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Road Information Monitoring System Design Based on Wireless Sensor Networks

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Current statistics show the main reason for road traffic accidents within China is the change in weather conditions. Poor weather conditions are more likely to threaten people's lives. Therefore, road traffic management must be improved, monitoring equipment should be installed on roads, and changes in weather conditions and road conditions must be monitored in real time to prevent these accidents. Through specific research and practices, weather changes along the expressway can be monitored by building wireless sensor networks, effectively reducing the probability of traffic safety problems. With the development of Internet technology and the popularization of data networks, people's lives have become increasingly convenient. The construction and development of the logistics network is the main way to promote the rapid circulation of products, and the construction and improvement of highway infrastructure is an important measure to ensure the smooth operation of the logistics network. Analysis shows China's highway construction has not formally provided assistance for the development of the logistics network, mainly because the construction of the highway road monitoring system is not perfect, and a complete highway operation and inspection system has not been formed.

Keywords: Wireless sensor network; Road information; Information monitoring; System design

1. INTRODUCTION

In the process of social and economic development, the construction of the transportation network is directly related to the speed of circulation of various products, and the construction of the transportation network is the foundation of China's economic development. The construction of a modern transportation network guarantees an improvement in the level of modern economic development. In the next development process, there is a need to build a more complete logistics network to improve the level of China's economic development.

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2. PRINCIPLE ANALYSIS OF WIRELESS SENSOR NETWORKS

2.1 Key Technologies of Wireless Sensor Networks

Monitoring the operation of the highway by establishing a complete wireless sensor network is the main means to improve the construction of the highway network. The wireless sensor network relies on a variety of technologies to achieve this, including sensor monitoring technology, communication network technology, an embedded computing mode, computer network technology and programming technology. In the actual application process, it is necessary to use the appropriate routing technology, accurate positioning technology, energy management mode, and data fusion method, etc. according to the characteristics of the highway operation in order to improve the safety of the highway network construction.

2.1.1 Routing

When setting up a monitoring system, the choice of routing nodes is very important. The process of routing node selection is to select a node that can actually carry out data transmission between the source node and the terminal node, and specifically select a suitable path for data transmission [1]. In order to select the appropriate data transmission node, routing algorithms can be used to calculate the transmission properties of different nodes.

2.1.2 Positioning Technology

To monitor the operating status of the highway, positioning technology is needed to locate and analyze different objects on the highway. The wireless sensor can collect the image information of the object movement on the road surface, and can judge the direction and state of the object movement by extracting relevant data. In addition, wireless sensor technology is also the main technology for monitoring road safety accidents as it can monitor road operation in real time. If an accident occurs, the time and place of the accident can be sent immediately to authorities, so that rescue activities can be carried out

2.1.3 Energy Management

By analyzing the application ability of the network system in practice, it can be known that the node computing capacity of the network system is limited during the application process, and the running time of the network system is relatively short [2]. Therefore, the issue of the energy requirements needs to be solved when designing a new system. To solve the energy usage problem of the sensor, it is necessary to manage its power supply as the battery life determines the standby time of the sensor.

2.1.4 Sensor Fusion

The technology of sensor fusion has recently begun to appear in people's field of vision, both in research and practice. Using this technology, people can realize the real simulation of the brain's operating environment. By observing the simulation results, people can intuitively know what the brain sees and listens to. The sounds you hear, the smells you smell, and the reaction to things you touch. During the early development of sensor technology, people applied sensor technology to the military field, and used this technology to improve the military's equipment level and improve the military's overall combat capability. In the long-term development process, people began to realize the importance of sensor fusion technology to social development and began to apply this technology to a wider range of fields [3]. Through long-term research and practice, sensor fusion technology has been applied to fields such as automatic control, intelligent monitoring, and air traffic control, which has brought more opportunities and a broader space for the development of different fields. The main principle of the application of sensor technology comes from the basic ability of the human body in the development process. In order to highlight the advanced nature of this technology, researchers have conducted in-depth studies on the information collection process shown in people's daily activities [4]. The process of processing external information according to its own needs and acceptance is actually the working principle of multi-sensor fusion technology. The different sensor combinations included in the multi-sensor technology are equivalent to the human body's information-receiving organs. The human body perceives external information through its eyes, ears, nose, and limbs, and then transmits the sensed information to the brain for processing. The brain processes the information. The result of the processing is actually a direct reflection of the things that people touch. The working principle of sensor technology is the same. The sensor receives external information and transfers the information to the central processing unit for corresponding processing. Through the fusion of information, some unevenly distributed information can be supplemented, so that the analysis can be made [5]. When using sensor fusion technology to analyze data, the process of data fusion can fill in the missing data of the analyzed things, extract effective information that is conducive to the description of things, and use the data collection advantages of multiple sensors to improve the description of things, and the degree of accuracy and reliability.

