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Real-Time Data Acquisition and Monitoring System of Wireless Sensor Network Based on Topology Control Algorithm in Cluster

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The intra-cluster topology control algorithm is very effective as it can reduce the energy consumption of a network, and extend the use time and life of the network. This control algorithm has a very significant impact on the development of wireless sensor networks, and therefore has attracted much research interest in the area of control algorithms. Its calculation involves dividing the network many times, and extracting data from each level after the division. Then the data is encoded and, ultimately, transmitted to the sub-network. This algorithm has energy-saving properties unmatched by other control algorithms, as well as the best scalability. In addition, for some common nodes, it can be adjusted. This study focuses on the application of the topology control algorithm in the cluster for the collection and monitoring of network data. In particular, this algorithm is used to establish a very effective data collection and monitoring system, and improve the efficiency and energy-saving capability of wireless sensor networks.

Keywords: in-cluster topology control; wireless sensor network; real-time data; data monitoring

1. INTRODUCTION

Nowadays, data plays a very important role in most sectors of society, particularly with the advent of the big data era. Scholars and experts are paying more and more attention to data research, particularly in relation to the source of the data and the methods used for data collection. Because data can be derived from many sources, the method used for data collection must be highly efficient and ensure accurate outcomes [1]. Moreover, the emergence of the Internet of Things (IoT) has brought about significant changes in most areas of human endeavour, and has seen data becoming an inextricable part of the daily lives of many people, companies and organizations.

The rapid development of wireless communication technology has led to the improvement of sensor technology, the development of electronic technology, and the continuous innovation of wireless devices. Wireless devices have evolved into a new type of network that has the ability to sense and can be self-powered. This is known as a wireless sensor network (WSN) [2]. Advancements in wireless equipment have greatly reduced its cost, maximized its flexibility, and improved the use of wireless equipment in outdoor

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Table 1 Comparison of typical topology control algorithms.

Algorithm	Complexity	Connectivity	Location information requirements	Time synchronization or not	Node density	Network size
DRNG	Bureau	Connected	Not needed	No	Sparse	Big
DLSS	Bureau	Connected	Not needed	No	Sparse	Big
CBTC	Low	Connected	Need	No	Sparse	Big
LMA	Low	Not connected	Not needed	No	Sparse	Big
LMN	Low	Not connected	Not needed	No	Sparse	Big
LEACH	Medium	Connected	Not needed	Yes	Dense	Small
HEED	Bureau	Connected	Not needed	Yes	Dense	Big
PEGASIS	Medium	Connected	Not needed	No	Dense	Small
GAF	Medium	Connected	Need	No	Dense	Small

environments. It can adapt to almost all external environments; even data transmission and extraction can be carried out under extremely harsh conditions. At the same time, the advantages of a wireless sensor network are unmatched by other networks. Its cost is very low, and although the energy consumption is very high, it has strong environmental protection characteristics. Furthermore, current wireless sensor networks have a wide distribution range [3]. Wireless sensor networks are used in many fields as they can be adapted to various environments. They can be combined with various types of communication and information-receiving devices, which greatly improves the network's quality, capacity and life cycle, and extends the life of the network. This paper first briefly introduces the background and impact of this research, and then summarizes the current research status of the topology control algorithm in the cluster of wireless sensor networks, and explains the problems and trends of the topology control algorithm in the cluster. Finally, this paper introduces the main content and organizational structure of the research.

2. TOPOLOGY CONTROL ALGORITHM IN WIRELESS SENSOR NETWORK CLUSTER

2.1 Analysis and Comparison of Typical Topology Control Algorithms

The main goal of research on topology control technology is to improve its energy-saving characteristics [4]. First of all, while ensuring network connectivity, by constantly adjusting its transmission power and frequency and trying to reduce energy consumption to the minimum, the efficiency is maximized, and unnecessary network consumption is reduced.

