Application of Bluetooth in Mine Gas Information Transmission

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Abstract: In order to solve the problem of information transmission, such as underground gas concentration, etc. Using Bluetooth Multi-hop Communication Technology based on VoWPAN, the feasibility of using Bluetooth multi-hop communication system to transmit data on aircraft is analyzed from three aspects: the transmission characteristics of radio in mine roadway, the construction of Bluetooth communication system and the Bluetooth multi-hop communication system mounted on aircraft. The most advanced detection vehicle is responsible for collecting data, and Bluetooth in the middle of the vehicle acts as a relay system. Theoretical research shows that this communication system has a good guiding effect on the downhole detection and rescue of aircraft.

1. Introduction
The detection of gas concentration is an important event, the slight change of gas concentration will bring certain influence to mine safety production, when the concentration exceeds the specified value, there will be explosion. In order to avoid this situation, we developed a post-disaster mine environment detection vehicle, and entered the mine roadway to collect information such as mine gas concentration. The collected information was transmitted through wireless transmission to the terminal carried by the rescuers. In order to judge the danger of roadway ahead, provide important information for rescue work. Considering the light load of the aircraft, we use Bluetooth module to transmit the collected information.

At present, the transmission mode of underground radio in coal mine can be divided into waveguide mode and single line mode. By consulting relevant information, we know that the influence of mine roadway on electromagnetic wave is band-stop when there is no metal conductor in mine roadway, as shown in the figure below.

2. Gas concentration detection system
The data transmitted by the gas detection system are gas concentration data, and the mobile phone data can be spaced, which belongs to the transmission of low data rate, but requires the system to work for a long time. The underground detection system consists of wireless sensor node and gas monitoring base station. Wireless sensor node includes wireless infrared gas detection sensor, signal conditioning module, data conversion module, wifi wireless module and other application software. According to the type of transmitter, the signal conditioning module can adjust the sensor signal to a suitable range and input it to the analog-to-digital conversion unit or send it to the executive unit after adjusting the digital-to-analog conversion result. Gas monitoring base station includes wifi wireless module, application software, RS-232...
interface, network interface module and so on. Real-time multi-task management module: responsible for the management and coordination of various tasks of the gas monitoring base station, including the mine station identification configuration, the specific application of users, it is responsible for the gas monitoring base station in all tasks scheduling. Coal mine gas monitoring and warning is a difficult problem that puzzles the coal mine safety production. At present, the coal mine gas monitoring system which is widely used in our country is based on the industrial bus. Underground gas monitoring system and ground information center are usually connected by cable and fiber, which constitute wired communication network transmission. These lines need professional personnel to set up and maintain, if the line construction is not in time, it will cause gas leakage. Therefore, it is necessary to transmit the information by wireless way, which is also the Bluetooth wireless communication proposed in this paper.

3. Design of Bluetooth Communication system

Mine mobile communication is an important part of modern mine operation. It can organize the underground personnel effectively and reduce the probability of accidents. It is of great significance to ensure the normal operation of the mine and the safety of the underground personnel. The effect of modern mine mobile communication is not ideal, which seriously hinders the development of mine modernization, so it is very important to find a more reasonable communication mode.

3.1. Characteristics of Bluetooth Technology

Bluetooth is an open wireless communication standard. Compared with other wireless communication technologies, Bluetooth has the characteristics of low power consumption, low cost, strong anti-interference ability and supporting mixed data and voice transmission. Bluetooth technology can easily and quickly establish links with other Bluetooth modules, and the portability of Bluetooth is special.

Bluetooth technology has the characteristics of frequency hopping, short data packet and low signal attenuation. Frequency hopping is one of the key technologies of Bluetooth. The so-called frequency hopping is to decompose the frequency band into several frequency hopping channels, and then in the process of communication, the radio transceiver follows a certain code sequence. The transmitter and receiver constantly jump from one channel to another, so other signals cannot be interfered with. Bluetooth uses frequency hopping and short packet technology, which can reduce the interference of the same frequency and ensure the reliable transmission of data. The forward error correction coding technique used in Bluetooth reduces the influence of random noise on long distance transmission of information. The Bluetooth technology is based on the universal 2.4GHz frequency band. The frequency hopping transmission is carried out at the rate of 1600 hops and the transmission width is 1 MHz. When using low power time division multiplexing to transmit data, it is only suitable for communication in the range of 10m, and the transmission distance can reach 100m when the power is increased. So this short-distance transmission characteristic of Bluetooth is suitable for mine roadway communication.