Throughout the entire sensor network, each sensor has its own clock, which leads to time errors when performing unified analysis. In order to keep the time of each sensor consistent, different algorithms need to be used to adjust the sensor's clock so that the time of each sensor is synchronized.

2.2 Road Information Monitoring Technology

With the continuous development and progress of society, many scientific and technological advances have begun to be applied to people's daily life, providing convenience within their life and work. In the long-term development process, people began to realize the importance of wireless sensor fusion technology to social development, and began to apply this technology to a wider range of fields [6]. Through long-term research and practice, wireless sensor fusion technology has been applied to the fields of automatic control, intelligent monitoring, and air traffic control, which has brought more opportunities and a broader space for the development of different fields. The main principle of the application of wireless sensor technology comes from the basic abilities of the human body in the development process. In order to highlight the advanced nature of this technology, researchers have conducted in-depth studies on the information gathering process shown in people's daily activities. The process of sensing external information and processing it according to its own needs and acceptance is actually the working

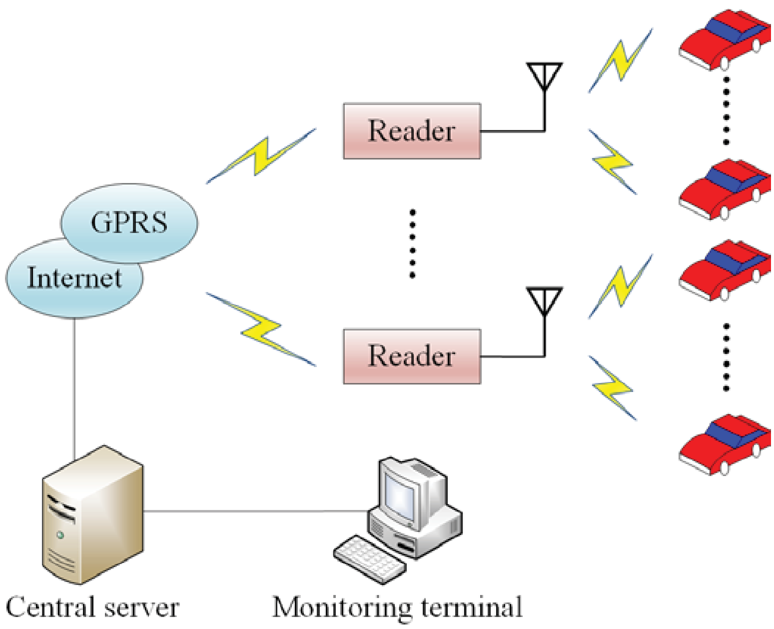

Figure 1 Overall architecture of urban traffic flow information monitoring system.

