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Wireless Sensor Network Applications: A Study in Environment Monitoring System

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Abstract

Development in the technology of sensor such as Micro Electro Mechanical Systems (MEMS), wireless communications, embedded systems, distributed processing and wireless sensor applications have contributed a large transformation in Wireless Sensor Network (WSN) recently. It assists and improves work performance both in the field of industry and our daily life. Wireless Sensor Network has been widely used in many areas especially for surveillance and monitoring in agriculture and habitat monitoring. Environment monitoring has become an important field of control and protection, providing real-time system and control communication with the physical world. An intelligent and smart Wireless Sensor Network system can gather and process a large amount of data from the beginning of the monitoring and manage air quality, the conditions of traffic, to weather situations. In this paper, we discuss and review wireless sensor network applications for environmental monitoring. In order to implement a good monitoring system, there are several requirements to be followed. From the studies, it has been proved to be an alternative way to replace the conventional method that uses men force to monitor the environment. It is also proven that these approaches can improve the system performance, provide a convenient and efficient method and can also fulfill functional requirements.

Keywords: Wireless Sensor Network; Environment Monitoring; Monitoring Applications.

1. Introduction

Recent technologies in wireless communications and electronics have brought the vision of Wireless Sensor Network (WSN) into reality which have increased the growth of low cost, low power and multi-functional sensors that are small in size and can communicate in short range. Each node consists of microcontrollers, memory and transceiver. The microcontrollers are used to execute task, data processing and assist the functionality of other components in the sensor node. For the memory, it is mainly used for data storage while the transceiver acts from the combination of transmitter and receiver functions [1].

Natural phenomena data such as temperature, light, sound and pressure are collected by sensors and then transmitted to a server. These battery powered nodes are used to monitor and control the physical environment from remote locations. In the past few years, the applications of Wireless Sensor Network have been widely used and applied in medical, military, industrial, agricultural and environmental monitoring.

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Fig 1. shows the Wireless Sensor Network architecture that is applied in environmental monitoring which contains sensor nodes, user and sink node. Sensor nodes will communicate with each other and transmit the processed data to sink node over a wireless communication. Sink node collects data from all the nodes, and transmits the analyzed data to user via Internet [2].

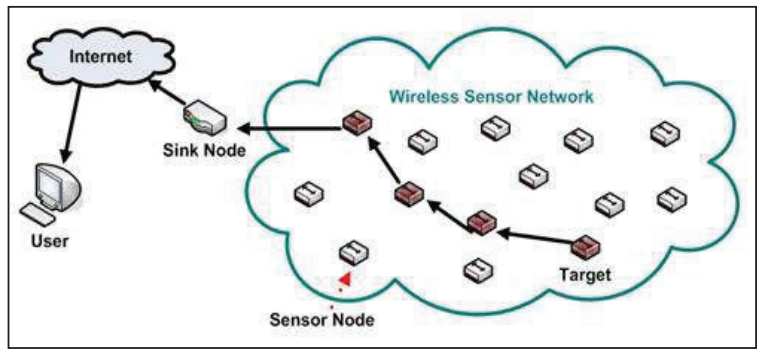

Fig. 1. Wireless Sensor Network Architecture

For the past few years, Wireless Sensor Network has been applied in various fields and mostly in environment monitoring applications. Environmental monitoring is the main autonomy which may contribute large effects. The unstable weather conditions recently demonstrated how important a deep understanding of our surroundings and its development is for human being.

This paper discusses the application study of Wireless Sensor Network in environmental monitoring. The rest of this paper is divided into Environmental Monitoring System, Environmental Monitoring System Applications and Conclusion.

2. Environment Monitoring System

Environmental monitoring has been an important part of Wireless Sensor Network applications. It grows widely along with the development of recent technology. In general, environmental monitoring system controls and monitors environment parameters such as temperature, humidity, light and pressure.

There are several studies that focus in environmental monitoring applications [4][5]. Some researchers implement the fault tolerant and studies the tradeoff between tool expense and lifetime of sensor network [6] to make sure the fault tolerance is in the three dimensional settings.[7] and [8] developed multi hop communication applications, which means the data of the temperature and humidity will be transmitted to the neighbour node and then sent to the end user PC. The environmental parameter data measurement will display the result using Java [3] and the data are interpreted into a graph and table.