3.2. Construction of Bluetooth Communication system

Bluetooth communication system adopts a new piconet structure, the host computer is combined with linear shape, and the topology between host and extension is piconet. The piconet structure has a great advantage, that is, it can make the communication transmit along the straight line, and then increase the distance of the information transmission, which is very advantageous to the communication in the underground. The topology structure of piconet is Bluetooth technology, which is composed of host and extension respectively. The number of extension can reach 256, so it can meet the requirement of communication in this special environment.

In the process of communication, the task of the host is to timing the information and control the access of the extension. The host allocates the wireless channel to the extension by polling. After the host computer distributes the information, the extension receives the information simultaneously and synchronizes, and then collects and encodes the sound of the downhole personnel, and then the host receives the information of the extension to transmit the information. The control part of the system is generally placed on the ground, responsible for the operation of the whole Bluetooth network, switching between hosts at the appropriate time, and finally controlling the sending and receiving of information. The piconet composed of the above three parts can realize the wireless communication under the mine.
3.3. Hardware composition of Bluetooth

Bluetooth hardware includes control unit, Bluetooth module and information codec module, as well as circuits connecting them.

In order to reduce the pressure of the control unit, the hardware module is selected to complete the collection of information and coding and decoding. Because of the serious noise interference, the CVSD coding chip with strong anti-jamming performance can be selected to process the baseband of the signal. Bluetooth components usually include speech encoder, Bluetooth module and antenna, and some auxiliary circuits are added. The data transmission function needs to modulate the signal 2.45GHz to receive the signal through the antenna. The initialization of Bluetooth module is accomplished by the control unit, and the voice signal is sent and received by establishing communication with the host computer.

![Diagram of hardware structure of host and extension](image)

Fig.1 Hardware structure of host and extension

In the process of developing Bluetooth communication system, Bluetooth module is usually composed of baseband control chip with RF function, antenna and peripheral expansion circuit. Bluetooth module can realize the transmission of data and voice at the same time, and improve the function to the host control interface. The main control unit and the Bluetooth module can transmit data through serial port (UART), and the transmission rate can reach 460 kbit/s. In addition, Bluetooth module also provides USB and PCM interface, which greatly facilitates the connection of other hardware circuits.

3.4. Software design

The main control unit and the software send and receive packet packets through the HCI (Host Control Interface) for data transmission. The core of the software design is to control the Bluetooth module by software programming to the HCI, in the stack layer of the Bluetooth module software protocol. After the control unit sends HCI to the Bluetooth module, the Bluetooth module receives it, and then the upper layer protocol in the Bluetooth module initializes the Bluetooth chip, edits the link management, establishes the link, removes the packaging and subcontracting of the link and data, and so on. Bluetooth also receives the HCI event feedback from Bluetooth module, and then makes corresponding processing according to the command of event packet. So HCI (host control interface) control unit and Bluetooth module exchange command and data format. According to the communication method of Bluetooth protocol, the packet format of data is synchronous Link oriented (64kbit/s).

Although Bluetooth technology has a short communication distance, Bluetooth protocol stack is perfect and suitable for limited space use, which makes Bluetooth has a great prospect in mine communication. It is a feasible scheme to use linear piconet to form Bluetooth technology to communicate in mine roadway.

4. Bluetooth Multi-hop Communication system based on VoWPAN

Because of the attenuation effect of mine roadway to the wireless signal, the wireless communication distance is limited. In order to solve this problem, the environmental detection aircraft that we developed adopted multiple formations to enter the mine. The aircraft at the front is responsible for collecting information about the mine environment and transmitting information to the aircraft at a certain distance immediately behind by wireless means. The rear aircraft is responsible for the task of relaying communications and continuing to transmit the signal to the aircraft behind. Finally, the signal is transmitted to the signal receiving terminal carried by the ambulance crew through the relay communication of multiple aircraft. So we use Bluetooth multi-hop communication system for this communication mode.
4.1 Overview of VoWPAN
After the mine disaster, the environment inside is quite complex, so this paper introduces the key technology of Bluetooth communication, analyzes the transmission characteristics of underground radio, and uses the Bluetooth multi-hop communication system based on VoWPAN to carry on the aircraft. In order to solve the problem of underground special environment information transmission.