principle of wireless sensor fusion technology [7]. In the wireless sensor technology development process, a certain wireless sensor network needs to be established in the computer system, and the information and data collected by the wireless sensor are used to optimize the relevant functions of the wireless sensor network. Specific research and analysis shows that the construction of a wireless sensor network is a new network platform that integrates traditional wireless sensor network construction and cognitive radio technology [8]. The cognitive wireless sensor network can determine the position of the spectrum hole in the signal frequency band through the system. Once the location of the spectrum hole is determined, the cognitive wireless sensor network can access the communication network and realize the communication connection between the network and the frequency band. In the process of data collection and analysis, the collected data needs to be processed uniformly in the data collection module. After processing, the specific needs of the research can be reached. By analyzing the application ability of the network system in practice, the node computing capacity of the network system is shown to be limited during the application process, and the running time of the network system is relatively short. Therefore, the energy requirement of the system needs to be considered when designing a new system [9]. Through specific research and analysis, it can be shown that the use of wireless sensor networks to realize the design of the monitoring system of highway road operation can improve the node computing power of sensor networks and increase the running time of the system. When designing the system, the variable weight of the signal-to-noise ratio is introduced in the system design through the analysis of the energy detection model to perform weighted detection on the energy reserve and use of the system; and the system can be optimized through this detection. Actual detection shows that the use of the energy detection model can improve the performance of network detection.

In order to reduce the occurrence of road traffic safety accidents, it is also necessary to analyze the structure of the road. The content of the analysis includes destructive experimental analysis and non-destructive experimental analysis. The first type of experimental analysis is mainly carried out indoors. It evaluates the pressure bearing capacity of the road by simulating the construction of the road [10]. In order to improve the reliability of road structure analysis, sensors are placed inside the road structure during construction, so that the load-bearing condition of the road can be monitored.

3. DESIGN AND IMPLEMENTATION OF ROAD INFORMATION MONITORING SYSTEM

3.1 Overall System Architecture and Working Principle

When designing the system, it is necessary to install a radio frequency identification (RFID) reader on the road, and all vehicles driving on the road should also be affixed with RFID tags [11]. When monitoring vehicles on urban roads, a variety of monitoring technologies need to be used to assess the safety of vehicle operation. The main structure of the system designed in this article is shown in the following figure:

Radio frequency identification technology is a kind of wireless identification technology, which can identify the relevant data of the target through the reception and identification of radio signals, and write the identified data into the system. Through the identification of the data by the system, the mechanism between the system and the target can be established [12]. This technology can accurately identify and analyze fast-moving objects, and has been widely used in the process of vehicle operation monitoring. As long as RFID

Table 1 Route establishment package.

Package type	Origin ID	Sending station ID	Information bit	Check Digit	Hop count

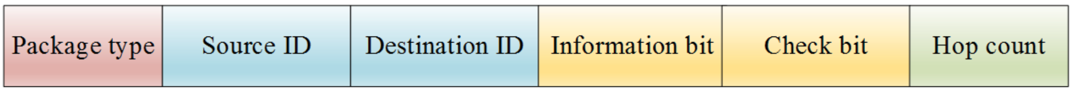

Figure 2 Schematic diagram of route establishment packet format.

Table 2 Sensor node routing table.

Destination base station	Neighbor node number	Time stamp

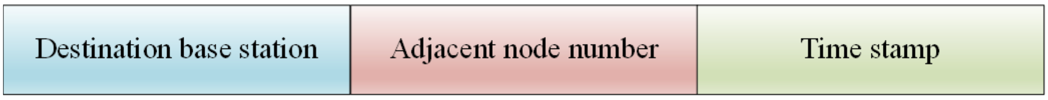

Figure 3 Schematic diagram of sensor node routing table format.

tags are affixed to all passing vehicles, all vehicle information can be identified, and the monitoring terminal can receive the specific conditions of the vehicle's operation.

3.2 Road Information Monitoring System Wireless Sensor Network Routing Realization

To establish a complete highway monitoring network, a network route must first be established. The establishment of the route requires the base station to send a data request packet to the network control center. The sending format is as follows:

If the package type of the data packet is 0, it means that the packet is a route established packet. If the type of the data packet is 1, it means that this packet is a data group of the query type. The source name is the specific number of the data packet sent by the base station. The base station will group packets according to the distribution of sensor nodes. After the node receives the routing packet, it will adjust its routing table. The format of the routing table is shown in the following figure:

