Wireless Sensor Network Technology for Agricultural Development: Challenges and Chances in Bangladesh

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Abstract— Bangladesh is preponderantly an agricultural country. Agriculture is the most dominant sector in our country due to its greatest contribution in National GDP and providing employment for a large volume of peoples. Wireless Sensor Networks (WSN) are network that consist of spatially distributed autonomous sensors which collaborate with each other to gather, process and communicate over wireless channel and co-operatively pass their data through the network to a main location (Base Station). Wireless Sensor Networks has become practical and real in developed countries by enormous research and advancement accomplished in Micro Electro-Mechanical System (MEMS) and Very Large Scale Integration (VLSI) technology. These self-organizing, autonomous, highly robust and energy efficient networks can be excellent for monitoring different environmental phenomena. This paper represents an overview on Wireless Sensor Network, different application areas of WSN in agriculture and explores their prospect and challenges in agriculture in context of Bangladesh.

Index Terms— WSN, agriculture, energy efficient, monitoring, remote controlling

1 INTRODUCTION

IN Bangladesh, Agriculture is one of the most ancient activities where latest innovation of science & technology are not usually accepted due to different difficulties. Where agriculture is the main source of our countries economy, there are most necessary requirement is to modernize the conventional agricultural practices for better quality and quantities. All peoples and organizations related to agriculture in Bangladesh are still facing a multifaceted problem and challenges in utilizing and maintaining their resources. Although the causes of inefficient utilization of resources are complex and their solutions are not evident and straightforward, we encourage and motivate the use of Wireless Sensor Networks to deal with those difficulties.

Wireless technologies have been under rapid development during recent few years. It becomes more and more popular day by day in the developed world, even developing countries as they are used for revolution in various segments of human life. Most of the general people feel the strong impact of wireless technologies due to the astonishing growth of cellular phone or mobile phone. In the recent years, an exciting new type of network has emerged, called Wireless Sensor Networks, was originally developed for military monitoring and now a day's reaching all aspects of human lives [1].

Wireless Sensor technologies are still at preamble stage of its development. Applications of Wireless Sensor Networks for agricultural development are still rare. This paper intends to give an overview of available wireless sensor technologies that are applicable for agricultural development and investigate their scope in Bangladesh. In this paper, we introduces wireless sensor network in details, different application of WSN especially in agriculture and investigate their scope & challenges in Bangladesh.

The rest of the paper is organized as follows: in section 2 Wireless Sensor networks, in section 3 Different applications of WSN in developed countries, in section 4 application of WSN in agriculture, in section 5 challenges and Scope of WSN for Agricultural Development in Bangladesh, in section 6 conclusion.

2 WIRELESS SENSOR NETWORK

Wireless sensor networks have been identified as one of the most important technologies for the 21st century. Wireless Sensor Networks are emerging research field of science and Engineering in the world. World famous scientists are trying to introduce WSN to solve such type of problems that traditional technologies could not address. The development of WSN technologies allowing us to find many new applications that could not have been considered before.

2.1 WIRELESS SENSOR NETWORK: EVOLUTION

Sensor Networks were developed by United States (U.S) during the Cold War. It was developed with an aim to detect and track Soviet Submarines in the battle field [2]. Sound Surveillance System (SOSUS), a system of acoustics sensors

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was placed at strategic location on the bottom of the ocean. Around the same time the United States (U.S) also deployed a network of radars for air defense. These sensor networks were wired sensor network, not fully automatic and human operator played an important role in maintaining the network.

In the early 1980's, Wireless Sensor Networks (WSN) was developed by the Defense Advanced Research Projects Agency (DARPA) [2]. These were called Distributed Sensor Networks (DNS) program where many low-cost sensing nodes were spatially distributed and they sensed & processed data collaboratively. Massachusetts Institute of Technology (MIT) started developing a Distributed Sensor Networks (DNS) to track low-flying aircrafts [2]. In collaboration with the Rockwell Science Center, the University of California at Los Angeles proposed the concept of Wireless Integrated Network Sensors (WINS). One out come of the WINS project was the Low Power Wireless Integrated Microsensor (LWIM), produced in 1996 [3]. The Smart Dust project at the University of California at Berkeley focused on the design of extremely small sensor nodes called motes [4]. The Pico Radio project by the Berkeley Wireless Research Center (BWRC) focuses on the development of low-power sensor devices, whose power consumption is so small that they can power themselves from energy sources of the operating environment, such as solar or vibrational energy [5].

