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Forest fire monitoring system structure and node design based on wireless sensor network

Abstract. *Wireless sensor network is a new research field of computer sciences. Introduced some applications of wireless sensor networks in environmental monitoring; proposed a three-tier forest fire monitoring system and defined the main function of each layer; designed a portable wireless sensor network node, the module had advantages of volume small, portable, low energy consumption, easy maintenance, it's very suitable for the application in forest fire monitoring.*

Streszczenie *Nowym polem badań w informatyce są bezprzewodowe sieci czujnikowe (WSN). Znalazły one szereg zastosowań w badaniach środowiska. W opracowaniu zaproponowano trój-poziomowy system monitoringu pożaru lasu oraz zdefiniowano główną funkcję każdej warstwy. Opracowano przenośną stację węzłową WSN. Posiada ona szereg zalet: małe wymiary i pobór mocy, łatwość transportu i konserwacji. Jest bardzo odpowiednia do wykorzystania w monitoringu pożaru lasu.* ***Struktura systemu monitoringu pożaru lasu na podstawie bezprzewodowej sieci czujnikowej oraz projekt stacji węzłowej***

Keywords: Three-tier structure; Sensor network; Forest fire monitoring system; Portable
Słowa kluczowe: Struktura trój-poziomowa, Sieć czujnikowa, System monitoringu pożaru lasu

Introduction

Wireless sensor network has a promising future of application, such as ahostile area, agricultural field, biological habitat, field surveillance, home security. Integrated with sensor technology, embedded computation technology, distributed information processing technology, and wireless communication technology, the wireless sensor network is able to undertake real-time monitoring, sensing, and collecting of data of diversified environments or monitored objects to process data and transmit them to users who need such data. As a new field in the study of computer science, wireless sensor network has been in the reports of America's Business Week and Technology Review of MIT for forecasting the future technological development named as one of 21 most influential techniques in the 21st century and one of top 10 techniques that change the world.

In a study on the application of wireless sensor network where the author is a participator, an experimental platform is used to study the application of wireless sensor network in a complex environment for the building of a WSN-based environment monitoring information platform through the construction of WSN-based disaster prevention and mitigation system, demonstrating how the wireless sensor network can be applied to environment monitoring and disaster prevention and mitigation.

Related Works

In a survey for techniques popular in the coming 20 years in China, among 157 technical tasks of information sector 7 tasks have direct connection with the sensor network. The National Guideline on Long- and Medium-term Program for the Development of Science and Technology issued at the beginning of 2006 defined three directions for information technology, among them two directions have direct connection with the study of WSN, i.e., intelligent sensing technology and self-organizing network technology. WSN is one of the major industries to be developed on the agenda of China's 2010 Planning and "Tenth Five-year" Planning.

The sensor network with huge application value has been in the great concern of military departments, industrial and academic societies of many countries in the world. America National Science Foundation made a sensor network study plan in 2003, investing 34-million dollars for the support of related studies on basic theories.

Research institutes of Canada, Britain, Germany, Finland, Japan, and Italy have joined in the study of sensor network. "Information society technology", wherein WSN (Wireless Sensor Network) is involved, is one of the sectors to have prior development in the sixth framework plan of Europe Union.

Traditional environment monitoring system with computer-base information processing has been applied in extensive sectors. However, this kind of system has limitations for environment monitoring in deserts, high mountains, or forests where people can hardly reach. For example, the data collecting equipment cannot be installed, or the existing wireless or wired network cannot be used. WSN technology provides a new solution for environment monitoring[1]. A sensor node has certain computation capability and storage capacity and is able to undertake sophisticated monitoring following the change of the physical environment. The sensor network is suitable for diversified disaster prevention systems, for wireless data transmission can be carried out in self-organizing network style. WSN is applicable for the study on weather and geography, monitoring on natural and man-made disasters (such as flood and fire), monitoring on irrigation for crops, changes of weather, surroundings of domestic animals and fowls, and wide-spread land survey and tracing of rare birds, animals, and insects for the study of species in peril.

Successful cases of WSN application in monitoring system are the following. In ALERT plan of America, researchers developed several kinds of sensors to monitor rainfalls, river water level, and soil water, predicting the possibility of a torrential flood. In 2002 the Intel Lab of the University of California Berkeley joined with the Atlantic College in the deploying of WSN for monitoring the life habits of seabirds on island. The MateWel team of Harvard University applied WSN in the observation of the active volcano Volcan Tungurahua. In 2005 scientists of Australia surveyed the distribution of toads in North Australia using the sensor network. Scientists of Norway monitored the change of the Frozen River using WSN, aiming to deduct the changes of the global weather by analyzing the environmental changes of the Frozen River.

The most successful case is the "in-situ" project that uses the sensor network to monitor the eco-system of the island, jointly carried out by the Computer Department of the University of California Berkeley and the Atlantic College. A well-established WSN monitoring system covering several islands is used in more than 9 months' monitoring that got a great number of first-hand data. This experiment shows that WSN has evident advantages in outdoor environment monitoring.

Design for System Structure

The system framework of a typical WSN is structured by distributed wireless sensor nodes, data gateway, communication network, and system management node. The sensor node is responsible for transmitting the collected data along other sensors by hops. The multi-hop routing transmits data to the gateway, wherefrom by satellite or Internet transmission the data arrive at the management node, by which the user manages the sensor network, dispatches monitoring tasks, and collects monitoring data. WSN has integrated the functions of data collection, data fusion, and task scheduling.

The construction of particular-application-based WSN system can be designed using the following principles: The hardware should take into consideration the compatibility and universality; common types are preferred in choosing parts; the software design should take application into consideration and the features of WSN are to be integrated to have modularized design with functions, layers, and sub-modules detailed.

