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Forest Wireless Monitoring System of Internet of Things Based on Zigbee Technology

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Abstract: In terms of artificial forest plantation, surroundings determine the growth situation of trees, which is an important factor for guaranteeing both quality and quantity. Previously, the growth information and growth situation are judged by experience. Compared with it, the newly-put-forward forest wireless monitoring system of Internet of Things which is based on the Zigbee technology can monitor the growth information and the surroundings of trees accurately and in any time as well as conduct reasonable and precise control over them through organizing the forest wireless monitoring system of Internet of Things. This system designs the modularized wireless node hardware with chip Atmega128L and CC2420 as its core and integrates them into various sensor modules such as growth, humidity and temperature of trees. It also completes the multi-sensor finite state machine program according to Z-stack protocol stack and improves composition of the gateway structure. The statistical data are obtained through a large number of experiments. The system has strong stability and can satisfy application of Internet of Things of the forest data monitoring.

Key words: Internet of things, forest, zigBee, wireless monitoring system

INTRODUCTION

Real-time and accurate remote automatic accumulating technique belongs to the category of precision forestry. Compared with precision agriculture (Jiang and Jiao, 1992), the development of precision forestry lags behind. It is mainly because that the production of forestry is characterized by long cycle length, various outdoor interfer-ence factors, large cover area, big variability and complex forest environment, which has made it quite difficult to collect the growth environment factors of forest and its data transmission (the important link of precision forestry) (Zhang *et al*., 2008). The-refore, it is of great significance to research a forestry information collection system which is low-investment, low-consumption and high-output and has integrated informatization with intelligence. The newly arising wireless sensor networks technology has provided suitable technological means for realizing objectives of forestry information collection system.

A sensor network layer is mainly composed of a series of nodes with sensors (Han and Zhang., 2011). After the informa-tion is collected by the sensor network, it will be transmitted to the management center through transmission network and then be analyzed and processed by the management center. Finally, it can be provided to and used by the application terminal. This is the whole processing procedure of Internet of Things. Internet of Things can collect real-time information of variation quantity of arboreal growth and their environmental information and figure out their changing pattern through data analysis, realizing precision and elaboration in its true sense.

SYSTEM STRUCTURE

The main functions of the system include data collection of sensors, networking and communication of Zigbee (Zhang *et al*., 2007; Li *et al*., 2007), gateway control and interface display and computation of sensor data. The main work of this paper includes design of wireless node hardware, programming of node, network establishing of sensor and definition of data protocol and low-power design of node (Baker and Copson, 1953).

The wireless sensor network system designed through this system is composed of three parts, namely wireless sensor node, aggregation node (cluster head) and monitor terminal. The wireless sensor network system adopts the cluster-tree network topology structure (Fig. 1), which can reduce energy loss and decrease the frequency of data packet dropout. The wireless sensor node is matched with the microprocessor Atmega128 L and is deployed in the forest or in the neighboring area or installed on the tree according to the optimized signal reception system. The end point of each Zigbee is a collection node, which collects environmental monitoring parameters such as the growth information of tochigi, the relative humidity of the atmosphere, temperature of the air