2.1.1 LEACH Algorithm

The workflow of the LEACH algorithm is defined as:

$$T(n) = \begin{cases} \frac{p}{1-p\left(r \bmod \frac{1}{p}\right)} & n \in G \\ 0 & other \end{cases} \quad (1)$$

2.1.2 HEED Algorithm

The HEED algorithm can receive messages from neighbor nodes. The process is as follows:

$$CH_p = \max\left(\frac{C_p E_r}{E_m}, p_{\min}\right) \quad (2)$$

2.1.3 GAF Algorithm

The conditions for the nodes of the GAF algorithm to communicate with each other are:

$$r^2 + (2r)^2 \le R, \quad r \le R/\sqrt{5} \quad (3)$$

2.1.4 Algorithm Performance Comparison

Here, we summarize and analyze the complexity, connectivity, time synchronization, node density, and network scale of the above algorithms. The specific comparison parameters and content are shown in Table 1.

The position of the node plays a very important role in the calculation process of the algorithm. Table 1 above shows that the GAF algorithm is suitable for node data with a relatively small calculation scale, and at the same time, it is very dependent on the acquisition of node location information. The HEED algorithm is compared with the GAF algorithm [5]. The dependence on the location of node information is relatively low and its shortcomings are also very obvious: the complexity is very high, and the accuracy of the algorithm is very low and excessively dependent on time.

2.2 Design Principles of Cluster Topology Control Algorithm

The most important step in the design of the clustering topology control algorithm is the choice of cluster head. This choice influences the progress of the clustering topology control algorithm and its effect. At the same time, it affects the wireless sensor network. In the design process, the use time and life cycle of the network should be extended as much as possible [6]. First, the importance of cluster heads should be continuously increased, and the positive correlation between the cluster heads and the remaining amount of energy

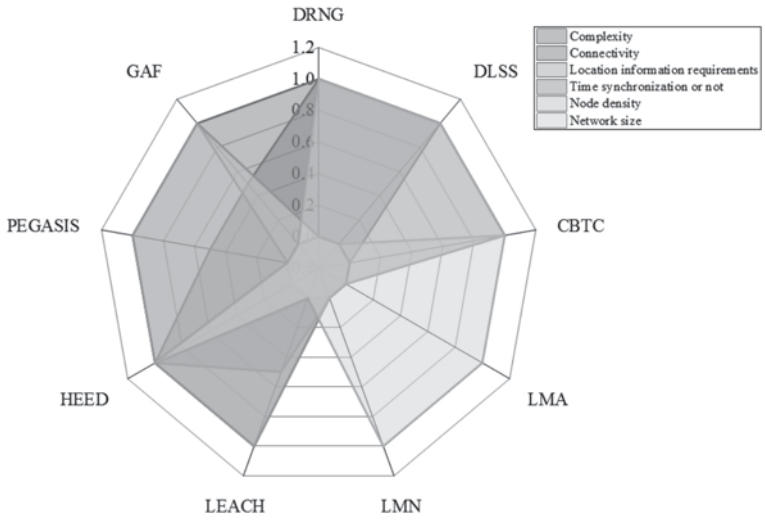

Figure 1 Comparison of typical topology control algorithms.

should be ensured as much as possible to guarantee the performance of the wireless sensor network. At the same time, when one cluster head is connecting with another, it is necessary to ensure that there is as much remaining energy as possible, so that the stability of the wireless sensor network can be guaranteed, the use time of the control algorithm can be guaranteed, and the data can be further improved [7]. The relationship between the cluster head and the remaining energy must be determined in order to guarantee the quality of communication in terms of speed and efficiency. In the design process, the cluster head has a very important position, together with the location and time information of the node. This means that the node as well as its distance from the cluster head should be kept within a controllable range [8]. If the distance between the two is beyond this controllable range, the probability of the node entering the cluster head is very low. In other words, the distance between the node and the cluster head indicates the probability of the node entering the cluster head. The greater the distance, the lower is the probability of entering the cluster head, which means that the stability is relatively poor, and energy consumption will increase.