While these previous efforts are mostly driven by academic institutions, over the last decade a number of commercial efforts have also appeared by the companies such as Crossbow (www.xbow.com), Sensoria (www.sensoria.com), Worldsens (http://worldsens.citi.insa-lyon.fr), Dust Networks (http://www.dustnetworks.com), and Ember Corporation (http://www. ember. com). These companies provide the opportunity to purchase sensor devices ready for deployment in a variety of application scenarios.

2.2 WIRELESS SENSOR NETWORK: WHAT IT IS?

Wireless Sensor Networks are established by a collection of small sensor nodes distributed spatially to monitor different physical or environmental conditions. Sensing is a technique used to gather information about a physical object or process. An object performing such a sensing task is called a sensor. The Wireless Sensor Network (WSN) is build of nodes: a few to several hundred even thousand nodes are deployed in a network where each node connected to one or several sensor node. The nodes can be stationary or moving. They can be aware of their location or not. They can be homogeneous or not. In Wireless Sensor Network (WSN), many sensors communicate the collected data wirelessly to a centralized processing station because many network applications require hundreds or thousands of sensor nodes, often deployed in remote and inaccessible areas. Therefore, a wireless sensor has not only a sensing component, but also on-board processing, communication, and storage capabilities. A sensor node is often not only responsible for data collection, but also for in-network analysis, correlation, and fusion of its own sensor data and data from other sensor nodes. When many sensors cooperatively monitor large physical environments, they form a wireless sensor network (WSN). Sensor nodes communicate not only with each other but also with a base station (BS) using their wireless radios, allowing them to disseminate their sensor data to remote processing, visualization, analysis, and storage systems.

Figure shows two sensor fields monitoring two different geographic regions and connecting to the internet using their base stations. When the transmission ranges of the radios of all sensor nodes are large enough and the sensors can transmit their data directly to the base station, they can form a star topology where each sensor node communicates directly with the base station using a single hop.

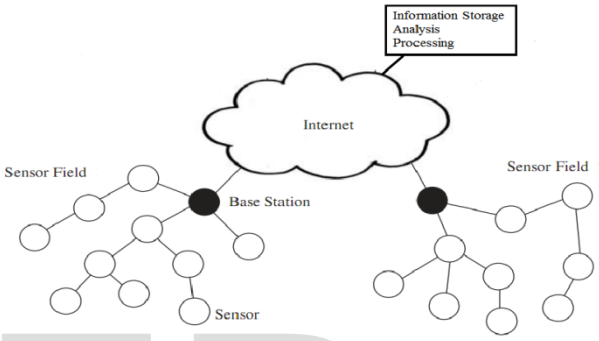

Fig-1: Wireless Sensor Network (WSN).

However, sensor networks often cover large geographic areas and radio transmission power should be kept at a minimum in order to conserve energy. Consequently, multi-hop communication is the more common case for sensor networks. Sensor nodes must not only capture and disseminate their own data, but also serve as relays for other sensor nodes, that is, they must collaborate to propagate sensor data towards the base station (BS).

The wireless sensor nodes are the central element in a wireless sensor network (WSN). The sensing, processing, and communication take place through a sensor node. It stores and executes the communication protocols and the data-processing algorithms. The node consists of sensing, processing, communication, and power subsystems.