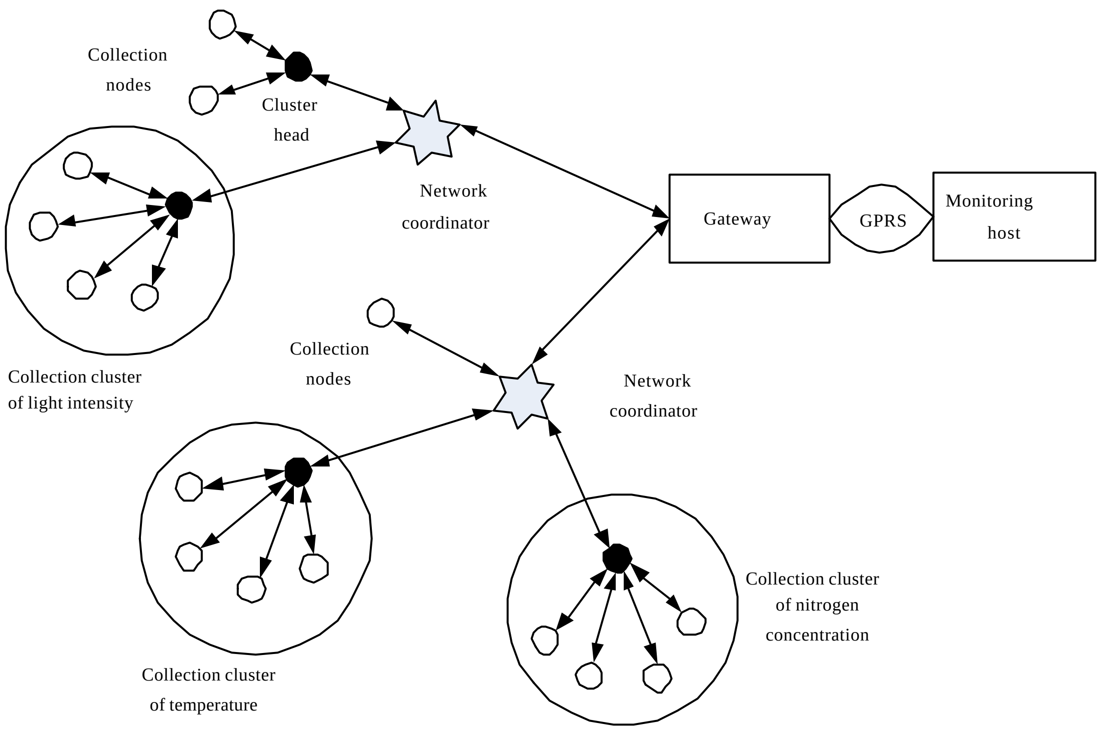

Fig. 1: ZigBee-based wireless sensor network system in plantation

and smoke scope and transmits them to the node nearest to the aggregation node (cluster head) or directly transmits them to another different aggregation node hop-by-hop through sensor nodes. Then the aggregation node integrates the data collected by the collection node which is governed by it. The processed data are transmitted to the nearest network coordinator. Thus the data integration and transmit of the data packet are finished. At the same time, the aggregation node is also responsible for broadcasting the data packet sent by the network coordinator to its governed clusters, in order to arouse the collection nodes at regular times. The network coordinator is responsible for connecting the field server to the wireless sensor network, managing the data collected and the nodes and controlling the wireless sensor networking etc. the data information is finally transmitted to the Router and the Router set up a local data base according to all the data sent by the sensor network. The local data base is transmitted to the monitoring host through GPRS, which is equipped with expert system. The monitoring, computation, evaluation and statistics of the data are completed through comparing the sent data base and the expert data base.

HARDWARE STRUCTURE OF WIRELESS SENSOR NODE

Figure 2 shows the hardware structure diagram of the data collection node and aggregation node (Fukatsu and Hirafuji, 2005). The most fundamental unit that forms the wireless sensor network is the sensor node. The wireless sensor network is established with the sensor node as its basic platform. The sensor node is generally made up of four parts, namely the sensor module, the data processing module, the wireless data communication module and the power source and its extension module.

NODE PROGRAMMING BASED ON Z-STACK PROTOCOL STACK

Node programming based on protocol stack application layer has the following functions: node output equipment control, sensor management, sub-node management, isolated point processing and administration of energy conservation etc (Hu *et al*., 2011).

Equipment output control of node: originator of control operation can be node of the network or the node itself or the gateway control platform. If the ZigBee node