4.2 Composition and operation of the system
The Bluetooth multi-hop communication system is composed of gateway and repeater. The system structure is shown in figure 3 below.

![System structure diagram](image)

Fig.2 System structure diagram

Each vehicle is equipped with Bluetooth module, the front-end aircraft is responsible for data collection and processing, the middle aircraft is responsible for relaying signals, and then the information is transmitted step by step to the ground command center. Bluetooth multi-hop communication system has a bit of good signal transmission quality and strong anti-jamming ability. The data adopts point-to-point communication mode, increases repeater, and expands the effective distance of system signal transmission. This is conducive to the transmission of data collected by the aircraft.

The repeater plays the role of relay signal. When the Bluetooth communication system on the aircraft cannot reach the required distance, the repeater plays a great role in extending the communication distance. The selection of repeaters depends on the distance from the device to the repeater, and the distance formula is estimated based on the Ferris formula.

\[
P_r = G_t G_r \left( \frac{\lambda}{4\pi R} \right)^2
\]

(1)

In the upper form, \(P_r\) represents the received power; \(P_t\) indicates the transmitting power; \(G_t\) and \(G_r\) the gain of the transmitting antenna and the receiving antenna are represented respectively; \(\lambda\) indicating wavelength; \(R\) represents the distance between an aircraft and the next adjacent aircraft. \(P_r\) is a known quantity, \(P_t\) it can be obtained by reading the received signal strength RSSI of the Bluetooth device connected to the aircraft, and the remaining parameters can be calculated. Therefore, from the above formula (1), we can calculate the distance between an aircraft carrying Bluetooth equipment and another aircraft carrying a repeater, and form a routing table based on the calculated distance information and signal intensity (RSSI). The path used for Bluetooth device selection of repeater hopping. Because the relative distance of the aircraft may vary during flight, the routing table needs to be updated at intervals.

Bluetooth is a two-way signal transmission which can transmit data while receiving data. Time division duplex transmission scheme is used to realize full duplex transmission. Bluetooth multi-hop technology can adaptively select the best frequency of frequency hopping in the process of data frequency hopping communication and eliminate the surrounding interference frequency in real time in order to obtain the stability and efficiency of data transmission.

The aircraft entered the mine linearly one by one in sequence, and in practice, the time when the Bluetooth on the adjacent aircraft set up the ACL (access Control list) connection \(T_{ij}\) it mainly depends on the mine roadway environment and the distance between the two aircraft. Under the same mine tunnel environment and the same Bluetooth emission power, the receiving power function can be approximately generalized as the distance function. Taking the \(R_s\) reference distance of 50 m, at this point, the time to establish a connection on the Bluetooth side of the aircraft is \(T_s = 0.7s\). Knowable

\[
T_{ij} = \alpha T_s
\]

(2)

In the upper form, \(\alpha\) represents the weighting coefficient, represents the relationship between the Bluetooth end and the reference distance on an adjacent aircraft. Thus, the following empirical formulas can be deduced.
\[ \alpha_t = 1 + \frac{r_{t+1}}{11r_s} \quad R_{t+1} > R_s \]  

Because of the special environment under the mine, there will not be too many frequency interference, and Bluetooth adopts frequency hopping transmission mode, which has strong anti-interference ability, and it can completely realize the function of data transmission.

5. Conclusion

After monitoring the gas concentration through the gas concentration detection device, the detected information is first transcoded in the conversion device, and then transmitted to the ground monitoring station through the Bluetooth wireless communication system mounted on the aircraft. The wireless communication of gas concentration information is realized. The Bluetooth multi-hop communication system, which is mounted on the aircraft, makes full use of VoWPAN technology to achieve the functions of low power consumption and strong anti-interference performance. After the mine disaster, under unnatural conditions such as electromagnetic interference and poor air environment in the mine, it can still have good communication function. The application of the system to mine environment detection aircraft not only improves the efficiency of mine rescue, but also ensures the safety of rescuers.

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