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A Review for Forest Fire Monitoring in Wireless Sensor Networks

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Abstract: Due to the occurrence of global warming forest fires more frequent, the damage caused was shocking in recent years. In order to reduce this natural disaster, forest monitoring as an important part of forest fire prevention, which is also more valued by the public and adopts the wireless sensor network as a new type of monitoring methods. This system can form a large range of real-time detection network throughout the sensing nodes, provide great convenience for protective workers. However, this technology still has some drawbacks, such as the endurance ability and the accuracy of locating the fire source, so this paper analyzes the problem, and provides a solution.

Keywords: Wireless sensor network, forest fire, accuracy, energy.

1. Introduction

Forest is biological communities dominated by woody plants, is known as the "lung of the Earth" for its important functions. In recent years, China has paid more and more attention to forests protection, and the concept of "Lucid waters and lush mountains are invaluable assets" has been deeply rooted in people's hearts. Forest fire is a sudden and destructive natural disaster, and due to global warming, the fire situation in various countries tend to increase. The 2019 Australian wildfires killed 3 billion animals and more than 30 people, and economic losses were hard to estimate; California burned more than 12,500 square kilometers in 2020, breaking the historical record. The occurrence of forest fire not only brings serious economic harm, but also leads to soil erosion and air pollution, which cause great positive impact to the natural environment.

Because of the hazards of forest fires, in order to reduce the losses caused by such disasters, early monitoring of forest fires is an important preventive measure, and many countries around the world use tools to monitor and protect forests. The United States has used the Earth satellites to monitor hot areas, smoke areas and fire remains on the ground, supplemented by drone warning, which is successful but has the disadvantage of huge cost. In most areas of China, the combination of ground patrol and observatory monitoring is generally used, but easy to be limited by the influence of environment and vegetation factors, as the natural environment such as fog and night or dense vegetation prevent regulators from detecting the initial burning phase of wildfires in time, result in missing the best extinguishing time and increasing disaster losses. Compared with the traditional forest fire prevention monitoring methods, the WSN-based technology has the advantages of good real-time performance, wide coverage area, and all-day monitoring.

2. Wireless Sensor Network

Wireless sensor network (WSN), as a new technology, is composed of a large number of nodes in a self-organization and multi-hop way, and has data collection, communication and other functions, which has been able to be applied in the military field and environmental monitoring. In the forest environment, a large number of battery-power nodes will use different types of sensors to monitor a range of environmental factors such as humidity, temperature, and wind speed, then upload the collected information to the terminal device through the fire related algorithm to analyze data, determine whether a forest fire, finally send the conclusion and location information to the staff, greatly reduces the preliminary work for fire discovery[1].

Although the wireless sensor networks have certain advantages in forest fire monitoring, it is undeniable that this technology still has some disadvantages in its applications, such as the problems of a long system monitoring cycle which often need several years, it requires the network endurance and power saving capacity to put forward high requirements. What's more, in the complex forest environment, there is a higher demand for the accuracy and efficiency to position the source of fire. Therefore, when designing a forest detection system based on the wireless sensor network, we need to consider many factors and requirements.

3. Wireless Sensing Network Power-saving Technology

3.1. Communication Technology

In the forest fire monitoring system, facing a large range of forest monitoring area need a huge number of sensing nodes to maintain the system coverage area. After collecting the forest data, the system transmits the processed data to the terminal device through the method of multiple jump. When a node runs out of power, because of the long distance and harsh environment, it is very difficult to replace the battery. Therefore, in order to avoid this problem to the greatest extent, adopting new communication technology is one of important solutions, and Zigbee technology is an appropriate choice.

In fire monitoring system, it is beneficial to use the Zigbee technology to transmit information from the nodes. This is a short-range wireless communication technology works in the 2.4GHz, 868 MHz, and 915 MHz frequency bands. In the Zigbee wireless sensor network, there are three types of

devices: Zigbee End-device, Zigbee Router, and Zigbee Coordinator.

(1) Zigbee End-device(ZED): It is the only network device with the largest number of technology in the system that allows low power consumption. Each node is equipped with multiple sensors to transmit the collected data to the coordinator or router. Some nodes are also loaded with GPS positioning to serve as beacon nodes, which provide location information for surrounding nodes.

(2) Zigbee Router(ZR): It plays an important role in information forwarding and assisting coordinators in maintaining the network.

