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Design and Implementation of the Safety Monitoring System of Chemical Toxic Gas Based on ZigBee Wireless Communication Technology

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Because of the special nature of the chemical industry, there are many toxic and harmful gases hidden in chemical enterprises. The hidden safety hazards caused by the leakage cannot be overlooked so it is extremely urgent to effectively manage the leakage concentration of hazardous chemical products. Based on ZigBee wireless communication platform, this paper designs a detection platform of toxic gas leak according to the objective requirements and characteristics of toxic and hazardous gas detection in chemical enterprises. The platform collects the information of toxic and harmful gas leakage through the collection point and then uses the ZigBee network to transmit the data. Finally, the potential toxic gases in the environment of chemical enterprises can be effectively detected so as to achieve the optimization of the safety production level of chemical enterprises, prevent potential crises and achieve the purpose of protecting the staff safety and the enterprise property safety.

1. Introduction

With the occurrence of many large-scale production safety accidents, it not only threatens the safety of the people, it also has serious social impact. At present, the government has a high concern for personal health and occupational environment and is extremely strict in reviewing the construction of the platform for the detection of harmful gases, debugging and application in many enterprises. Accompanied by the rapid development of the Internet of Things, many fields have been reformed. By integrating toxic detection and advanced technologies, the practical significance of such research is particularly prominent. At present, more efficient and scientific information processing and collection technologies have not been used in industrial production, especially for safe production (Chen, 2018; Dutta et al., 2018; Powis et al., 1988; Yang et al., 2015). The wireless network technology has a short development time but a very broad prospect. The ZigBee technology provides a brand new platform for the research and development system of the paper.

2. introduction of related theories

2.1 ZigBee wireless communication technology

Based on the IEEE 802.15.4 standard, the ZigBee, a LAN protocol with relatively low power consumption, is formed, which is a type of wireless communication technology with low power consumption and short distance (Cahill and Jakobsen, 2015; Lorwongtragool et al., 2014; Jian et al., 2013). It has distance limit and high level of automation, which are all its characteristics. The construction process and usage of this kind of network are relatively simple, which has outstanding quality of work, less investment. The sensors of all nodes are connected with each other to complete the key task of collecting the data information. In addition, data forwarding and transferring the data from other network nodes can also be implemented.

2.2 Wireless Sensor Network

Transmission sensors, measured objects and information collectors jointly constitute a complete network. Sensors are placed in the areas to be monitored, and the target information is collected while performing the

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monitoring work. The wireless network is used to send abnormal conditions and collect information to monitors. At this point, the process corresponding to the wireless sensor network has been formed.
As far as the composition is concerned, the sensor node equipment involves a total of four blocks, namely sensing devices, wireless transmission, processor modules and power supply system, as is shown in Figure 1.

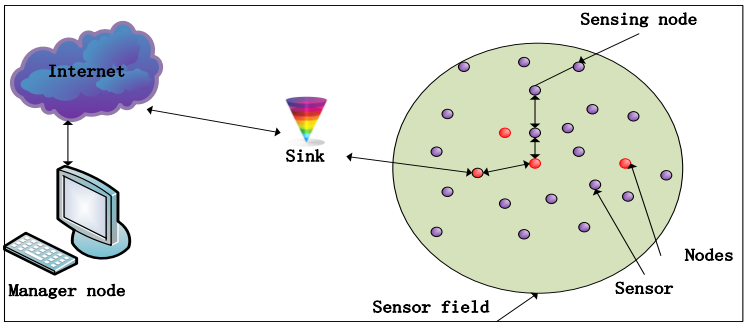

Figure 1: Wireless sensor network structure

2.3 Zigbee network structure and topology

ZigBee is a type of wireless personal area network with lower transmission rate (WPAN) based on ZigBee technology (Chen et al., 2006; Buonicore, 1989). The network can be divided into the following four layers: physical, MAC, network and application layer in a bottom-up sequence. The networking capability of this type of technology is particularly prominent, specifically involving three major forms, namely star, mesh and tree network. The system environment is relatively complex and involves a relatively wide area, so the transmission distance of the router needs to be extended. Here, the cluster network topology is applied.