2.3 Design of Topology Control Algorithm in Cluster

The region segmentation parameter t of clustering is defined as:

$$t = \left[\frac{Np}{2}\right] \tag{4}$$

2.3.1 Topological Structure Establishment in the Cluster

The existing topology control algorithm is defined as:

$$ED(i, j) = \frac{Ploss(i, j)E_0(j)}{E_r(j)} \tag{5}$$

The definition of the imported node id is:

$$W(i_1, j_1) < W(i_2, j_2) \Leftrightarrow ED(i_1, j_1) < ED(i_2, j_2) \\ \&\& \min\{id(i_1), id(j_1)\} < \min\{id(i_2), id(j_2)\} \tag{6}$$

2.3.2 Selection of Cluster Head

The remaining energy threshold is defined as:

$$E_{th} = \left(\frac{r_{\max} - r_{cur}}{r_{\max}}\right) E_0 \tag{7}$$

The predicted maximum number of network work rounds can be expressed as:

$$r_{\max} = \frac{E_{int}}{E_{each}} \tag{8}$$

With reference to the topology, this section analyzes the network energy consumption per round of each reference topology. The related parameters are shown in Table 2.

Therefore, the energy consumption of each round of the network can be expressed as:

$$E_{each} = \frac{E^1_{each} + E^2_{each}}{2} \tag{9}$$

The MCHTC algorithm expression is:

$$Q(i) = \frac{E_r(i)}{d_{toBS}(i)} \tag{10}$$

3. DESIGN AND IMPLEMENTATION OF REAL-TIME DATA ACQUISITION AND MONITORING SYSTEM FOR WIRELESS SENSOR NETWORK

3.1 System Function Analysis

The main function of this system is to collect and monitor real-time network data; this is done through the wireless sensor

Table 2 Network energy consumption analysis related parameters.

Parameter	Parameter meaning
m	Number of cluster heads
E_{Tx}^{ch}	Energy consumption when the cluster head sends data packets
E_{Rx}^{ch}	Energy consumption when receiving data packets generated by the cluster head
E_{Tx}^{bs}	Energy consumption when the cluster head sends data packets to the base station
E_{Tx}^{in}	Energy consumption of nodes in the cluster when sending data packets
E_{Rx}^{in}	Energy consumption when receiving data packets generated by nodes in the cluster
E_{fuse}	Total energy consumption during packet fusion

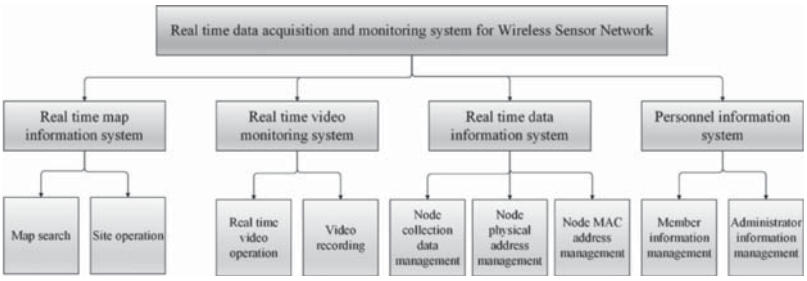

Figure 2 System function framework.

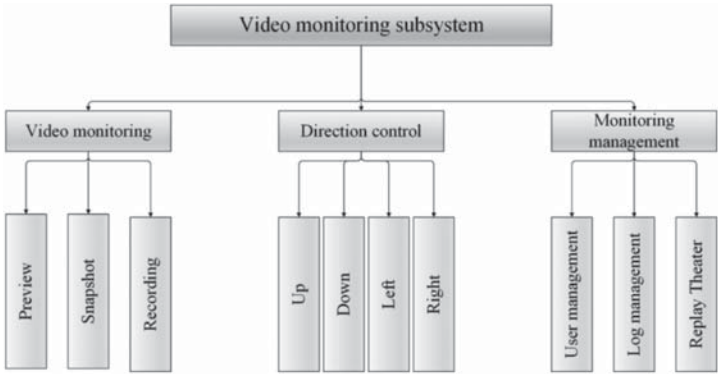

Figure 3 Schematic diagram of the functional structure of the video surveillance sub-system.

network as shown in Figure 2. During the collection and monitoring of data, there is a certain dependence on geographic location, so it is necessary to integrate a geographic information system to continuously determine a specific geographic location or geographic environment [9]. At the same time, this can be combined with the Internet to provide ongoing updates of real-time video surveillance. Hence, video surveillance and geographic information systems are combined so that real-time network data collection and monitoring across distances can be achieved, and users can watch real-time video surveillance images from a distance.