(3) Zigbee Coordinator(ZC): It's the only one, and is the core of the network, play an necessary role in construction and maintaining the network, managing all nodes in the network, which is a parent node with the highest level.

Table 1. Comparison of common wireless communication methods

Common wireless communication methods	Number of nodes	Consumption	Cost	Communication distance	Life	Working frequency
WiFi	About 20	high	high	About 50 meters	5 years	2.4G
Bluetooth	About eight	middle	low	About 10 meters	7 days	2.4G
ZigBee	More than 60,000	low	low	50-200 m	0.5-3 years	868MHz、915MHz、2.4G (Chinese)
NB-IOT	50,000-100,000	lowest	low	About 15km	10 years	Operator frequency band

From table 1, in short distance communication technologies: WiFi, Bluetooth and Zigbee, ZigBee has significant advantages. Its power consumption and cost are the lowest of three, has the longest communication distance, have the ability to expand the detection range as far as possible and reduce the number of node needed. What's more, it is also suitable for the life span, thus becoming a widely used technology in forest fire warning system. For example, ZigBee was used to establish a a real-time forest fire monitoring and early warning system based on wireless sensor network, which can provide important decision support for fire fighting [2]. And ZigBee End-devices equipped with sensors to obtain environmental data and upload it to the Cloud Platform to achieve the purpose of intelligent control, which had remarkable results [3].

3.2. Accuracy of the Wireless Sensor Network

In forest fire monitoring system, it is very important for sensor nodes to position wildfire combustion point. As we known, we can't deal with a fire without knowing its location, and fire data which is lack of location is meaningless. Thus the higher accuracy makes the forest fire data more valuable, it can also further improve the efficiency of forest ranger, reducing the economic and natural losses. So in the construction of wireless sensor network, how to improve the accuracy of positioning is an important reference point. In the operation of the system, it mainly depends on the location of the nodes to locate the fire location, supplemented by the positioning algorithm of the node to locate the fire position, therefore improving the accuracy of the relevant algorithms can improve the accuracy of the wireless sensor network.

Algorithm refers to the strategy mechanism to solve a problem in a systematic way. When the fire data are collected, sensor nodes will calculate the location of fire source according to algorithm combined with the location information of several nodes, and finally feedback on the terminal device. Wireless sensor networks have a wide variety of localization algorithm. Based on whether related to distance, they can be divided into distance-based localization algorithm and distance-independent localization algorithm, such as the DV-Hop algorithm is a distance-independence localization algorithm, then RSSI ranging technology was used to correct the average jump distance, and this method improved the algorithm and increased the positioning accuracy of the calculation [4]. The common criteria for judging algorithms: the precision of positioning, node energy consumption, node density and so on. Because each algorithm has their different advantages, in order to develop strengths and avoid weaknesses, it is essential to improve algorithm. Such as Zizhao Zhao and Honglei Wang reported an improved cluster routing algorithm, which can reduce the energy loss of network nodes and extend the working cycle [5]. What's more, Honghong Zhang et al. used the improved nuclear fuzzy clustering algorithm to obtain the specific location of the ignition point, realizing the real-time monitoring of forest fire and the automatic identification of fire points, which has the effect of high sensitivity and accuracy [6]. Fire prediction is also an important part for forest management. For example a forest fire method based on machine learning was reported by H Zhou et al. to evaluate the forest fire hazard index [7].

Sensor nodes can not always operate normally all the time and will cause some failure because of internal and external reasons, finally transmit the wrong data. However, the network is unaware of this situation, accepting information as usual and may eventually result in the consequences of serious positioning accuracy, so we can use the algorithm that can check the fault nodes. Such as fuzzy logic for calculating nodes and fire probability, trying to minimize the generation of error and improve accuracy [8].

4. Conclusion

The wireless sensor network needs to lay the sensor nodes within the forest range to be detected under the premise of ensuring the electricity quantity, it can effectively monitor the location data of the forest fire, and the collected data can be reflected on the terminal equipment through communication technology, which greatly reduces the reaction time and improves the work efficiency. Moreover, in the face of the complex forest environment and harsh natural weather conditions, compared with the traditional forest fire monitoring, WSN has some advantages. However, because of the characteristics of this technology, lead to the increasing requirements for the types and accuracy of communication technology, which has become the focus of attention and discussion.

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