Application of Theory and Technology of Wireless Sensor Network System for Soil Environmental Monitoring

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Abstract: With the environment problem increasingly high degree of attention, need for environmental data acquisition is also more and more, the emergence of wireless sensor networks to provide convenience for the study of random access to data, and can also avoid invasive traditional data collection methods for environmental damage. For example, researchers at Intel research laboratory had 32 small sensor is connected to the Internet, to read the main "great duck island" on climate, used to evaluate a sea Yanchao conditions. Migration of wireless sensor network can also keep track of birds and insects, effects of environmental change on crops, monitoring the ocean, atmosphere and soil components. In addition, it can also be used in precision agriculture, to monitor crop pests, soil pH and fertilization. In this article, according to the application demand of farmland environment monitoring, based on the composition and application conditions of wireless sensor network technology, we design a soil energy consumption monitoring system with the JN5121 wireless microprocessor as the core, which has the advantages of low cost, high stability, multiple functions function characteristics, and we have carried on the corresponding technical test, the results show that it can achieve effective environmental monitoring of soil in the monitored regional. Copyright © 2013 IFSA.

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1. Introduction

Wireless sensor network technology has attracted more and more attentions of the researchers, and especially as a large agricultural country, its application in farmland soils has become an inevitable trend. In view the advantages of the wireless sensor, as well as the important significance of real-time monitoring of soil moisture and temperature, it is necessary to promote the rapid development of China's agriculture, and to develop a low cost, high stability, strong application farmland environment monitoring system based on wireless sensor network technology.
2. Composition and Application Conditions of Wireless Sensor Network System in Soil Environmental Monitoring

Compared with the traditional means of environmental monitoring, environmental monitoring has three significant advantages of using sensor networks: firstly, the sensor node is small in size and the whole network only needs to be deployed at a time, so the deployment of sensor networks has very small impact on the human environmental monitoring; secondly, the number sensor nodes are with large quantity and high density of the distribution, and each node can gather the detailed information of local environment detected the base station, so the sensor network is with the characteristics of large quantity of data collecting and high precision; third, the wireless sensor node itself has a certain degree of computing power and storage capacity, and it can conduct more complex monitoring according to changes in the physical environment, and the sensor node is also with wireless communication capability, which can carry out the cooperative control among the nodes.

2.1. Composition of Soil Environmental Monitoring System

Implementation of wireless sensor network technology function, is through a series of technical support of the routing, location, synchronization, security, network management, and energy saving. And on the soil environment, in view of the actual application value for monitoring soil, while the farmland soil has the following characteristics: 1. monitoring environment requires the knowing ability; 2. the soil needs plenty of sunlight, namely the solar energy resources; 3. the crop is with fixed growth cycle; 4. the monitoring environment will change according to the natural and human factors; 5. in farmland, the infrastructures with the scientific and technological content is less.

2.2. Application Conditions of Soil Environmental Monitoring System

In view of the above characteristics, the soil environment monitoring system can be divided into the two parts of wireless sensor network and remote data center. Between them, the remote data center functions are receiving, storage as well as the corresponding spatial analysis of relevant monitoring data, namely remote operation can be completed in the interior. While the wireless sensor network is installing a plurality of intelligent sensor nodes in the field, and the network formed by the connection of these nodes is wireless sensor network, which is responsible for the real-time acquisition of soil temperature, humidity, moisture and other data.


According to the characteristics of the soil, the key to effective application of wireless sensor network to soil environmental monitoring, is to establish remote data transmission and effective data transmission of each node, namely to establish the Mesh network based on ZigBee wireless communication protocol, to ensure all the node data can go through the gateway node of routing transportation belt, then the data will be transmitted to the remote data center by a gateway node through GPRS wireless communication mode, in order to realize the real-time monitoring of soil for the remote data center, and in view of the consideration of saving energy and reducing consumption, all the monitoring nodes use solar power supply mode. According to the principle above, now the analysis of the design of wireless sensor network is as follows.