This system can take screenshots, and record and store real-time video recordings. Users can observe everything in the monitored area through this system. This system comprises video surveillance, direction control and surveillance management functions [10]. The direction of the real-time video can be adjusted, allowing the user to watch things from different angles. At the same time, users can manage the real-time monitoring of what they watch, and they can also play back surveillance videos. The video surveillance process is shown in Figure 3.

3.2 System Database Design

The real-time video monitoring sub-system is a network system. The user determines whether there is a camera and, after determining the specific location, clicks on the camera and accesses the video sub-system in real time. The user can transfer, pause, take screenshots, etc. in real time. Also, videos can be recorded in real time and saved locally. The next time the user wants to see the file, it can be dragged directly to this video sub-system so that it can be viewed again. The system database design comprises the following:

3.3 System Construction and Realization

3.3.1 System Development Environment

This study uses Windows+Apache+Mysql+Php (WAMP) to build a database, which can then be used to build a network server. During the software development and design process, each software must be independent and

Table 3 User table

Field content	Field Name	Type of data	Is it empty	Remarks
User ID	user_id	Varchar(12)	Not null	PK
Username	username	Varchar(40)	Not null	username
Password	password	Varchar(20)	Not null	MD5 encryption
Registration time	registration time	Datetime	–	Year month day hour minute second
E-mail	email	Varchar(50)	Not null	E-mail
User type	type	Varchar(1)	Not null	0 means administrator 1 representative member

Table 4 Node information table.

Field content	Field Name	Type of data	Is it empty	Remarks
ID	ID	Varchar(20)	Not null	PK
Node MAC address	MAC	Varchar(50)	Not null	–
Node physical address	address	Varchar(50)	Not null	–
Remaining battery	battery	Varchar(20)	Not null	With unit
Temperature	Temp	Varchar(20)	Not null	With unit
Humidity	humidity	Varchar(20)	Not null	With unit
Light intensity	sunlight	Varchar(20)	Not null	With unit

Table 5 Camera information table.

Field content	Field Name	Type of data	Is it empty	Remarks
ID	ID	Varchar(20)	Not null	PK
Camera name	Name	Varchar(50)	Not null	Model
Camera physical address	address	Varchar(50)	Not null	–
Camera open time	Opentime	Datetime	Not null	Year month day hour minute second
Camera off time	Closetime	Datetime	Not null	Year month day hour minute second
Whether to show	Show	Varchar(1)	Not null	0 means not shown 1 means display

not interfere with another, although it must be compatible [11]. An attempt should be made to combine the use value of the software with the use efficiency is increased to the maximum, the development environment of the system is constantly improved, and the efficiency of system construction is improved.

3.3.2 System Development Tools

The development language selected by the system is PHP which is a scripting language. It places HTML files on the server side. It has both user-oriented Java language and process-oriented C language. This is an important advantage of PHP language. Given the characteristics of the Chinese language, it is easy to learn and is becoming more widely accepted by the general public. PHP makes it easy to store, update and obtain information, especially when used with Apache [12]. The later version is based more on MysQL. There is a complete MysQL function in PHP which can expand the database, facilitating the establishment of a database-based dynamic website and the consolidation of MysQL.

Codeigniter is a flexible PHP framework with many functional modules and great flexibility that users like. It also has a rich standardized database, simple interface and logical structure, and is generally compatible with various versions and configurations of standard hosts. Codeigniter is based on the MVC design model. C represents the driver, which is the core of the entire application and decides how to handle the application.

3.3.3 System Realization Process Based on The Topology Control Algorithm in The Cluster

There are multiple nodes in a wireless sensor network, and many different nodes are often distributed. When applying the control algorithm, firstly, the nodes should be classified and then grouped into different clusters according to their characteristics. Nodes form different clusters, and each cluster will have an independent cluster head. The clusters are independent of each other and do not affect each other; however, the nodes can communicate [13] and transmit data through the multi-hop mode, which can greatly improve the efficiency and effectiveness of data transmission. The main function of the cluster head is to process the cluster nodes. Data transmission occurs when one cluster head connects with another; hence, the data notes are being merged continuously. Figure 4 illustrates this process.

