International Journal of Advanced Computer Research (ISSN (print): 2249-7277 ISSN (online): 2277-7970)
Volume-3 Number-2 Issue-10 June-2013

Monitoring Greenhouse using Wireless Sensor Network

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Abstract

Recent advances in science and technology have been led to facilitate monitoring the environment, collecting data, processing the sensed data, threshold-decision making process and lastly performing of suitable actions by using of distributed wireless sensor networks and actor networks. Wireless sensor actor networks (WSAN) is a combination of at least one coordinator node with sensors and actor nodes that communicate wirelessly to perform some specified tasks of sensing, monitoring and actuation. This paper summarizes an idea that can be carried out to provide an efficient control mechanism of microclimate into greenhouses through the implementation of an infrastructure of Wireless Sensors Network to control environmental parameters.

Keywords

Wireless sensor actor network; Agriculture applications; greenhouse monitoring and control; remote sensing.

I. Introduction

Agriculture has been always considered in Ecuador and many other countries as one of the most important productive sectors. Traditionally, agriculture has used manual methods to carry out the production process. However, technology is advancing and today it is possible to have mechanisms and tools for automizing certain processes in order to achieve greater efficiency in managing. Due this fact, producers who want to reach a higher level of competitiveness in their productions should consider the use of technological support tools to complement their traditional production methodsRecent developments in the field of wireless sensor actor networks as well as the smaller size sensor and actor nodes have facilitated precision agriculture to emerge.

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Precision agriculture concentrates in providing the means for harvest information, work management and growth information. Also, agricultural productivity enhancement is in advance progressing through introducing sensor networks technologies combined with actor networks to monitor and control agriculture applications. The environment monitoring and control of greenhouses is of crucial aspect for enhancing the productivity and preventing diseases in the crops. There are many researches being carried to adapt the new technology of wireless sensor network (WSN) to agriculture fields.

Greenhouse monitoring and control based on a TINI embedded Web server unit which collect data and routes it from local sensor/actuator networks to a base station has been studied and done by the researcherStipanicev [2].Also, Zhou et al has introduced an architecture and application of a ZigBee; network combined with event-based control techniques [3].The environment of a greenhouse having a WSN has been monitored by Ahonen [4].

The WSAN integrates wireless communication embedded computation, sensor and micro electro-mechanical system (MEMS) that has have gained increasing attention during recent years. The MEMS technology facilities the development of smart WSAN effectively. Those sensors/actor nodes have limited resources in terms of power, processing and computing, also the size must be small as possible so that those nodes can provide with many particular applications. The main function of those sensors is to sense the environment, measure and make use of the decision making unit for actuating processes. The automated and wireless interaction with the physical world using sensors nodes that sense the data of the environment and a group of actor nodes which can be responsible of decision making is known as a wireless sensor actor network (WASN). WSAN provides suitable actions which affects the environment under supervision. Fig. 1 shows a typical WSAN architecture [6]. Sensor nodes and actor nodes that communicate wirelessly with the sink node or the main node gathers the data by sensor nodes and then sends to the main node. Main node will then evaluate and analyse the data received then infers a suitable action to be taken. Actor nodes wait for the action commands to be sent by the main node. Actor nodes connected to devices that perform

adjusting to the environment under vision. Gateway can be used to connect the WSAN with the WSAN based agriculture applications. Afterwards, many proposed agricultural applications of WSAN have been mentioned in Section 6. The relevant applications have been discussed in detail in Section 7. Finally, Section 8 concludes the paper.

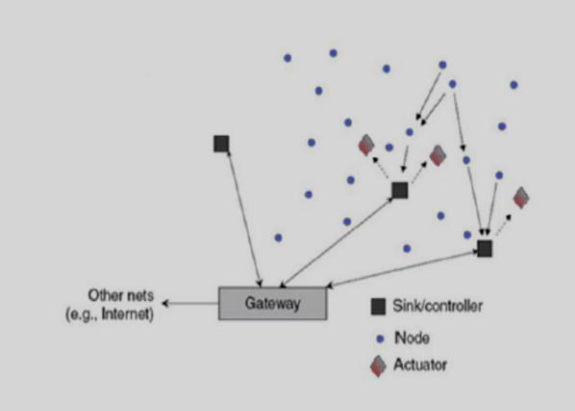

Figure 1: WSAN Architecture

II. Main Concepts ofWSAN

WSAN nodes has different functions like some of the nodes working as a sensing nodes while others working as an actuator nodes. Almost the sensing nodes are greater in number than actuators nodes. The information flow through the network coming out from sensor nodes to main node and from the main node to the sensor or actuator nodes. The network topology protocol must maintain many-one, one-many or one-one links between nodes and their administration node. Fig. 2 depicts the single and multi-hop sink based WSAN proposed architectures.

