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# Wireless Sensor Network for Precise Agriculture Monitoring

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*Abstract*--**Precision Agriculture Monitor System (PAMS) is an intelligent system which can monitor the agricultural environments of crops and provides service to farmers. PAMS based on the wireless sensor network (WSN) technique attracts increasing attention in recent years. The purpose of such systems is to improve the outputs of crops by means of managing and monitoring the growth period. This paper presents the design of a WSN for PAMS, shares our real-world experience, and discusses the research and engineering challenges in implementation and deployments.**

***Keywords-wireless sensor networks, precision agriculture, intelligent management system***

## I. INTRODUCTION

Without doubt, human beings cannot exist without food and water. In recent years, however, due to climatic change, water scarcity and reduction of land resources, human sustainable development is threatened. The traditional watering or fertilization methods are derived from experience, having less scientific basis, and cause waste of water or soil deterioration. Humanity depends on agriculture and water for survival, so optimal, profitable, and sustainable use of our land and water resources is critical. And How to protect, develop and make use of the water and other resource is an acknowledged problem.

Alongside with the evolution in wireless technologies, miniaturized devices and sensors, the number of application that uses them for automatic environment control and monitoring have grown.

In the recent years, Wireless sensor networks (WSN), which integrate sensor technology, MEMS technology, wireless communication technology, embedded computing technology and distributed information management technology, has been under rapid development. Thus, it is expected that the WSN will be used commonly in applications in consumer electronics, PC peripherals, home automation, home security, personal healthcare, toys and games, industrial control and monitoring, asset and inventory tracking, intelligent agriculture, and so on [1].

The importance of WSN arises in this context, due to their capacity to automatize certain tasks in agriculture, especially monitor systems. Through their particularities, WSN are able to monitor those systems by controlling physical parameters like humidity, temperature and others.

The WSN are composed of many nodes, thickly distributed and able to sensor. They enable information to be captured by using a set of sensors able to communicate with each other and process data inside the network itself (processing in-network) in order to do a specific set of tasks which cannot be done by humans due to their inherent limitations and physical survival conditions. Additionally, the WSN can also be applied where there is ongoing need for environment monitoring and control and in tasks that would demand too much time and resources if manually done.

An agricultural greenhouse [2] can be considered as a manmade solution to emulate a suitable ecosystem in order to grow crops rapidly. Unfortunately, we cannot use greenhouse to cover all of the farmland. So we need a robust network monitor system which could place in the actual farmland and resist the environment interference. The Precision Agricultural Monitor System (PAMS) deploy the sensor nodes in actual farmland and greenhouse, which could collect the real-time information to a computer or the cell phone used by farmers, so that farmers could know the real-time conditions of the crops and decide whether to water or crop-dusting.

The rest of this paper is organized as follows. Section 2 describes the backgrounds and general requirements of the WSN based PAMS management. Section 3 describes detailed system architecture that solves problems such as energy consumption and others. Finally, the paper concludes with a summary of our work and a statement of future work.

## II. REQUIREMENT OF PAMS

The Precision Agriculture Monitor System is motivated by the need of monitoring the western region special agriculture products, e.g. apple, kiwifruit, salvia miltiorrhiza, melon, tomato and so on, which monitors the surrounding environmental factor and the content of soil fertilizer and analyzes the data to provide excellent environment for crops with human intervention.

Through the study of crop growth, we know that the crops have different requirement of environment factor, i.e. air temperature and humidity, soil temperature and moisture, $co_2$ concentration, illumination intensity, etc, in different grow period. Let's take the apple tree as an example. The appropriate temperature for apple tree is range from 13° to 25° ,and the soil moisture is greater than 11%. With these standard parameters, farmer could change the moisture automatically and water the farmland in need to avoid the waste of water resource. Of course, through the detection of environment factors, we could also prevent the pests of apple tree. For example, the apple borer will mostly appear in 17° air-temperature , 19° soil-temperature and the greater moisture than 10%, so that we would have crop-dusting when detected

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the above-mentioned conditions to inhibit the apple borer growth and guarantee the health of tree.

If the crops were grown in greenhouse, we implied the automatically water, temperature and illumination control without human interaction when the environmental conditions are not suitable for crops.