3.4 System Realization

The main function of the homepage is to provide users with registration and login functions. After registering personal information on the homepage, users can log in to their personal accounts. They can view real-time video surveillance of their personal accounts, but the user has the right to real-time video recording. Restricted to viewing and browsing, only the administrator can change the real-time surveillance video [14]. The administrator can adjust and control the

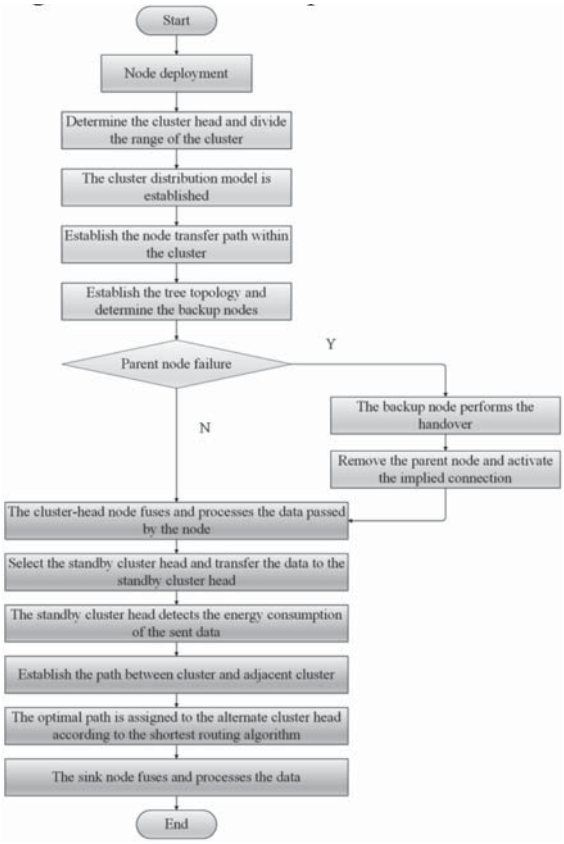

Figure 4 System realization process based on topology control algorithm in cluster.

transmission speed of the real-time video through wireless sensors and the network. At the same time, the administrator can also change the user's information. When the user forgets the registered password or registered account, s/he can contact the administrator to change it promptly. The personal information administrator can also view and edit the user's camera and node information. Any wrong information can be deleted and changed. Most importantly, the administrator has the authority to change the user registration and login information through wireless sensors [15]. The network greatly improves the node processing capacity of real-time video, while simultaneously expanding the storage capacity. The administrator can access the video through this network. Any rainy and unnecessary information in the file is deleted. At the same time, users browse real-time video monitoring through the wireless sensor network to make the traffic consumption very even. Because the wireless sensor network has the hierarchical characteristics, the subsequent technical maintenance is more convenient, and the subsequent algorithm update will be more convenient and convenient.

The administrator's authority is executed through the privilege.php controller, to which only the administrator has access [16]. The user cannot access the controller. The administrator receives a verification code when entering the controller, and needs to input the verification code correctly on the controller before they can enter. This controller needs the CAPTCHA function in order to run. If the user information is incorrect, the administrator is contacted promptly. The controller transmits the incorrect user information to the administrator, and the auxiliary function determines whether the user's data complies with the rules; if it does not, it is handed over to the administrator to change [17]. The real-time video monitoring of this system is done through the wireless sensor network, and the video information is updated through the continuous update of nodes. The administrator edits and changes the video information. The efficiency of this system is better than that of the general system. It provides improved and faster transmission and better user experience.

4. CONCLUSION

Topology control technology can optimize the selected target, strengthen the system structure, and form a new type of network structure. At the same time, through ongoing maintenance and strengthening of this network structure, the life cycle and service life of the network can be improved. Moreover, the energy consumption of this network structure can be reduced, and other energy-saving characteristics can be improved, together with the network's efficiency. This paper examines wireless sensor networks and their control algorithms, and studies data collection and monitoring. The topology control technology is examined in terms of: i) power and ii) clustering. By continuously strengthening and optimizing the topology control structure, we can further reduce the power consumption of the topology control technology thereby improving the energy-saving features of the topology control technology. When clustering, the first step is to establish a backup node, which can improve the processing capability of the topology control technology on

the node, reduce the dependence of the control algorithm on the node information location and the dependence on the node time, and improve the storage capacity of the topology control technology.

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