3.3 Time Synchronization Algorithm of Wireless Sensor Network

In the entire sensor network, each sensor has its own clock, which leads to time errors when performing unified analysis. In order to keep the time of each sensor consistent, different algorithms need to be used to adjust the sensor's clock so that the time of each sensor is synchronized [13]. A specific time synchronization algorithm is mainly used in practice to standardize the timetable of each sensor. The algorithm is convenient to use, without too many calculation steps, and it can ensure that the time of each sensor is synchronized. In the process of adjusting time, the time synchronization algorithm can only adjust a small range of sensor nodes. Therefore, the TPSN algorithm has been introduced to synchronize the time of each node. The processing principle is as follows:

$$\Delta T = [(T2 - T1) - (T4 - T3)]/2 \quad (1)$$

$$d = [(T2 - T1) + (T4 - T3)]/2 \quad (2)$$

3.4 Road Information Monitoring System Simulation Scheme

By analyzing the process of the wireless sensor network in the process of highway weather detection and safety accident detection, it can be seen that the wireless sensor network is connected through multiple sensor nodes to perform specific detection and analysis of highway operating data [14]. In the analysis process, the sensor node will transmit the data information collected by itself to the base station, so that the overall situation of the road can be grasped. In the simulation experiment, only the sensor nodes near the two base stations need to be selected for the experiment.

4. SYSTEM SIMULATION RESULTS AND EVALUATION

4.1 Early Warning Information Level and Release

In the process of monitoring and analyzing the meteorological information of highway sections, it is necessary to establish a meteorological early warning system [15]. This system can be based on the corresponding information issued by the local meteorological department and combined with the changes in the meteorological conditions during the road transportation. In the specific implementation process, researchers divided the early warning information into different levels according to the degree of impact of meteorological changes. The specific situations are shown in the following table:

Table 3 Classification of early warning levels of the visibility impact on highway traffic conditions.

Warning level	Classification	Information Sources	Impact on road traffic
Level 1	<50m	Real-time observation, 3–6 hour forecast	The weather conditions for driving are extremely poor, vehicles must leave the foggy section and the highway is closed. Measures: Provide alarms for business personnel and travellers, take measures to restrict travel, notify business personnel and maintenance personnel, use carbon dioxide to disperse heavy fog and other measures.
Level 2	(50, 100) m	Real-time observation, 3–6 hour forecast	The driving weather conditions are very poor and the vehicle is running at a low speed. This has a greater impact on driving safety. Measures: Provide early warnings for business personnel and travellers, put in place speed or travel restrictions, notify business personnel and maintenance personnel, and use carbon dioxide to disperse heavy fog.
Level 3	(100, 200) m	Real-time observation, 3–6 hour forecast	The driving weather conditions are poor, and the vehicle should slow down appropriately, this will slightly affect driving safety. Measures: Provide early warning for business personnel and travellers, take prescribed actions such as limiting speed.
Level 4	(200, 500) m	Real-time observation	The driving weather conditions are poor, and the vehicle should slow down appropriately.

4.2 Traffic Meteorological Travel Index

By analyzing the meteorological change information collected by the sensors, researchers can predict the meteorological changes in the road operation process and provide people with some travel suggestions. Depending on the degree of impact, travel indicators will also change. The criteria for determining indicators are shown in the following table:

The description of the comprehensive index levels of traffic weather travel is shown in the following table:

4.3 Evaluation of road interruption status

By analyzing the collected data, the specific situation of road interruption can be judged, and the transportation department can determine whether to advise drivers to pay attention to safety based on this judgment. The specific calculation method is as follows:

① Road section interruption status

This state mainly describes the safety state of the road. If the road is in a connected state, then vehicles can be allowed to pass normally; if the road is in an interrupted state, vehicles cannot drive on the road.

② Road network interruption status

A formula can be used to determine whether the road is in this state, the formula is as follows:

$$A_N = \frac{\sum_{i=1}^{N} a_i}{L} \times 100\% \tag{3}$$

4.4 Evaluation of Road Congestion

4.4.1 Congestion Degree

Through specific calculations, the degree of road congestion can be accurately judged, this is the main basis for determining if the travel is without interruption [16]. The degree of congestion in the road section can provide the traffic management department with the implementation of road traffic operation conditions, and can provide people with a basis for judgment on travel.