The requirements in the aspect of WSN based PAMS functions can be mainly summarized as 2 points:

- environmental monitor

  We deployed the various sensors in the monitored area. Administrator and user could remote access the real-time information. When detecting an abnormal situation, the system could send an alarming message to the user by some effective ways, e.g. send SMS.

- remote control

  After receiving the real-time conditions, administrator could remote take the device on or off in greenhouse to change the temperature or humidity.

In addition, there is a performance requirement have to be noticed. The Precision Agriculture Monitor System is a long-term sensing for continuous application, precise agriculture measurements and agriculture research, so we should make the system lifetime as long as possible.

## III. THE DETAILS OF PAMS

Any control system has two main set of components, namely, a sensor or monitoring component to collect data and an actuator component to perform specific actions as a response to the collected data. Now we describe the system architecture, and the details of Precision Agriculture Monitor System. The Precision Agriculture Monitor System consists of WSN, gateways, and a communications sever. We deployed the nodes in the monitored farmland, which could sense the related environmental information of crops, e.g. temperature, humidity, illumination and $co_2$ concentration, etc. After the data collection, nodes would pack the data using the specific protocol and along the multi-hop routing send the package to the Root node. And then, the Root node transmits the data to gateway. When receiving the data, the gateway extracts the effective information that saved in local flash, at the same time, the gateway send the data to communications server by GPRS. The communications server handles the data and then stored them into the agriculture database. Then the administrator or user could remote monitor the environmental conditions of monitored farmland or greenhouse by assessing to the database. The communications server also has SMS alarming function, which will send the alarming message to user when detected the information beyond the threshold we set or monitored the low battery. In addition, the administrator could also remote control the exhaust fan or the irrigation equipment or the sunscreen to achieve the purpose of monitoring crops growth, as shown in figure 1.

### A. *PAMS Prototype*

The NPUMote is an Agriculture sensor node developed to be deployed in a PAMS and to sense the environment of the monitored areas. We use the 8-bit high-performance microcontroller Atmega128L [3] as the microcontroller unit. Why we choose this type? There are two reasons. One is Atmega128L used RISC technology has high computing performance. Another reason is the proven open source development of software and supported by TinyOS. By the same, we also choose the AT86RF230 as the radio frequency chip and AT45db041B [4] as the memory, which are all well supported by TinyOS.

In terms of sensor selection, we all choose the sensor of fast-response, well anti-interference ability, low-power. All of the choice is in order to achieve high performance of our monitor system. Figure 2 shows the NPUMote and the encapsulation of the mote.