Nodes of WSANs continuously perform sensing and acting tasks, respectively. Sensors are low of power, small volume and low cost devices with mediocre sensing, processing, and transceiver capabilities. Actors can be either identical to sensor nodes with actuation interface for other external devices, or can be as a resource rich nodes in terms of better processing capabilities with wide coverage area of transmission and longer battery life[7][8]. Simply, actuators are devices that can be used to control different components in a system. According to the type of the application and type of sensors, actuators can be embedded within the sensor node. Most of current application uses external circuitry for actuation with proper interfacing to node hardware. Actors used to actuate different devices such as heating, humidifier, and lighting and also may tunes sensor parameters, or adjust and monitor the power consumption and resources within the node. The sensor node maybe equipped with a variety of sensors to measure the properties of the environment. It is preferable to use sensors of type digital to be matched and eased to interface within the nodes hardware. The deployment of sensor nodes within scattered area and mostly difficult to access locations, lead to use of wireless communication systems to transfer the data between sensor nodes and the base station. As the critical problem of sensor node is the power resource, solar panels can be used as a secondary power supply[9]. Harvesting power from the environment depends on the environment that the sensor node had been deployed with [10]. WSAN whichconsist of a number of nodes that may be deployed in a static or in mobility manner in order to monitor/control the region. WSAN for agricultural application will assist in monitoring and modification of parameters that affects the crops under supervision; it is also to prevent diseases that arise when some parameter diverts from its local settings values such as temperature or relative humidity which causes many diseases of crops. For greenhouse application, WSAN is a typical solution of crops monitoring and control of environment inside the house. Because of the shield of the house, the moisture of soil, temperature, relative humidity and others parameters can be sensed easily and forwards it to the main sink node, which processes these data and sends actuating commands to actor nodes that actuate adjusting devices like humidifier, heater, fan system and door or windows.