3. Demand analysis and architecture design of chemical safety detection platform

3.1 Functional demand of chemical safety detection platform

The chemical leakage gas detection network: it requires multi-node acquisition, dynamic established network, network of non-fixed number of nodes and simple deployment of nodes.
The hardware functional demand of chemical safety detection platform: fast processing speed, large program storage space, small module size, sensors configured with digital components, improved radio frequency transmission power, good scalability, high cost and long communication distance.
The software functional demand of chemical safety detection platform: intuitive and concise graphical interface, powerful display function, alarm and information processing.

3.2 Overall scheme for the design of chemical toxic gas safety monitoring platform

Based on the monitoring of the specific requirements of gas leakage from hazardous chemical goods, the following parts involved specifically in this platform are: relays, acquisition and coordination nodes. The acquisition node can automatically search for the surrounding routing points and select the optimal path to complete the data communication. After that, the leakage gas concentration is collected and the calculation result of the data is transmitted to the coordination node through the transmitter. The routing and collection nodes can achieve mutual conversion based on the data transmission route. Based on the simplest and optimized data transmission route, the conversion of various functional nodes such as control coordination and information acquisition can be realized.

4. Analysis and design of the safety monitoring system of hazardous chemical products

The object of the project is the site where the chemical company detects the leakage of toxic gases. Through the development of the wireless sensor network, the concentration can be detected and the alarming can be implemented. Figure 2 is the system framework diagram:

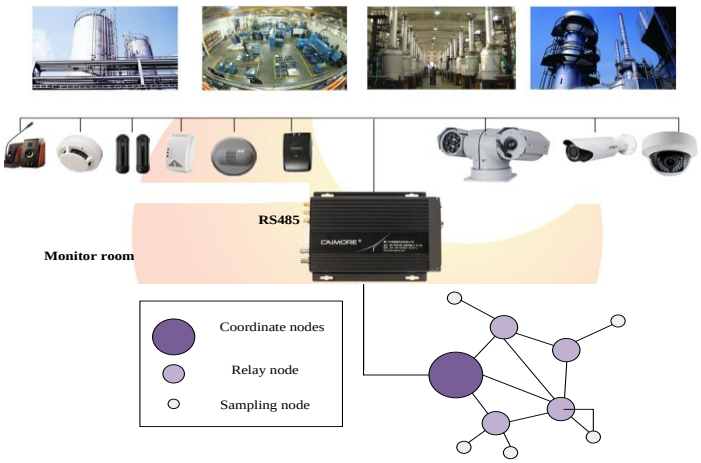

Figure 2: Overall system diagram

In this, the monitoring room is equipped with a host computer combined with the 485 bus to achieve the connection of the coordinator and the host computer. There is a coordinator outside the monitoring room; the storage site and manufacturing shop is distributed with data acquisition nodes and relays. It is developed based on the monitoring network system of the leakage of toxic and harmful gases in current stage.
The data acquisition nodes are located in the monitoring area and belong to the first layer of the system. The second layer is used to transmit information, which is mainly based on RS485. The third layer is the monitoring platform, which can set up the monitoring platform away from the monitoring area based on the requirements of users. The monitoring platform stores the corresponding data in the database. After that, it conducts comparisons and calculations and finally displays the collected and calculated information on the monitoring platform. Based on the user settings, the graded warning is used to reach the acquisition node position beyond the leakage threshold.

4.1 Hardware design of the safety monitoring system nodes of hazardous chemical products

The chemical toxic gas sensor, which is the equipment that converts the toxic gas concentration into electrical signals. After the processing of electrical signals by the electronic circuit, the concentration of toxic gas can be displayed and the alarming can be issued. The sensor is taken as the key to the detecting alarm device in terms of the detection alarming equipment. Based on the actual condition of chemical plants, the hydrogen sulfide gas is selected for the test. Table 1 level shows the corresponding parameter of probes:

Table 1: Basic parameters of hydrogen sulfide probe(H2S)

Parameter	Explain	Value
Sensitivity（aA/ppm）	Under 20ppmH2S	525~850
response time(s)	From 0 to 20ppmH2S	<25
Zero current	Same as the air content(ppm)	<±0.3
Resolution ratio	Square root noise (equivalence ppm)	<0.05
Range	Within the period of validity	100
Overblowing limit	The maximum stable response	500
Sensitivity drift	Laboratory gas (Monthly measurement)	<3
Temperature range	℃	-35~55
Pressure range	Kpa	85~125
Humidity range	Sustained relative humidity	20~95