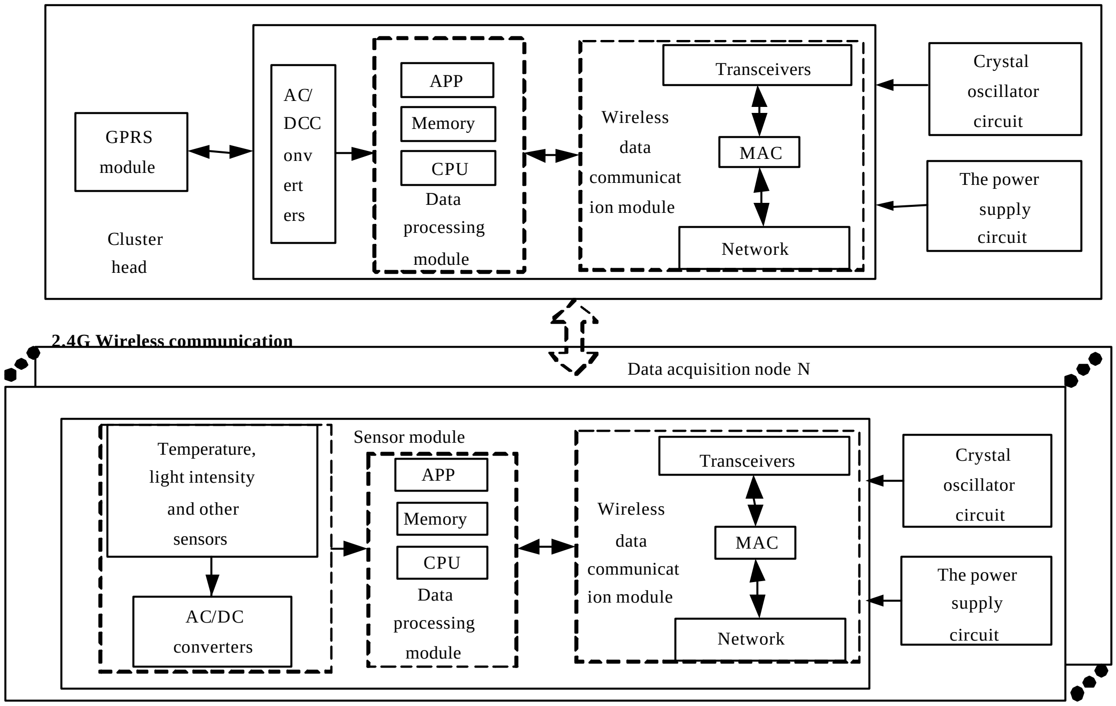

Fig. 2: Block diagram of the node

Table 1: Names and functions of the specific data structure

Category	Data structure name	Function
Sensor attribute data structure	Z_atr	Sensor node properties
	NWK_add	Sensor nodes in the network address
	EXT_add	Sensor nodes extended address
	Num	Sensor node no.
	Crro_add	Father sensor node network address
	Dev_ID	Sensor No. (1~n)
	STA	Status word
Sensor node data structure	SCR_add	Sensor nodes in the network address of the source
	NUM	No. of sensors
	C_ID	Sensor No. (1~n)
	Data/Sta	Sensor data state(1~n)
Sensor control command structure	DIR_add	Target sensor node network address
	C_ID	Sensor No. (1~n)
	Cmdp	Sensor control command word

is the controller of the humidity warning device and the node itself is equipped with humidity sensor, the node can launch a signal when the humidity reaches the set value.

Isolated point processing is for the purpose of improving utilization rate of network resource. Management of energy conservation sends power self-adjustment mechanism and sleeping mechan-ism to sensor node, improving service efficiency of energy and avoiding energy loss caused by unnecessary transmission.

DATA DESIGN

During the communication process, the data are transmitted through frame. The system uses different frames to communicate according to different commands, realizing the function of control. The device descriptor data structure reports the relevant information such as node attributes, network address, extended address and network addresses of node and parent node and the number, type, equipment label and control/status of the equipment it supports to the coordinator. In terms of data structure of the sensor node, the data width is 16 bit (Li *et al*., 2013). The node device data is formed through the source node application layer. The control of the device over the command structure is the controlling process of the designated peripheral device control of the designated node. The users can initiate a control through the gateway and the sensor node can also issue control command. Table 1 sets out the names and functions of the specific data structure.

PROCESSING OF THE ISOLATED POINT

Isolated point refers to the node which has lost contact with the network for some reason (including failed nodes because of battery failure or hardware failure). When a node calls its child node for three times and does not receive even one response, then this child node is considered to be an isolated node. The parent node saves the current arousing periodic table and increases the transmitting power directly to call the isolated child node. If successfully, this child node will be still regarded as its child node and the parent node will report to the base while the data is uploaded. Given that failure of the node may not be permanent, disorder of the program caused by interference, for example, the child node can return to normal if using the watchdog. Therefore, it is necessary to conduct isolated point recovery operation when conducting the arousing work the next time. The process is as follows:

- The base issues the command to recover the isolated point
- The original parent node of the isolated point performs the command to recover the isolated point. This parent node will call the isolated child node according to the old arousing periodic table which has been saved. The number of attempts will be set by the command of the base
- If it is successful to wake up the isolated point, then the original network topology structure will be recovered. Otherwise, the current network topology will be saved
- The parent node will report to the base when the data is uploaded the next time