3.1. Design Requirements of Wireless Sensor Network

In view of the consideration of advantages and applicability of the application of wireless sensor network, in the design it should be mainly taken its economy and technicality two aspects into consideration: 1. The economy, soil environment is closely related to agricultural production, and given the agricultural income level is relatively low, so big cost of input is not practical, and we must reduce the cost, namely we should adopt products of relatively low prices in a variety of hardware and software related to the nodes of wireless sensor network, and for monitoring in the field, the objective conditions of large-scale power system generally does not exist, so we use the solar power, and use the common battery for standby power supply as the main way. 2. The technicality, on the basis of considering the economic cost, monitoring the effect is not affected, to ensure the accuracy of the corresponding data index monitoring for the system, namely under the premise of considering the cost, and in case of great influence of the environmental changes on the field monitoring data, to get the accuracy of the data as far as possible, of course, this process allows some error in it; Real-time characteristic of monitoring process, we must ensure that the information of each monitoring node can be instantaneously transmitted to the remote data center, so that the users can timely master the corresponding changes of indexes of soil of the monitoring area; The stability of the system, in addition to the corresponding maintenance and supervision of hardware and software of the remote data center, the key is to monitor every node module in the field, and to keep them in the normal work in the change range of soil environment, and these three aspects are also the basic demand of the wireless sensor network system.
3.2. Structure Design of Network Sensor Network

3.2.1. The Hardware Design

In this article, the sensor nodes adopted are on the basis of using the JN5125 wireless microprocessor module as the core component, and the communication interface, bus interface, power supply interface, and the sensor interface are with developed corresponding design. In view of the integrated features of the JN5125 module, which has 32 bits, 16MHz processor, and ADC input, DAC input, asynchronous serial port, SPI interface, hardware design reliable and effective to achieve system integration. Network structure design of the sensor node structure is shown as in Fig. 1.

In the picture below, the power supply adopts the solar power components for power supply, and it supports data acquisition of six sensors after extending, and the remote data center realize the corresponding receiver design and program downloading function through the serial port. For the sensor network data local storage, we use the USB interface storage mode, which has the advantages of large capacity, extensible and hot-swap. For the power input, the part of the power supply adopts the solar power, and because the gateway node is with large amount of energy consumption, we select the power of solar power components of 8 W, and also need for the corresponding hardware optimization, to reduce energy consumption.

![Diagram of Sensor Node Structure](image1)

Fig. 1. The sensor nodes structure.

In addition, the sensor for the monitoring of soil moisture is through a flat frequency domain technique to collect the data of soil water mixture; Sensor for temperature monitoring is based on the principle of measurement of the semiconductor PN level, and the effective measuring range is between -20 °C - 50 °C, while the measuring accuracy is ± 0.5 °C. After completing of the design of the two kinds of soil environmental monitoring, the node of each sensor and the sensor interface of the corresponding control board can be connected, and then connected to the A/D channel in the JN5121 module through the corresponding signal adjustment, and then we can obtain the specific measurement parameter values of the corresponding soil moisture and temperature through the determination of the curve transformation. So, we complete the process of "sensor nodes collection in monitoring area, each node autonomously to form a wireless network, each node information gathered to the sink node or network coordinator, remote data center", so as to realize the real-time monitoring of the moisture and temperature of the soil in monitoring area.

It should be noted that, in the deployment of sensor nodes, it should ensure all sensors in the pre-planning monitored area, and forming multi-hop network in the self-organized way, and among them, the sink node may be artificially arranged, because the sink node has to handle many tasks, and is responsible for the activities of the whole wireless sensor network, and consumes more energy, so it needs artificial arrangement and adopts the artificial method to replace the battery if necessary. For ordinary nodes, because it is only responsible for the collection of soil environmental data, we do not have too much trouble, but the routing node is responsible for forwarding the data acquisition information of other nodes in addition to data collection, so it will transmit it to the sink node or network coordinator in the multi-hop way, so as to realize the purpose of transmitting the monitoring data of all the nodes in the whole region to the remote data center by long...
distance link. In addition, the wireless sensor network adopts the topological structure, so even there is individual node failure of the application, the system can network again by changing the topological structure, which effectively improves the robustness of the system.