4.2 Communication design of chemical safety monitoring system

The TCP server can provide the service combined with the access to the software. The programming flow chart is shown in Figure 3:

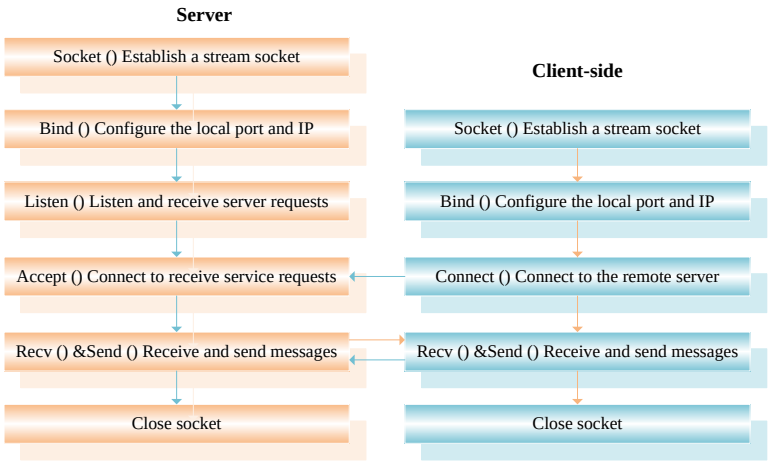

Figure 3: The flow chart of server and client communication programming

4.3 Software design of chemical safety monitoring system

The detection probe can realize the conversion to the analog electrical signal after collecting the leakage concentration and combine the operational amplifier to amplify the signal. Then, the A/D converter can be connected so as to convert the signal into a digital quantity and return the concentration percentage combined with the computing activity. The specific process is shown in Figure 4:

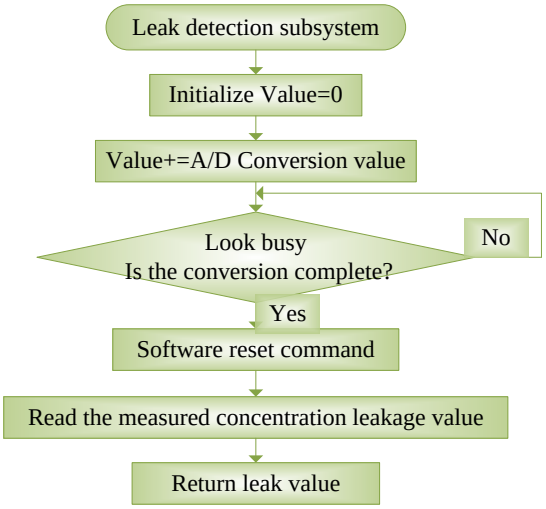

Figure 4: The flow chart of leakage concentration detection

4.4 Programming of relay nodes

In terms of the data acquisition node, there is a stable launch distance of approximately 75 meters. Therefore, when it is applied to chemical plants, it is necessary to add the corresponding node so that it can be used as a router. At this point, the data collection nodes can be collected and the transmission can be performed, thus forming the wireless data acquisition and transmission network. In the ZigBee network of this system, the relay node equipment in the network mainly plays the role of routing and other nodes that they can join in the network. By calling the function apljoinNetwork0, the relay node can join in the network and receive the call of subroutines combined with the radio frequency transmission. This type of subroutine can be used for data transmission.

4.5 Programming of coordinator nodes

In the ZigBee network, the coordinating control module belongs to the node that can initiate new network construction. In the research and development of the coordination control module, it is necessary to ensure

that the network has the ability to remove or enter the terminal, deploy the network logical IP to the terminal, establish the neighbor list and transmit the collected information to the upper computer.

4.6 Design of server-side database management system

If the terminal sensor collects the data and sends the data to the coordinator, the coordinator will transmit the received data to the computer based on the serial port, then, it can be stored in the database and be displayed on the computer. The Access2003 database is selected here and the Visual C++ 6.0 is used as a program development tool. Among them, for the design of database management system, it is specifically related to the three major tables. Tab. 2 is the management table of node types. The specific effect is that it can control the internal node types of the network and store the collected information and name in the table.