Thus, it is necessary to understand the requirements for the development of monitoring applications [9].

2.1 Autonomy

It is compulsory to make sure the battery used is able to function properly throughout the deployment because the radio transceiver is a solid energy consumer and the network must be energy-wise.

2.2 Reliability

Simple handling and predictable operations are needed in order to avoid unexpected crashes system. Besides, maintenance by any person should be avoided because the end users may lack the knowledge on networking and also the changes on the area of interest that often happens while transmitting the packet data. Therefore, it is important to achieve reliability in order to prevent packet loss during bad weather conditions.

2.3 Robustness

The network has to be robust to encounter problems such as hardware failure and poor signal connectivity. For example, the effect of humidity can bring short circuit problem and lead to system reboot.

2.4 Flexibility

User must be able to add, move or change stations in any time depending on the requirement of stations. For example, the current location of the stations may be out of range for the nodes to transmit signal, or the user may want to add new stations in order to improve the nodes point of interest.

Therefore, these requirements are essential when deploying a network in order to implement a good and stable monitoring system.

3. Environment Monitoring System Applications

Recently, the development of environmental monitoring system has been applied in many applications in order to assist people in their job and reduce cost and time. The applications of environmental monitoring have grown rapidly in agricultural monitoring, habitat monitoring, indoor monitoring, greenhouse monitoring, climate monitoring and forest monitoring. It is a good effort and brings advantage because the community has realized the importance of the wireless sensor network technologies in their life.

3.1 Agricultural Monitoring

Agricultural monitoring always focuses mostly on farming area. Some studies define animal monitoring as animal tracking [10] but the concept is the same. There are methodologies to be implemented in order to get through each phases well-defined for the entire life cycle [11]. The interaction between animals and human has been developed and recognize for decades. The contribution of animals love, true-hearted and continuity live can provide positive impact on human physical and mental [12][13].

However, nowadays many animals lack proper treatment and there are also cases where these animals' diseases are not detected. Therefore, it is important to have a monitoring system to monitor animal behaviour and produce a report regarding their health or behaviour in real-time system.

There are many identification methods in monitoring animal health, but some of them either fail or lacking in and efficiency and also not user-friendly. The design of RFID-based Mobile Monitoring System (RFID-MMS) [14] helps users control animal behaviour and movement.

[15] and [16] proposed tracking collars for wild animal monitoring. It will monitor the habitat, pattern of movement and animal behaviour. Wild lynxes or canines are used as the target animals. The sensor nodes built around the collars will collect the position of GPS and data of multimodal sensor, distribute via the system to the client. From tests done, it shows that the range of signal communication can be achieved from 200 - 250 metres and this should be in consideration in order to design a self-sustainable system which is more efficiency in the future.

[17] build an agricultural environment monitoring system which includes the sensor nodes design hardware and software development which consists of the software flowchart. From the test conducted, the system proved to have consumed low power but provides high reliability, which can control real time monitoring for unprotected agricultural and environmental monitoring.

Monitoring system for poultry also contributes a big advantage to users especially farmers. [18] proposed and developed a poultry monitoring system which is web based application. They use Crossbow's TelosB motes that can integrate with the sensors to measure the temperature and humidity of the chicken. At the end of the study, they obtain maximum distance of signal range up to 40 meter with 5% packet loss tolerable. From the result, they have concluded that the system is capable to detect the environment anomalies in the chicken farm. This type of monitoring is not only applied for poultry, but also for cattle monitoring [19] [20].

3.2 Habitat Monitoring

Habitat monitoring is one of the essential parts in environmental monitoring. Habitat means a place in which an animal or plant naturally grows or lives. Therefore, habitat monitoring is important to make sure their species autonomies and prevent any ecological disturbance for animals and plants. Pollution can cause negative impact to health and ecological balance. Therefore, it is important to manage a system that can monitor pollution so that it is under controlled. [21] develop a web-based graphical user interface to manage the data of pollution efficiently . The sensor nodes are used to read current sensor reading. At the end of the study, they manage to improve the performance of the sensors technology by gaining a stable communication even though the average lifetime of the sensors has declined due to the requirement of latency.