3.2.2. The Software Design

Compared with the hardware design, the software design of wireless sensor network is relatively simple, because it uses the mesh topology, and the JN5121 module embedded in the gateway node is the network monitoring coordinator under ZigBee protocol, while for the JN5121 module, its development company has introduced the software development platform and network stack, so in the system software design part, we only need to design the corresponding target, and input specific regulating parameters, and specific procedures are as follows: 1. After sensor nodes are deployed, the nodes start, and wait the command to join the wireless sensor network. 2. The gateway sends start commands to each sensor nodes in the network. 3. The node joins the network after receiving the start command, acquires the address information of the network, configures the local link address, and creates the routing. 4. The node collects data according to the data acquisition cycle set in advance, and transmits the data information in the form of data packets to the network coordinator (Gateway) and monitoring equipments.

According to the working process of the system, the brief work flow of the data transmission is shown as in Fig. 2.

![Fig. 2. Data transmission work flow.](image)

3.2.3 GPRS remote Data Transmission

The communication module of Siemens MC35i is connected through another asynchronous serial port, and to realize GPRS remote data communication needs from bottom to top to complete the designs of the driving layer, protocol layer and the application layer. In the configuration of embedded Linux kernel, we select the equipments supporting the serial port to drive the MC35i module; The embedded Linux kernel supports the PPP (Point-to-Point Protocol) protocol and TCP/IP protocol, and we select to support these options in compiling the Linux kernel; The application layer realizes the particular function of forwarding data to the remote data center after the network is connected.

3.3. Design of Wireless Sensor Network Node

3.3.1. The Sensor Node Design Principles

From the above known, sensor nodes generally can be divided into the network nodes and the sink nodes, which is the body to realize the sensing function of the wireless sensor network, and its position in the system is very important, and the nodes based on the sensor will receive limits of many conditions in practical application, therefore in the design, we must comply with the following principles. 1. The node needs low power consumption, and under normal circumstances, the nodes use disposable batteries, while in the application of wireless sensor network, because of a...
number of nodes, and the broader regional
distribution, and the current situation of more
difficult for the artificial replacement battery
operation, in the design of the sensor node, we must
hold the pass of the power consumption, namely
reducing the power consumption in the two aspects
of hardware and software, and using the chip of low
voltage and low power consumption as far as
possible in the hardware, and correspondingly adding
the power management function in the software, in
order to effectively control the capacity allocation.
2. Optimization of the radio frequency performance,
improving the radio frequency performance of the
node can improve the network capacity, for example,
under the same power consumption, if the distance is
further, the practicability of the node will be stronger.
3. Nodes miniaturization, the node size should be
small enough to ensure that it will not constitute
influence on the target system itself, and it is simple
and convenient in terms of the actual deployment. 4.
The node should be low cost. As already stated
above, if it costs a lot for the measurement of soil
environment, then the study itself will lose some
value, so as to make it widely used, we must control
the number of nodes in the design, and the structure
of the network topology should be simple and clear
as the original intention, not too complex. 5. The
node should have expandability. 6. The node should
have expandability, namely using the modular
design, and adding different function modules at any
time according to different needs, such as connecting
different types of sensor boards in different
applications, or connecting other corresponding
modules for other needs, or connecting the coprocessor through the general interface and so on.
Of course, in addition, it needs to ensure the accurate
transmission of data and safety of the transmission
process, assuming the node likely to work in harsh
environments, to ensure the stability of the node in
the work.