As shown in Fig. 1, the system we studied is logically divided into three layers: physical support layer, data management layer, and system application layer, as required by the study on application system.

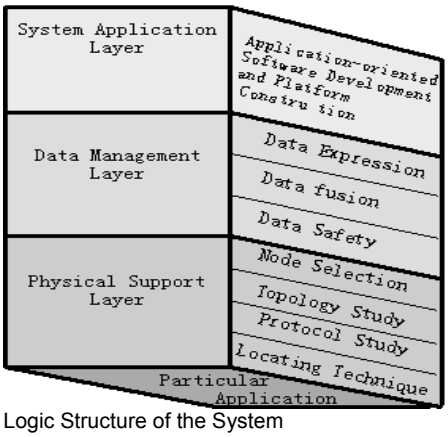

Fig.1. Logic Structure of the System

Physical Support Layer

The main tasks of the physical support layer are selection of node device, study of topology structure, protocol design, and locating technique study etc.

Device Selection: The main task of device selection is to choose a network node. The early node of integration of single-function chips has been developed into full-functional-chip-based node, which facilitates the construction and realization of WSN system.

Study of Topology Structure: Some nodes will enter a sleep state occasionally to save power, resulting in the constant change of the network's topology. In order to enable the normal running of the network, topology management shall be available to control the status conversion of the nodes to keep smooth communication in network for effective transmission of data[2].

Protocol Design: The communication protocols are for the physical layer, data link layer, network layer, transmission layer, and application layer. As generally the study of applications use accomplished nodes for network construction, the design can be carried out only for protocols of network layer, transmission layer, and application layer. The network layer is specialized in packet routing, network interconnection, and congestion control. The transmission layer provides data flow control in a reliable and rationalized transmission way. The application protocol shows its value in the application system.

Study of Locating Technique: Node locating is to determine the relative or absolute location of every node. During the application of WSN, an observer shall carry out responses to the monitored area based on the acquired data. For example, the temperature above 65℃ measured at somewhere of a forest shall initiate the movement to put out fire in the forest[3]. Therefore, data collected by nodes shall be used with additional location information in the coordinates. As nodes are distributed, data are useless when they are received without the information of node location. So it is critical to get the location information of nodes in the application of WSN.

Data Management Layer

The main tasks of the data management layer are data expression study, data fusion technique study, and data safety study.

Data expression study: The purpose of this study is to separate the logic view of data in the sensor network and the physical realization of the network, allowing the user and application of the sensor network only cares about the logic structure while neglecting the details of the sensor network. This technique is similar to the software middleware[4].

Data fusion technique: The data collecting sensor network should process multiple data or information to get more useful data that meet the user requirement. In this paper the data fusion technique used in the data-based sensor network is studied to behold the sensor as the sensing data flow or sensing data source, the sensor network as the sensing data space or sensing database, and the data management and processing as the target of network application.

Data safety study: Many safety policies and mechanisms of traditional network are not applicable to the wireless sensor network. We should design a new network safety mechanism using the techniques of spread-spectrum communications, access authentication and authorization, digital watermarking, and data encryption.

Fig.2. WSN nodes

System Application Layer

The main task of the system application layer is to carry out application-oriented software construction and information platform construction, providing objects to be operated by the user. The software design based on WSN disaster prevention system will combine the database technique and network technique seamlessly using the sensing data management and processing as the center. From the aspects of logic and hardware/software techniques a high-performance data-centered network

system is to be established to provide the user or observer with an effective sensing data space or sensing database management and processing system. Thus the user may manage and process the sensing data in the sensor network in a way similar to the use of common database management system and data processing system.

Design for Portable WSN nodes

In order to meet the requirements of forest fire monitoring, as shown in Fig. 2, we designed portable WSN nodes, the volume of the node is only like a matchbox, being quite portable; we have dealt with some following key issues in design process.

Basic format

The server interacts with the terminal equipment in the form of packets, as shown in Fig. 3, a complete command packet consists of three parts, beginning mark unit, command unit, ending mark unit. The data characters are all ASCII code. The length of beginning mark unit is 1 byte, indicating the beginning of a complete command packet. The command unit is composed by two parts of control command head and command body. The length of command control head is 6 bytes, consists of four fields of device address, command number, the length of command body. The analytical methods of command body and the actual length are determined by "device address", "command ID" and "command length" of the control part. The length of ending mark unit is 1 byte, indicating the end of a complete command packet.

Fig.3. The Command Packet Format

Data transfer requirements

Adopt UDP/IP communication mode, the packet length should not exceed 100 bytes. The terminal equipment takes the initiative to establish in a connection. The server receiving port number: 8500, Server IP is pre-configured.

Authentication

Whether it is functional module or control module, the authentication must be handled after receiving the data packet. The authentication processing includes the following links: beginning and ending marks validation, command No. validation, command data validation. If any of these aspects didn't pass the validation, then the authentication fails, and the receiver should response the error mark to the sender based on the actual situation.

Protection timer

In order to ensure the reliable reach of the messages or commands in the timing, the system uses a timer protection method. Prior to the receipt of the response, the main sender must set protection timer. The response received before the timer expires is an effective response; otherwise it is an invalid response.

Conclusion

Forest fire detection system based on wireless sensor network is a new application of the sensor network. With nodes of small size, the system has the excellences of on-line monitoring, cost-efficiency, and easy maintenance. In actual application many critical techniques, including node deploying, remote control, data sampling, and communication mechanism, are to be studied in particular for the sensor network has a strong correlation in application.

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