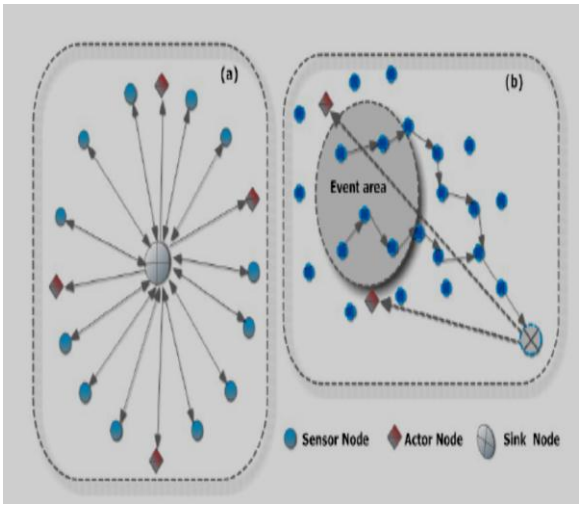

Figure 2. (a): Sink Based WSAN Topology, (b) Multi Hop Sink Based WSAN Topology

III. Agricultural WSAN Architecture (AG-WSAN)

Fig. 2 depicts the fundamental elements of WSAN of sensor and actuator nodes which communicate wirelessly with their coordinator node. Usually, the coordinator nodes and even the actor nodes are more complex devices than sensor nodes, therefore the cost and the size of these nodes is a relevant issue when designing a WSAN and must be as low as possible. Careful attention is needed for sensor selection because of its importance in measuring and controlling the environment which affects crop growth in practical greenhouse cultivation. It is important to select sensors which can withstand the high temperatures and high humidity of the greenhouse environment and have high sensitivity and reliability within a suitable range for crop cultivation. Fig. 3 shows the main blocks of the WSAN based agriculture applications. It consist mainly of four groups, the sensor group, which is responsible of sensing the environment and forward the data to the main node, the main node , which acts as a bridge between the groups , it receives and forwards the data from the sensor to the management group and from management group to the actuator group. Management group contains a database, Webpages and a Server. The gathered data will be analysed and stored within the database for monitoring and further statistical analysis. Web pages used as a source for the monitoring group devices that contained in the management group. While the PC server used for decision making and controlling of the actor nodes, it also serves as a main controller node and as Server for the monitoring group. The monitoring group that uses terminals for remote monitoring. It is connected to the management group through internet. All the groups communicate wirelessly.

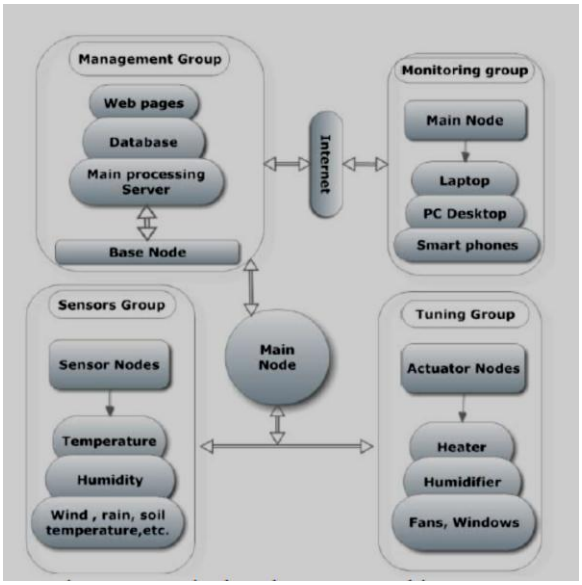

Figure 3: Agricultural WSAN Architecture

One of the most important parameter with WSANs is the life time, the network must adapt a good strategies for minimizing the overall power consumption especially with sensor nodes that works within limited power supply. Thus, will enable the network to work for long time and reduces the cost to maintain nodes with new power resources? Fig. 4 depicts the structure of senor/actuator node. All the node tasks managed by the microcontroller, sensors which gathers data of the environment, then forwards the collected data to the transceiver unit to be sent wirelessly to the main node. The transceiver unit can be in ON or OFF status depending on controller decision. Power supply can be mainly the battery and can be combined with solar panel as a recharging source of the batteries. The overall nodes must have the mode of sleeping and wake up to sustain the life of the network.

IV. AG-WSAN Design Parameters

Current studies surveys shows that it is not fully integrating all the factors driving the design of sensor actor networks, while almost, all studies focus on optimizing one or more issues at a time [6]. The main features of a WSAN that must be considered when designing a network are:

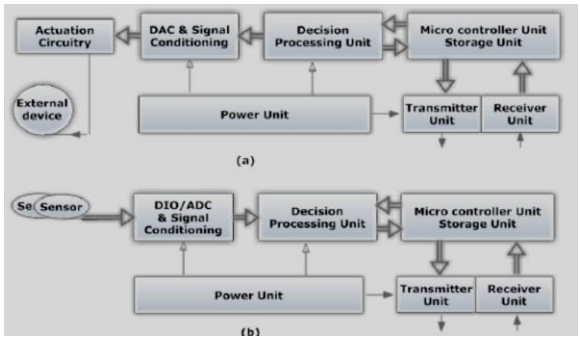

Figure 4: WSAN nodes (a) Actor Node, (b) Sensors Node

Energy efficiency , which covers the power conservation and power management schemes.[11], *Scalability*, which is the ability of the network protocol to manage high degree of a network, *Transmission Media*, The using of the proper transmission media depends on the application environment, availability of suitable simple and low cost effective solutions which can adapt to the region for monitoring and actuating tasks[12], *Environment*, The environment of application influences the nodes specification and overall the network issues. For remotely scattered area or inaccessible locations, nodes need to be in suitable size, media of communication and power resources need to be fully adequate the tasks. *NodeCosts*, The cost of a single node must be low as possible with efficient performance, *Fault Tolerance*; the WSAN should continue flow the information in spite of some failure within the network's nodes. Also, WSAN must have these extra features: Self-healing, self-organizing and acceptable probability of connectivity between network nodes. To create a WSAN that has the ability to implement several types of application, the above features and the target application must be combined in an optimizer decision unit that optimized the frame work parameters.