4.7 Software design of upper computer monitoring management

The Visual C++ 6.0 is taken as the monitoring management software, which has outstanding reliability, relatively short development cycle and outstanding generation capability of the graphic pages. It can be based on the layout of field devices to formulate the charts and dynamic pictures, vividly displaying the status of parameter variation. It can also store the toxic gas content data in corresponding databases and lay the foundation for the analysis of safety production.

Table 2: Node management table

Field	Data type	Value	Explain
Serial number	Integer type	Self-motion	Node number
Address	Byte type	0X01	Node address value
Describe	Character string	Leakage of CO	Node text description
Node types	Integer type	Corresponding node number	No. in the node type table
Time	Character string	Time	Time information
Standby application	Character string	——	——

For the data obtained by monitoring, it can be displayed in real time in the monitoring page. If the monitored value is greater than the limited range, an alarming will be issued. For the data monitoring window, the leak concentration can be displayed in real time. If the value is higher than the preset value, the red and white flashing will appear in the white frame and the audible and visual alarming will be generated. The alarming can be cancelled based on the mute button and it can return to the main interface by pressing the return button.

5. Implementation of the safety monitoring platform for hazardous chemical products and analysis of the test results

5.1 Parameter detection test

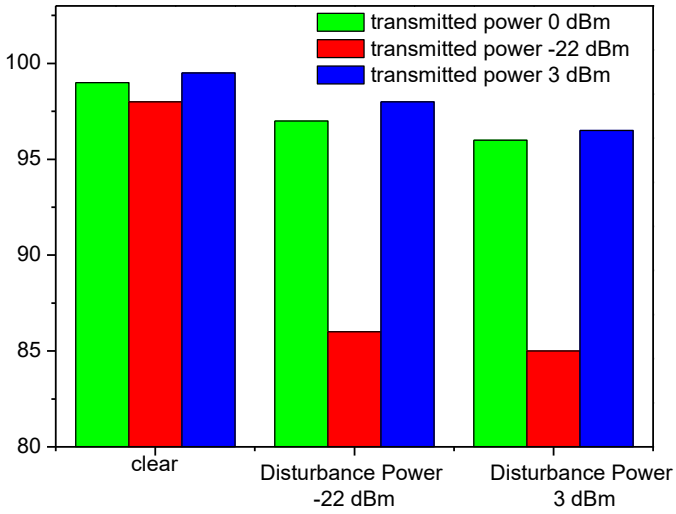

Figure 5: Influence of transmitting power and interference on the success rate of packet delivery

(1) Wireless communication distance test
Through the testing, the operating voltage tends to have a significant effect on transmission distance. If 2.6 and 3.3V are used as the power supply voltage to perform the corresponding test work, the corresponding indoor and outdoor transmission distance is 30 to 50m and 80 to 120m respectively.
(2) Success Rate of System Data Transmission
Based on the laboratory environment and combined with various interference environment, the transmitting power of nodes is different. At this time, it can be seen from the following figure that the success rate of the packet transmission will also be affected. Therefore, it can be recognized that if the interference occurs in the environment, the transmission power needs to be increased. If not, a higher packet loss rate will occur.

5.2 Effect

According to the actual test, the system is smooth and stable. If the concentration of harmful gases is higher than the monitoring range, an alarming will be issued in time and the prompt work will be carried out for a specific range and location. Meanwhile, an alarming will be sent to the operator. It can play an important role in preventing the wide spread of toxic gases. The monitoring interface can display the monitoring data in real time and if the value is significantly higher than the calibration range, an alarming will be issued.

6. Conclusion

(1) The toxic gas leakage monitoring and wireless sensor network are effectively integrated, enabling the construction of data transmission and acquisition network system and providing a new channel for the monitoring of gas leakage data, which has extremely outstanding application value.
(2) The sensor node can realize single-hop transmission of 75m through the use of CC2430 and the data transmission hop count is more than a hundred so that the coverage can satisfy the monitoring requirements.
(3) The stability and reliability of the system hardware can be tested based on the experimental work carried out in the field. Combined with software control, the specific performance of the hardware can be understood so that all nodes in the network can work smoothly and coordinate with each other to facilitate the acquisition, conversion and control of information. Finally, more stable and long-term monitoring work of toxic gas parameter can be conducted.

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