① Average speed of road section-calculation based on detector data

$$\bar{V}_{ij} = \frac{1}{m}\sum_{k=1}^{m} \bar{V}_k = \frac{1}{m}\sum_{k=1}^{m}\left(\frac{1}{n}\sum_{i=1}^{n} v_{kl}\right) \tag{4}$$

② Average travel speed of the road section-calculation based on toll data

$$\overline{V_{ij}}' = \frac{1}{n}\sum_{i=1}^{n} \frac{L}{t_{\text{iout}} - t_{\text{iin}}} \tag{5}$$

In order to better describe the congestion of the road, we can judge the proportion of the congestion over the entire road, which can be expressed by the following formula:

$$F_N = \frac{\sum_{i=1}^{m} d_i + \sum_{j=1}^{n} e_j}{L} \times 100\% \tag{6}$$

5. CONCLUSION

According to specific statistics, the main reason for most road traffic accidents in China is changes in weather conditions. Poor weather conditions are more likely to create accidents

Table 4 Judgment method of comprehensive index level of traffic meteorological trip.

Visibility Meteorological Travel Index Pavement	Level 5	Level 4	Level 3	Level 3	Level 1
Level 4	4	4	3	2	1
Level 3	3	3	3	2	1
Level 2	2	2	2	1	1
Level 1	1	1	1	1	1

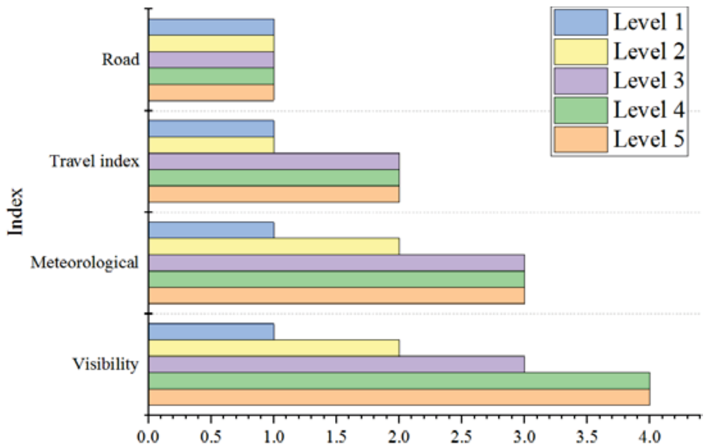

Figure 4 Judgment of comprehensive index levels for traffic weather.

Table 5 Description of comprehensive index levels for traffic weather travel.

Index level	Grade description	Impact and suggestions
Level 4	Visibility (200–500)m	The visibility is within 500 meters, the road is wet or there is a small amount of water, it is safe to travel.
Level 3	Light rain, sleet or light snow Light fog, blowing sand; Visibility(100–200) m	Visibility is significantly reduced to within 200 meters, which will affect traffic, there is obvious water or ice on the road, and the weather conditions are poor, vehicles should slow down.
Level 2	Moderate or heavy rain 1–2 days after moderate or heavy snow Dense fog, sandstorm; Visibility(50–100) m	Within 100 meters of visibility, the road is covered with snow, the friction co-efficient of the road is reduced, weather conditions are poor and travel is not safe.
Level 1	Medium snow, heavy rain, or wind force level 7–8 Heavy fog; Visibility $\leqslant$50m	Visibility is within 50 meters, the road area is underwater, the road is covered with snow, the weather conditions are bad, travel is unsafe, and is the road must be closed quickly.

and threaten people's lives. Therefore, road traffic management must be improved, monitoring equipment should be installed on roads, and changes in weather conditions and road conditions must be monitored in real time. Through specific research and practice, weather changes along the highway can be monitored by building wireless sensor networks, effectively reducing the probability of traffic safety problems. The pavement monitoring system designed in this research combines the video information of the pavement, the operation of the highway network, the release of information and the road toll, and provides a reference for the construction of road traffic monitoring systems in various provinces throughout China. Monitoring the operation of the highway network and building a complete highway monitoring system are the main means to ensure the rapid operation of the logistics network. By monitoring the construction of the network, people can gather more information about road operation and improve the efficiency of people using the road network.

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