In [22], they propose a system architecture for seabird nesting and behaviour monitoring. Instead of performing their research physically, by using the sensor nodes, now they are allowed to collect data online without disturbing the birds' life and routine. From this study, the guidelines of habitat monitoring kit are created for the usage of other researchers and scientists in other fields.

There are also studies that present practical issues in the integration of sensors, actual power consumption rates and develop a practical hierarchical routing methodology. In order to get real-time information, it is impossible for people to collect the data at remote place. Thus, a real-time monitoring for unprotected habitat environmental monitoring are developed by [23]. They measure the environment temperature and compare it with the real temperature. This improves the reliability and accuracy of the monitoring system.

Furthermore, [24] present an application for water quality monitoring. It is built to monitor hardware and the visualization of data and then analyze the data using expert knowledge to perform auto control. This will ensure the quality level of the water. From the deployment results, it is proven to be a user-friendly system since it can send message to the user regarding unpredictable events that occur.

3.3 Indoor Living Monitoring

Sensor technologies for security in living monitoring have become one of the main options for people for safety indoor environment. It has provided many benefits to the user in terms of security. [25] implemented wireless sensor network for security system using Bluetooth technology. This system consists of relay nodes, control nodes and a control system that can be placed in a room in a building. The nodes are composed of a Bluetooth module, an RF daughter board, one UART port and a 4-bit on-off switch to emulate external inputs. When certain events happen, such as an intruder entering a security area illegally, the sensor and relay nodes will detect the events and report to the control nodes. Then, control nodes send the report to local security control system. From there, it replies ACK message to the corresponding nodes. In the end, they manage to develop applications program which can integrate the Bluetooth module with the HCI interface and also used tree topologies for network configuration and routing.

Furthermore, wireless home security system is also designed [26] to detect any intruder in the house. It uses motion sensor as the sensor node. When the motion sensor detects an intruder, it sends a report to the end node. The end node is linked with the computer at RS232 serial port, while the computer acts as user interface (UI) between user and system, while integrating the data with the user mobile phone too. After seconds, user will receive the information via short messaging system (SMS).

[27] design a detect intruder motion by using TMote Sky Platform as the sensor nodes. Unfortunately, during the development stage, many problems occur. The program cannot be compiled into the sensor and in the end, it reached the end of life. Therefore they have to analyze and recommend an alternative way for future work using other sensor modules such as Sun Small Programmable Object Technology (SunSPOT), ZigBee Technology and Sentilla. For power supply, they recommend the use of solar energy or rechargeable batteries rather than a disposable battery to save the environment.

There are also studies on fire detection in buildings [28] . The system provides real-time monitoring and alarm in the presence of fire, and also informs the exact location of that fire. It also distributes directions by continuously collecting, analyzing, and keeping real time information.

3.4 *Greenhouse Monitoring*

The greenhouse effect occurs when solar radiation which is sun heat, is trapped by the gases in the earth's atmosphere and reflected back from the earth. Thus, it will heat the surface of earth and leads to global warming. Therefore, greenhouse monitoring system is important to ensure the stabilization of the environment. [29] develop greenhouse monitoring system using TinyOS as the based platform to measure and monitor environmental parameters including temperature, light and humidity. The sensor module used is SHT 15 and photovaristor as the light sensor while nesC as the programming language. The system collects, sends and controls the parameters information automatically and it is proven that the performance of the system is efficient as the user can colllect high precision data of the environment without any disturbance.

The implementation of greenhouse environment monitoring based on ZigBee wireless sensor network in [30] use oretical analysis and experimental test method to ensure system efficiency. It collects the humidity, temperature and carbon dioxide concentration which are the parameters of greenhouse environmental parameters, and demonstrate the nodes and network coordinator communications, perform network stabilization, and compliance between theoretical data and real situations. The system is proven to be robust, reliable, and easy for user installation. The same studies in [31] implements wireless sensor network, ZigBee that can measure the temperature and humidity of the greenhouse. They manage to design low

power consumption monitoring system by enhancing the stability of the system and extending sensor node working time.