2.3 WIRELESS SENSOR NETWORK: WHY?

Wireless nodes are now smaller, tiny and with powerful processing than earlier nodes. Although the most crucial aspect of WSN is energy efficiency, a common technique to manage energy is Dynamic Power Management (DPM) where a node can be moved between different operational modes such as active, idle and asleep. Main advantages of Wireless Sensor Networks are reliability, cost and energy effectiveness, accuracy, flexibility and ease of deployment even in harsh places. The Fundamental characteristics and benefits of Wireless Sensor Networks (WSN) are listed below-

- **Adaptability:** A key characteristic of a WSN is its ability to self-manage, that is, it can adapt to changes in the network, including changes in topology, network size, density, and traffic characteristics.

- **Higher Accuracy in Sensing Task:** Deployment of larger number and variety of sensor nodes provides high accuracy for gathered information.
- **Reliability**: Reliability is a common requirement for most communication networks. In Wireless Sensor Network, reliability is increased by detecting and recovering from transmission errors and collisions (e.g., using acknowledgments and retransmissions).
- **Scalability:** Most wireless sensor networks (WSNs) rely on multi-hop and peer-to-peer communications without centralized coordinators and they can consist of hundreds or thousands of nodes.
- **Operability in harsh environment:** Sensor nodes can be deployed in harsh and inaccessible environment that makes the sensor network more effective.
- **Coverage area:** Scalable and efficient sensor network could span a greater geographic area without any adverse impact on the overall network throughputs, performances and cost.
- **Minimum human interaction:** Minimum human interaction make possible of having less interruption of the system.
- **Connectivity:** Multiple sensor networks can be connected through sink node, even with wired networks. The clustering of networks enables each individual network to focus on specific areas or events and share only relevant information.

3 APPLICATION AREAS OF WSN

The applications of wireless sensor network are varied. Wireless sensor networks are used in the applications that require monitoring, tracking and controlling any event or occurrences. In an application nodes are deployed in a region to collect information through sensor nodes. In developed countries, the wireless sensor networks are used in different areas. Theses application areas are listed below-

- Environmental Observation and Forecasting
- Disaster Prevention
- Structure Health Monitoring
- Habitat Monitoring
- Area monitoring
- Environmental monitoring
- Greenhouse monitoring
- Landslide detection
- Industrial monitoring
- Machine health monitoring
- Water/Wastewater monitoring
- Landfill ground well level monitoring and pump counter
- Agriculture
- Fleet monitoring
- Smart aeration

4. APPLICATION OF WSN IN AGRICULTURE

Agriculture is an interesting area where wireless sensor networks motivated a large number of researchers. Deployment of wireless sensors and sensor networks in agriculture and is still at the beginning stage. Modern agricultural management relies strongly on many different sensing methodologies to provide accurate information on crop, soil, climate, and environmental conditions. Almost every sensor and sensing technique may find an application in agriculture. There are a number of available sensors currently using in agriculture [6][7]. They are- Humidity sensor, Soil moisture sensor, Temperature sensor, Barometer sensor, Capacitance sensor, Electrical / Electromagnetic Sensor, Bio sensor etc.

4.1 ENVIRONMENTAL MONITORING

In spite of the rapid development of computer technology, weather data and geo-referenced water quality data still depend on stationary sensors and data loggers, pencils and paper notebooks, which are labor-intensive and susceptible to recording errors during transcription [8].

The Discovery Channel (2003) reported an application of a wireless sensor network in a vineyard in BC, Canada [9]. Sixty five motes were installed in a 1-acre land to remotely report temperature, moisture and sunlight intensity to a central PC every 5 min. The owner could easily monitor each area of the vineyard in real-time to avoid frost, manage irrigation, determine fertilizer applications and arrange harvest schedule.

A solar-powered wireless sensor network was reported by Crossbow Technology Inc. (2004) to provide weather information in fields. A remote application server relayed data from the sensor network to local users via a WLAN and remote users via cellular network and the Internet [9].

