside the greenhouse.
Crop monitoring system for agriculture using Wi-Fi	Wi-Fi [15]	Temperature, Humidity, Pressure, Soil Moisture, PH	2.4 GHz	100 m	2 – 3 hrs	Low	High	The module allows for relatively easy connection to nodes and communication
Precision Farming using WSN Networks	RF [14]	Temperature, Moisture	315, 433, 868, 915 MHz	100 m	6 – 12 months	Low	Low	Allows monitoring dangerous hazardous unwired or remote areas and locations
Time monitoring system using Zigbee	Zigbee [9]	Temperature, Humidity, Gas	2.4 GHz	100 – 200 m	Greater than one year	Low	Low	It achieves energy saving effect and provides rich application space
Wireless Network for Precision Agriculture using Wi-Fi	Wi-Fi [1]	Water level, Soil moisture (Sensor Nodes collect the information)	2.4 GHz	500 m	1 – 2 hrs	Specific nodes used wire for connecting to the Server is costly	High	The nodes were not put at the maximum coverage distance because of power efficiency

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V. OPEN RESEARCH ISSUES AND FUTURE WORK

Current research mainly focuses on providing full or partial coverage for sensing in order to obtain energy conservation. In this approach, some nodes remain inactive when other nodes work for them. However, large number of sensor nodes is to be employed for reliable data which is again energy demanding. But this needs to be overcome by identifying favorable and unfavorable areas for employing the nodes.

Though the Wi-Fi systems are user-friendly, they do possess certain challenges. Its security system and high power consumption are seen as disadvantages currently. And also its reduction of speed and quality beyond its medium-range is an issue that needs careful look-over. Similarly, Bluetooth systems also have security issues combined with slow data transfer rate, which can be thought of as researching areas.

Optimistically, the shortcomings will be overcome in every respect possible to upgrade the agricultural sector.

VI. CONCLUSION

Precision Farming supports agriculture greatly. This paper mainly makes comparative study of certain WSN based precision farming techniques to analyze them for efficiency. The systems' are briefly described with specifications such as range, bandwidth, etc. Different systems own several advantages with some flaws when real-time functioning is considered. Of the systems compared, Zigbee is seen to be more efficient with low cost, low power consumption and excellent networking ability. The other systems although help serve the purpose, need further research and experimentation in order to be cost-effective and more efficient.

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