Greenhouse monitoring system can also be web-based system (remote system) [32] to allow user access, control and monitor of greenhouse laboratory using Internet connection. The user, which are the students, manage to build their learning skills and improve their practical skills to develop and control the simulator laboratory as they can easily access to the system from their house. The system hardware is made up of several modules which are the essential part of the system such as the sensor board, processor board and console monitoring while the Sun SPOT devices are used as their software platforms for monitoring the temperature and measuring the light. The system gives benefits to the user as it can be accessed and controlled from everywhere using only web browser and it is also high reliable because it can submit report from the controlled objects.

3.5 *Climate Monitoring*

The climate change of the world nowadays have brought many effects such as the breaking of sea ice, increasing in sea water level, heat waves, glasier melting, lake temperature warming, and many more. Thus, in an effort to control and monitor the climate change, [33] develop a monitoring system that manages and keeps data in real time and focuses on the processing of spatiotemporal query. They are using spatial and existing temporal approach to assist spatiotemporal queries and keep sensor data and build a system for environmental monitoring sensor network. The incoming data is kept as a segment and labelled with timestamp if changes occur in the value of item.

The real-time data collected is displayed and the value of the segment is modified or new tuple is inserted to show the updated value after comparing the original values with the latest value in the database. They manipulate the segment-based method to keep the data stream and decrease the saved record without any data loss. From the query result, the accuracy of the system is improved and the method used can reduce handling cost.

3.6 Forest Monitoring

Forests are important sources for biodiversity and ecological balance. They provide many benefits and it is the main functions for water and soil conservation, genetic resources for plant and animal, and also source of wood supply and other forest goods. However, recently the green forest environment has been interrupted by non ethical activities such as illegal logging and also country development activities that decrease the benefits of the forest contribution.

Thus, in order to ensure long term forest autonomy, it is important to implement a monitoring system that is responsible in providing effective monitoring for forest environment [34]. Several studies have highlighted forest monitoring system [35][36]. Rather than using disposable batteries as power supplies,[37] use node solar power system and lithium-ion battery for power continuity and introduce the regulator control of the system method and design of software system briefly. Their system can improve the lithium-ion battery life to ensure business continuity of system. But for the implementation of solar power system, it still needs to redo the experimentation on the operation of charge and discharge control to make sure the control and estimation of battery power accuracy fulfil the system requirements.

Forest monitoring is not limited to environmental issues only, but it also includes fire monitoring and detection in forests [38][39][40][41]. We know that fire forest can lead to environmental degradable. Therefore, based on this awareness, [42] develop a framework on forest monitoring and fire detection which discovers sensor nodes deployment approach, an architecture for fire detection sensor network, interaction protocol of intra-cluster and inter-cluster. They develop a simulator to perform simulation tests in order to examine the proposed system protocols and components. In the end, their system manages to provide effective and efficient operation that conserve less energy without disturbing the rapid reaction capability.

In other studies, [43] proposed a fire detection system that uses a wireless local area network (WLAN) together with sensor node technology. The system set in wireless mesh network uses multi-sensor nodes with IP-based cameras to detect the presence of fire. When a fire is discovered by the nodes, the sensor alarm propagate via wireless network to a central server. The closest wireless camera to the multisensor is selected by the central server, and it transmits a message to it to retrieve real-time figures from the area. The most important benefits from this study is that it integrate sensory data with images.

4. Conclusion

This paper reviews the wireless sensor network applications which focus mainly on the environmental monitoring system. These systems has low power consumption, low cost and is a convenient way to control real-time monitoring for

unprotected agriculture and habitat. Moreover, it can also be applied to indoor living monitoring, greenhouse monitoring, climate monitoring and forest monitoring. These approaches have been proved to be an alternative way to replace the conventional method that use men force to monitor the environment and improves the performance, robustness, and provides efficiency in the monitoring system.

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