4.2 PRECISION AGRICULTURE

Precision agriculture is the art and science of using advanced technology to enhance crop production [10]. Wireless sensor network is a major technology that drives the development of precision agriculture. Remote sensing can direct the farmer's efforts toward crop zones in need of water, nutrients or other attention. This information can increase farming efficiency providing the farmer receives it in a timely manner and has the capacity to act on it. Various kinds of sensors can be integrated into the sensor node, therefore, the conditions of the crops and the soil, including temperature, humidity, illumination, crop disease, pests and etc can be monitored remotely and in real-time. With the determination of soil conditions and plant development, these technologies can lower the production cost by fine tuning seeding, fertilizer,

chemical and water use, and potentially increasing production and lowering costs.

A lit of research work have been done in precision agriculture. Wireless sensors have been used in precision agriculture to assist in (1) Spatial data collection, (2) Precision irrigation (3) Variable-rate technology and (4) Supplying data to farmers [9].

4.3 SPATIAL DATA COLLECTION

A mobile field data acquisition system was developed by Gomide to collect data for crop management and spatial-variability studies [11]. The system consisted of a data collection vehicle, a manager vehicle and data acquisition and control systems on farm machines. The system was able to conduct local field survey and to collect data of soil water availability, soil compaction, soil fertility, biomass yield, leaf area index, leaf temperature, leaf chlorophyll content, plant water status, local climate data, insect-disease-weed infestation, grain yield etc.

Lee et al. developed a silage yield mapping system, which included a GPS, load cells, a moisture sensor and a Bluetooth wireless communication module [12].

Mahan and Wanjura cooperated with a private company to develop a wireless, infrared thermometer system for in-field data collection [13] . The system consisted of infrared sensors, programmable logic controllers and low power radio transceivers to collect data in the field and transmit it to a remote receiver outside the field.

4.4 PRECISION IRRIGATION

Damas et al. developed and tested a distributed, remotely controlled, automatic irrigation system to control a 1500 ha irrigated area in Spain [14]. The irrigation was performed by dividing the total land into seven sub-regions where sub-region was monitored and controlled by a control sector. The seven control sectors communicated to each other and with a central control through a WLAN network. Field tests showed 30–60% saving in water usage.

4.5 VARIABLE RATE TECHNOLOGY

Cugati et al. developed an automated fertilizer applicator for tree crops. The system consisted of an input module for GPS and real-time sensor data acquisition, a decision module for calculating the optimal quantity and spread pattern for a fertilizer, and an output module to regulate the fertilizer application rate. Data communications among the modules were established using a Bluetooth network [15].

4.6 SUPPLYING DATA TO FARMERS

A web server developed by Jensen et al. provided information on pest and disease infestation and weather forecasts [16]. Farmers can download the information directly via Internet and use them for operation scheduling.

USDA conducted a research in Mississippi to develop a high-speed wireless networking system to help farmers download aerial images via WLAN to their PCs, laptops or PDAs. The images were mainly used for precision farming applications.

5 CHALLENGES & CHANCES IN BANGLADESH

Bangladesh is a developing agricultural country where a large volume of people depends upon agriculture. Wireless sensor networks are in developing stage in developed countries like USA, Canada, Germany, Spain, UK etc. and a lot of research work have been continuing perspective of those countries. In case of Bangladesh, any comprehensive study did not take place to determine the effectiveness and prospect of wireless sensor networks in different agricultural sector. Agriculture sector in Bangladesh are facing varieties types of challenges in utilizing and maintaining resources while the cause of inefficient utilization are complex and their remedies are not easy. Therefore, here wireless sensor networks can be a good solution. In developed countries, WSN's are using to increase productivity and lowering the production cost.

Although the cost for wireless sensor products would decline sharply (fall 50% every 18 month, Crossbow Technology Inc., 2004), it is still costly for Bangladesh economy. Lack of experienced staff for design, deployment and troubleshooting is great challenge for Bangladesh.

6 CONCLUSION

In this paper, we presented wireless sensor network as emerging technology for agricultural development in developed countries that can help in monitoring, controlling and maintaining. We present here different types of application areas where sensor networks could be helpful for agricultural development in developed countries. Bangladesh as a developing country may use it but it will take some time. Although any the research work and practical implementations are yet not to be developed, we expect essential progress from the research community in the near future.

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