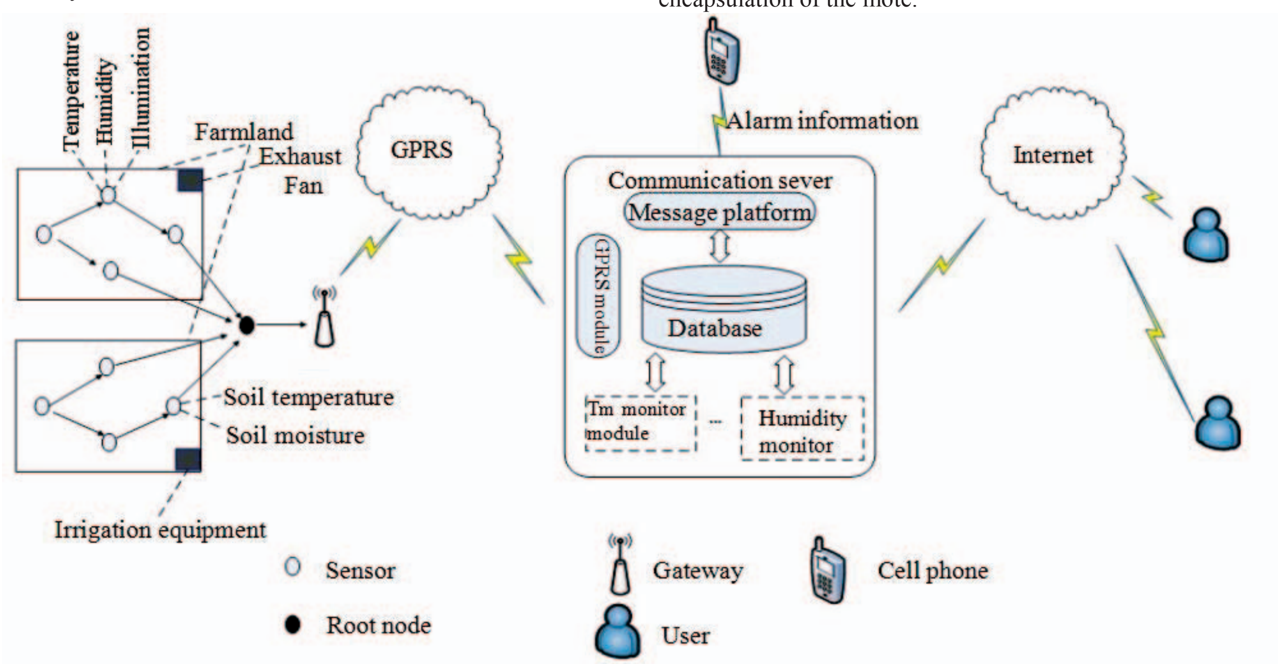


Figure 1.The architecture of PAMS

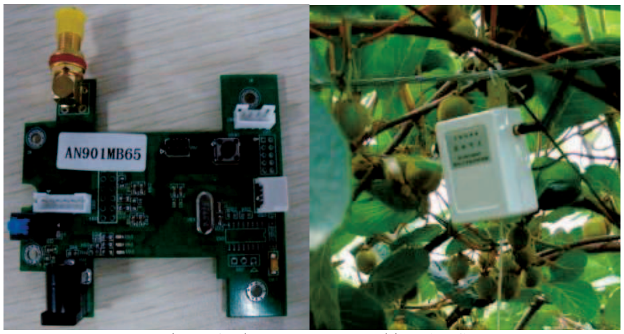

Figure 2.The NPUMote used in PAMS

The PAMS prototype is based on TinyOS 2.1, using a globally synchronized duty-cycling mechanism for all the nodes. In each power-on period of the nodes' radios, we adopt the CTP protocol [5] to collect the sensory data, whereas the beacon frequency is modified to save communication cost. Data disseminations from the Root node are enabled to control the nodes' operational parameters, such as the transmission power, sampling frequency, duty ratio, and the length of a duty cycle.

Now, the PAMS is used in many areas of Shaanxi province, such as Yangling, Zhouzhi, Ansai and others. We use this system to monitor the surrounding environments of special agriculture products and achieve some good results.

### B. *Energy efficient*

Energy constraint is a major stumbling block that limits the long-term sustainability of WSNs. For the conventional sensor motes, radio communications consume most of the energy, while the receiving and transmitting modes have comparable power consumptions. PAMS as a long-term deployment must consider the energy consumption to improve the performance.

The NPUMote uses two cell dry batteries to provide power. The long-term deployment is a challenge for power. Although we implement duty cycle mechanism in node, the power consumption is also non-optimal.

Therefore, we proposal a program named EDABA [6](Energy-balanced Data-aggregation Algorithm Based on Ant) to balance the rest energy of every node and prolong the lifetime of the network. This program based on the adaptive ant colony algorithm [7], adds an inspired factor of energy, implements the balance energy with Directed Diffusion program [8].

Although EDABA could prolong the lifetime of our system, but it is not our original intention about the energy saving. The challenge is design an effective dynamic duty cycle mechanism based on the rest energy, which is our future research direction.

As known to all, time synchronization is very significant for distributed systems, especially the application of wireless sensor network. In the same way, the synchronized data in PAMS are meaningful to users. But the requirement of time precision is not the most significant need for agriculture application.

Because of the little requirement of time precision, our point of time synchronization also is energy efficient. We proposal a program named BLP [9] (Balance Low Power Time Synchronization) to implement time synchronization with low power consumption. This program prior selects the node which has the more power and the less packet loss ratio to broadcast the synchronization message. Finally, the program implements the low power consumption with the acceptable time accuracy. And compared with RBS [10] and BTS [11], the BLP consumed the least energy.

In our future work, we will research the time synchronization affected by environment, and hope to proposal an optimal time synchronization program to be adequate for our agriculture application.