MEASURES TO SAVE ENERGY

In order to extend life cycle of the node in the large scale forest environment, the battery modules of all the nodes within the network are expanded in the system design. The controlling and switching modules of solar photovoltaic power are increased, which can continuously supply power for the wireless sensor network nodes. Besides, the stability of power supply of the sensor node is guaranteed through controlling the charging and discharging of the capacitor energy storage device and power supply strategies of the system. Thus, power supply of the node in the forest environment can be guaranteed no matter in high light conditions or in low light conditions. At the same time, the system has designed various voltage outputs to satisfy different power supply needs of different sensors in the forest environment. And mechanisms such as the energy consumption, node sleeping and node arousing which have to be taken into account while designing the routing process within the network have been simplified.

SYSTEM TESTING AND ITS RESULTS

According to the above-mentioned plan, a set of testing system has been designed, which includes twelve monitoring points such as temperature, humidity and growth information as well as a coordinator. This system is put in the biennial Chinese white poplar forest to conduct a point-to-point communication test. The specific performance indicators are as follows after repeated tests:

- The point-to-point reliable transmission distance within the forest is below 50 m
- The temperature can be monitored is between -40 and 60°C. The deviation is within 0.5°C. The humidity scope is between 0 and 100% RH and the deviation is not more than 4% RH (It is measured when the normal atmospheric temperature is 25°C)
- The maximum value of the outdoor point-to-point data transmission rate is about 250 kbit sec^{-1}, which is measured through the SmartRF evaluation platform
- Working life of the monitoring node can be as long as more than three years. According to the test, power consumption of the node under sleeping mode is about 2uA. Power consumption of the node when it is sending information is about 20 mA. The volume of the lithium battery this design uses is 500 mA. If its working life can reach more than three years, then its average daily power consumption has to be lower than 2 mA

ACCURACY TEST OF DATA COLLECTION

As important climatic factors, temperature and humidity of the air are the results of the combined effects of the climate background and the regional climate factors. Therefore, this paper takes the temperature and the humidity as the examples. The system uses the temperature and humidity sensor SHT10 to collect temperature and humidity of the environment. Through comparing results of the testing and data from the TES-1360 digital thermometer, the testing results show that the average temperature difference between the forest and the spare field is 1.3 and 0.2°C, respectively in July and December of the year 2012. The average value of the average daily temperature difference in July is obviously higher than that of December. The maximum value of the average daily temperature difference appears on 5th July. The average daily temperatures of the forest and the spare filed are 18.0 and 19.6°C, respectively, the difference of which is 1.6°C. The maximum value of December appears on 5th December. The average daily temperatures of the forest and the spare filed are -10.9 and -10.1°C, Tabele 2: Data acquisition accuracy test

Temp. °C		Humidity %RH	
SHT10	TES-1360	SHT10	TES-1360
21.06	21.1	61.45	61.5
22.15	22.2	61.16	61.2
21.07	21.1	61.64	61.6
22.24	22.2	60.97	61.0
22.28	22.3	61.57	61.6

Table 3: Stability test

Transmission times	Reception times	Transmission success rate (%)
3600	3589	99.69
3600	3598	99.94
3600	3595	99.86
3600	3596	99.89
3600	3600	100.00
3600	3595	99.86
3600	3599	99.97
3600	3593	99.81
3600	3599	99.97
3600	3594	99.83

respectively, the difference of which is only 0.8°C. Taking July December as the example, the results are set out in Table 2. It can be concluded that this system can collect the temperature and humidity in the monitoring area successfully and the testing results are within the normal measurement range. Compared with the traditional thermometer, SHT10 has some advantages over others in terms of precision of the collected data.

TEST OF STABILITY

Test of stability is aimed at testing the communication transmission reliability between the sensor and the coordinator. If ten temperature and humidity sensors are used to collect data, the time period is one second each time and the total time of data collection is one hour, results of the stability test are displayed in Table 3. It can be seen that if the sensor node and the coordinator node send data 3600 times, the average time of receiving data of the coordinator is 3596. Success rate of the transmission is 99.88%. Packet loss takes place during the transmission process mainly because environment in the forest is relatively complicated and transmission of signals is remarkably disturbed in the forest. But normal use of the system is not influenced. The system is still strong in stability.

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