V. Agricultural WSAN Physical Aspects

WSAN faces challenges within agricultural fields due to deploying of nodes for wide area and reliable link connectivity within crop canopies. WSAN must have the ability to work with various ranges of environments, such as open fields, orchard, with simple flat or complex topography and with different range of weather conditions. All of these factors affect the quality of the radio propagation and hence the reliability of the network [13]. In greenhouses the radio signal has to pass through many obstacles and the link power will depend on crop growth and the terrain, beside, node spacing and antenna height [14]. A signal power of 10 to 20dB higher than the sensitive limit of the receiver is an accepted value for link quality [14]. *Atmospheric conditions* are widely affects the communication links [14] and causes of signal lost. The effects of moisture due to humidity, precipitation and wetting on signal propagation must be considered. Investigate thepropagation of radio signals in potato field using motes of 433MHz has been studied byGoenseandThelen, their experimental results show that a better propagation under wet conditions and higher relative humidity and rain provides increased in signal strength within receiver side [15]. In contrast, experiments carried out with 916 MHz motes showed opposite behaviour [16]. *Ambient temperature* affects the battery life of nodes. Lower temperature shows that battery life decreases and measurements in nodes become more erroneous when power supply voltage goes below a certain threshold [17]. Therefore, it is necessary to, as possible, to isolate changes in battery voltage from affecting the measurement accuracy. *The density of the leaves* in the crop will change over time and will result in attenuation of the propagate signal above the cross canopy [16-19]. When there are less leaves the message rate increases [22].

VI. Agricultural WSAN Application Areas

Recently, the advances in technology allow the fusion of wireless sensor actor networks (WSANs) with variety of applications such as agriculture microclimate control, building and home automation, and early detection of disaster, medical health monitoring, chemical and biological attack, and environmental monitoring. Wireless sensor network (WSN) shares main application areas within WSANs. Currently there is a great interesting within WSN that combine actor node (WSAN) for monitoring, analysis and decision making with variety of fields like agricultural, military, medical, environmental and industrial fields. The fusion of WSANs with these applications will facilitate significantly in automation process of sensing and acting tasks by the network base station. An overview of main application areas for which WSANs are proposed, is stated below: The sensing of parameters change and hence controlling it, is one of the crucial task of agriculture applications which is to be implemented with a wireless sensor actor network which that includes variety types of controlling and sensing tasks such as ventilation,

heating, CO2, dew point and many other parameters that affects the crops. Irrigation and nutrition systems of crops have to sense the environment of crops precisely in order to conclude a true decision for actor nodes that actuate these systems. Studying of the agricultures environment for a specified application must be provided within WSAN to conclude the optimal solution for the WSAN design [20-22]. The fusion of WSAN in precision agriculture leads to increase productivity, efficiency and profitability.

The real time monitoring and acting will help in fully analysing and controlling of the crops due to tuning of environment parameters that affects crop growth inside the greenhouse. The immediate information gathered from the fields will provide a solid database for planters to adjust their strategies at any time based on immediate sensed data of the crops [24]. Applications like plant monitoring, irrigation and climate control are easier to implement with the WSAN. One of the most important applications of agricultural WSAN is theautomation of greenhouse environment. WSAN which combines two types of nodes of sensing and actuating are essential for greenhouse monitoring and control. Crop conditionsinside the greenhouse such as dew point, climate and soil wetness do not depend on natural factors. Thus, the implementation of such monitoring and control network is easier than outdoor applications. The earliest application of WSN in a greenhouse was reported in the year 2003 using Bluetooth technology. A distributed greenhouse system for monitoring and controlling using Zigbee. The result of real implementation of WSN to monitor and control the melon and cabbage crops has been done so far. The experimental work done with melon and cabbage. A network of sensor developed by Lea-Cox et al. which measures the temperature , electrical conductivity , substrate water leaf wetness and daily photosynthetic radiation in real time. The works produces more benefits in terms of enhance plant growth and reduction of disease problems.