### C. *Information management*

As shown in figure 1, the gateway and communications server play the role of media in the management system. The gateway transforms data over RS-232 from a sink to data over TCP/IP to communications server and vice versa. And the

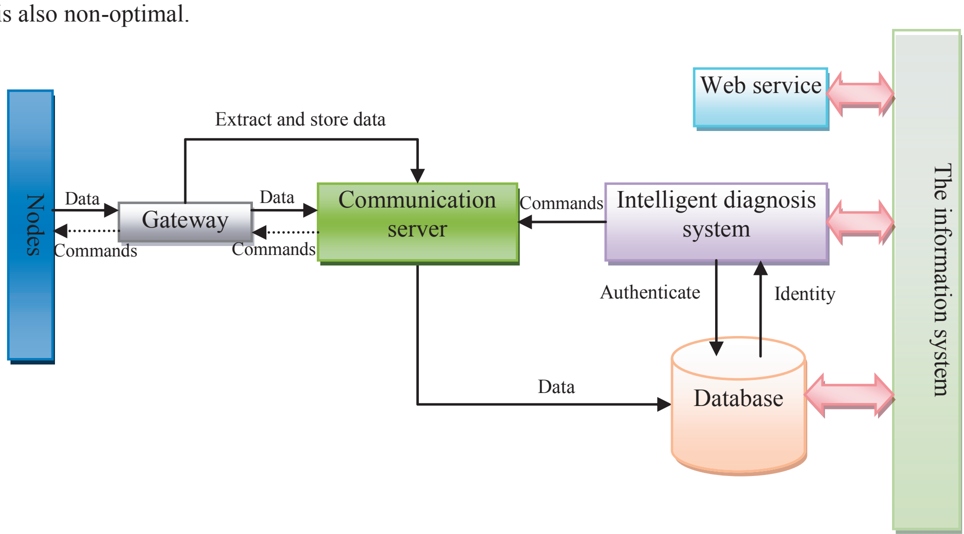

Figure 3.The information flow of PAMS

communications server provides service to user and administrator. The most important, user can use the management system to remote control the device placed in the monitor farmland.

Figure 3 shows the information flow of PAMS. As mentioned above, the gateway and communications server provide information path in the system. The monitored data are stored in the Database and supply service to other applications, e.g. web and intelligent diagnosis. The intelligent diagnosis system is an expert system which can determine the environmental factor whether accord with the given threshold. Once detecting the exceptional conditions, the diagnosis system will send commands, including take on or off the irrigation device, exhaust fan and sunscreen, to communications server and then transmitted to the monitored greenhouse of farmland. The web service provides the on-line query and management function. If user wants to change the detection threshold of environmental factor, he must be authenticated by PAMS and then next to send the commands of changing parameters.

There's another problem in front of us. PAMS is a long-term deployment application, the monitored data will be more and more along the time. And then the capacity of database which storing the monitored data will be less and less. How to handle the history data is a big question for all of the long-term applications based on WSN.

### *D. Remote user interface*

The remote server stores, processes and presents the information gathered by the WSN. Data are not only sensing (measures, battery level) but also control and management messages (synchronization, node-reset). Final user might check the system status by means of a graphical user interface (GUI) accessible via our website [12]. The user is able to observe the real-time data reported by the nodes. After the log-in phase, the user is able to manage the device which equipped in the monitored region. The system monitoring could be performed both at a high level with a user friendly GUI and at a low level by means of message logging.

## IV. CONCLUSIONS

In this paper, we proposed real-deployment of WSN based greenhouse and actual farmland management named Precision Agriculture Monitor System which is designed and implemented to realize modern precision agriculture. Characteristics of sensor node such as low energy wastage, short communication range and self-organized combine with the need for predictable operation guide us the application architecture and services. From the PAMS prototype to some details of our system, the whole system architecture is explained. Users can tailor the motes operation to a variety of experimental setups, which will allow scientists to reliably collect data from locations previously inaccessible on a micro-measurement scale. Such a system can be easily installed and maintained.

Our PAMS is used in many areas of Shaanxi province, such as Yangling agricultural demonstration garden, Zhouzhi Kiwifruit Park, Ansai Apple Park, etc. After a period of deployments, the environmental information provided by PAMS is useful and easy for the administrator. And the PAMS is satisfied by the farmers who used.

In our future work, we will achieve the long-term deployment. There are many rooms to improve and perfect the sensor network and monitor system including the challenge mentioned above. Our future research will focus on the energy saving, data fusion and other directions.

## ACKNOWLEDGMENT

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