3.3.2. Specific Design of the Sensor Nodes

We will design the sensor nodes in accordance
with the wireless sensor node design principles
above. From the above known, the sensor node is the
basic unit of wireless sensor network, so the design is
good or bad will directly affect the quality of whole
network. The sensor node is the main unit of
composing the soil moisture and temperature
acquisition system, which besides in charge of
composing the soil moisture and temperature
acquisition system, which besides in charge of
collecting the information of the environment and
processing the information, also needs to transfer
other nodes to the gateway information and in the
specific application environment, it also needs to
cooperate with other nodes to complete certain tasks.
Therefore, the stable operation of the sensor node is
the basic guarantee for the reliability of the network.
Generally, sensor nodes can be regarded as a
miniature embedded system, whose processing
power, storage capacity, as well as communication
capability are relatively weak, and in different
applications, the components of the sensor nodes are
not the same, in terms of soil environmental
monitoring in this article, which consists of the
sensor module, processor module, wireless
communication module, and the energy supply
module four parts, and the diagram below is the
structure of the sensor node.

4. Technology Application of Wireless
Sensor Networks

Application of wireless sensor network in the soil
environmental monitoring system mainly includes the
construction of development environment, data
receiving, storage module selection, monitoring data
analysis three aspects, and the concrete application
steps are as follows.

4.1. Create the Development Environment

We choose the Microsoft Visual C++ 6 as the
development tool for base station data management
software, and use the database operation to achieve
the node data storage and reading. In addition, for the
effective implementation of real-time monitoring data
in farmland soil, it integrates the function of
geographical information system, which uses ArcGIS
Engine embedded component library of the ESRI Company. ArcEngine is composed of the ArcObjects core package, and it can call in various programming interfaces, and without the need to install the ArcGIS desktop platform. Compared with the traditional map control, on the basis of the drawing, data editing and the function of GIS, the ArcEngine adds the space and 3D analysis and other advanced operation functions.

4.2. Data receiving and Storage Module Selection

4.2.1. The Function Module Selection

The C/S client server mode is used between the gateway node and the base station, based on Socket programming technique; it can listen to the bound ports of the local IP address, after confirming the connection request of the gateway node it will work on data receiving, reading and parsing.

4.2.2. The Data Storage Module Selection

According to the data acquisition time, and the corresponding period data storage divisions, the data after analysis will be stored in the corresponding table.

4.3. Analysis of Monitoring Data

4.3.1. The Time Change Analysis

After extracting the monitoring data from the database table, we use the time T as the abscissa axis, to draw the change curve of the monitoring data according to the time change, and then analyzes the characteristics of monitoring contents.

4.3.2. The Spatial Variation Analysis

The management and analysis functions of GIS are integrated into the design of wireless sensor network applications, and then through the ArcEngine spatial analysis module to realize spatial interpolation, and to obtain the spatial distribution of monitoring for any period. Then using the corresponding function algorithm can get the spatial variation of real-time monitoring data.

5. Wireless Sensor Network Communication Test

Because wireless sensor will appear the phenomenon of obvious path loss in transmission, it needs to verify whether the sensor node layout is reasonable, and we must carry on the distance transmission text on the JN5121 module. In view of the influence of the antenna height of the sending end and receiving end of on signal transmission, as well as the influence of the gradual growth of the crops on farmland soil environment, for example, if the general plant height of the wheat is 60 cm, in this farmland, the antenna height of 150 cm, then the effective transmission distance of low power module is only 50 meters, and high power module can only reach 150 meters, so in the arrangement of the wireless sensor networks, special attention should be paid to the following points. First of all, in the same area of farmland, if all it using are low power modules, it should be appropriate to raise the arrangement density of effective monitoring case. Secondly, if there are cover crops in the farmland, a node antenna should be designed suitable for raising the placing height, to reduce the signal transmission path loss. Finally, attention should be paid in the design of network topology, and each sensor node should communicate with more than two nodes in the effective communication range, to ensure that after the occurrence of a single link fault, it does not affect the normal monitoring of the entire network.

5. Conclusions

In the process of the design and implementation of wireless sensor network with JN5121 wireless microprocessor module as the core, not only the development cycle is short, but also it achieves the desired purpose of effectively reducing the economic cost, guaranteeing the system effective and steady operation, and it is a kind of soil environmental monitoring system worth widely popularizing. Of course, in the process of the practical application, it is believed that there will be a better and more optimized wireless sensor optimization network developed.

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