Remote PC monitoring system based on WSN has been developed by Liu et al., the system consist of a group of sensor nodes where used to measure the light, temperature and soil wetness and a GSM module, a management software and a PC . The whole system used to gather the information from the sensor nodes and forward it for the PC that contains the analysis part. RFID technology with spectral imaging has been integrated with a remote sensing system by Yang et al. The multi spectral imaging system was used for remote monitoring of the canopy of cabbage seedlings. Greenhouse humidity, temperature and lighting conditions were measured and reported to the remote base station. Many other researchers investigate greenhouse parameters based on aspect is to monitor and management of the environment within the greenhouse to enhance the productivity and control the diseases spreading within the crops.WSAN for agricultural field and greenhouse is the most advances in the development of the monitoring system carried by normal WSN to a system that can react to environment changes and offer a control and adjusting on the environment parameters through using of dedicated devices which connected to actor nodes. The network of sensing and actor nodes provides a complete solution for crops monitoring and environment control.

VII. Relevant WSAN Applications

WSAN has been emerged also in many other applications and the adopting of this technology has been widely increased during recent years. The early prediction of natural disasters such as floods and earthquake will help in limits its affects. Security and surveillance application implemented within network of sensor and actor nodes provides real time monitoring and protecting systems that provide valuable help. Also Structural and eruptions of volcano are relevant application of environment protection and control. Therefore these applications require real-time monitoring acting technologies. Hence, environment monitoring for emergency services is a typical domain which can benefit from networked tiny sensors and actor node that build sensing and controlling aids. Health monitoring applications using WSN can improve the existing health care and patient monitoring. Patients anddisabled peoplehave crucial neediness for WSANs to assist them throughmonitoring, warning and acting systems. Medical health care concerns with a remote monitoring of human physiological data, tracking and monitoring of doctors and patients inside a hospital beside drug administrator to achieve flexible and efficient health care and system in hospitals. Recently there are increased demands for home automation applications. Controlling lights, washing machine, electric consumption, heating system and monitor a sleeping baby. Nowadays, Home power controlling through acting on full controlling of power within the home or building is highly recommended and supported by many developers and researchers. Smart homes have the capacity to acquire and apply knowledge about

human surroundings and adapt it in order to improve human experience. Real time relative positioning system is one of the most important applications. It can be used within people, vehicles, animals or any moving or static objects. According to that movement and position many react process can be established at moment. Real time data for a variety of governmental or commercial services can be achieved for traffic monitoring and jam reporting. Early observing of a high way vehicle accident and intelligent traffic management system is promising application that many researches done to optimize the methods and the hardware for this application. Autonomous transportation system is the main target of this kind of WSAN. There are many other applications that can be fused within WSAN. Optimizing the WSAN with respect to actuation circuitry and response time lead to adapting WSAN with all current application based WSN. Using of current WSN topologies, protocols with modified hardware of nodes that embed actuation circuitry will provide a real time monitoring and controlling of all applications concern WSN as a base for their tasks.

VIII. Conclusion

The using of WSAN in agriculture field provides high benefits which have the potentials to beaneconomically worth. WSAN can be defined as a networkcomprising of sensor and actor nodes which cooperatively sense the environment and, if need, controls it. This enables a real time action process that aims to atomise the network tasks. Based on the advantage gained from the small size of the network, low cost distributed sensing network that can be employed anywhere and even with harsh environments. Currently, WSAN come out to combine the monitoring task of WSN with controlling actions. It explores the ways of sensing of events and reacting as per the environment changes. This research paper focuses WSAN as a solution of monitoring and controlling system for agricultural. Application includes, but are not limited to, Industrial machine monitoring and control, agriculture monitoring greenhouse environment control, field combat monitoring and target tracking and surveillance systems. Greenhouse crops are in essential neediness for WSAN system which achieve better monitoring-controlling and hence avoiding damage of the crops due to unstable inside parameters like temperature, humidity , soil moisture, leaf temperature and many other parameters which affects crops growthand may cause of diseases. WSANs for agriculture application need new efficient algorithms, protocols of communication anddesign to be more focusing on automation jobs, optimizing the response time, and providing instant solution. Implementation of WSAN in agriculture with such dedicated hardware, software and applications may be the next researcher's and developer's challenges.

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