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Implementation of Wireless Communication System Using ZigBee and WiFi Technology in the Coalmine Tunnels

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ABSTRACT:

Implementation of Wireless Sensor Network (WSN) used under the coalmine tunnel is an emerging area of research that promises to provide reliable and flexible communication. This paper first discussed the best working frequency about the WSN in coalmine. Then, according to the actual circumstances of coal mine, the network structure should adopt cluster-tree topology. We also develop a multifunction communication wireless system using ZigBee and WiFi technology, which can achieve the functions of gas monitoring, wireless communication, personnel management and video surveillance, etc.

Keywords: ***WiFi; Communication system; Coalmine Tunnels***

INTRODUCTION:

At present, the situation of safe production is very serious in Chinese coal mine. Especially in the recent few years, disasters occur frequently in coal mine, which brings huge loss of possession and life. Therefore, the safety of underground mine become an important issue. Management of the hazards in underground mines requires continuous monitoring of critical information: the presence and concentration of flammable and toxic gases and dust, the structural integrity and stability of the mine tunnels, water ingress, and the current locations and communication status of all underground mine personnel. In the aftermath of an accident, it can be vital to maintain communications with trapped miners and rescuers, and to establish and track their positions. Current monitoring system in underground mine were cable based which play a key role in safe production. However, these systems have some disadvantages for coal mine monitoring. It is inconvenient to dispose in many areas such as abandoned laneway and exploiting areas for the trouble reconnection. But just in these areas, they really have a lot of danger. To overcome shortcomings of wired systems, people proposed the Wireless Sensor

Networks (WSN) to implement the wired monitoring system. But the WSN has its own limitations, such as not having enough bands to communicate and transfer image data efficiently. So, how to overcome the limitations and provide one communication system with wide band is concerned.

II. WORKING FREQUENCY AND NODE DEPLOYMENT

In the past studies, people focus on the applications mainly on the design and deployment of WSNs in underground mines . The methods they adopted are similar to the grounds. But, the WSN used in the coalmine tunnel have their own characteristics different from the WSN used on the ground or the other tunnel, such as the radio attention, the nodes density and deployment, etc. So, we will first discuss the choice of working frequency.

A. Frequency Choice.

The IEEE802.15.4 PHY has been designed for three bands as 868MHz, 915MHz and 2.4GHz . Although above the ground, the 868MHz band is used in Europe, the 915MHz band in North America, Australia, etc., and the 2.4GHz band has been accepted in almost all the countries of the world. When the WSN is used in underground coal mine, it may not comply with the regulation. So choose the appropriate working frequency is worth concerned. The shape of the coal mine tunnel is generally rectangular, arch or trapezoid. Through the theoretical analysis and experiment, it shows that the tunnel section area has great affect on the radio propagation, while the shape ofcross section has little . For convenient discussion, rectangular tunnel is as an example.

The geometry of an electromagnetic wave in a rectangular tunnel is showed in figure 1. The coordinate system is centered in the tunnel with x horizontal, y vertical, and z along the tunnel. The width of the tunnel is d1 and the height is d2.

Figure 1. Rectangular tunnel model

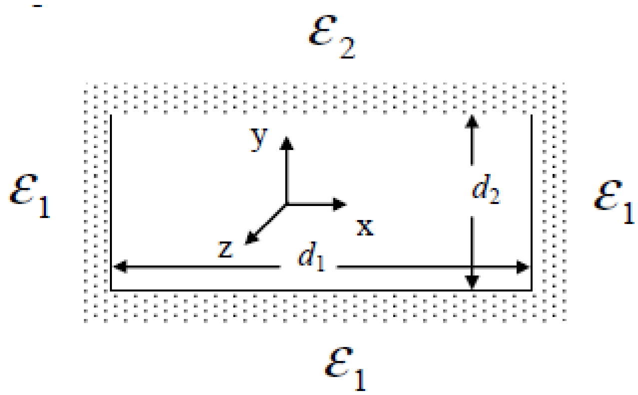

Figure 1. Rectangular tunnel model

The propagation modes with the lowest attenuation rates in a rectangular tunnel in a dielectric medium are the low (1,1) modes, which have the electric field (E) polarized predominantly in the horizontal and vertical directions, respectively. We refer to these two modes as h E and v E modes. As the propagation attenuation in the tunnel is dominated by the (1,1) h E mode, we only consider the attenuation of the (1,1) h E mode.
The attenuation constant L in dBm/m for the (1,1)
h E mode is given by

$$L = 4.343\lambda^2 \left(\frac{\varepsilon_1}{d_1^3(\varepsilon_1 - 1)^{1/2}} + \frac{1}{d_2^3(\varepsilon_2 - 1)^{1/2}} \right)$$

Where ε1 is the dielectric of the side walls and ε2 is of the roof and floor of the tunnel.
Considering the actual size of the coal mine tunnel, we take: d_1 =4m,d_2 =3m, and also considering the effect of moist in the tunnel, we take: ε_1 =2, ε_2 =6. The curve of the calculated attenuation changing with frequency is showed in figure 2. From the figure, we can see that with the increase in communication frequency, the attenuation decreases continuously.

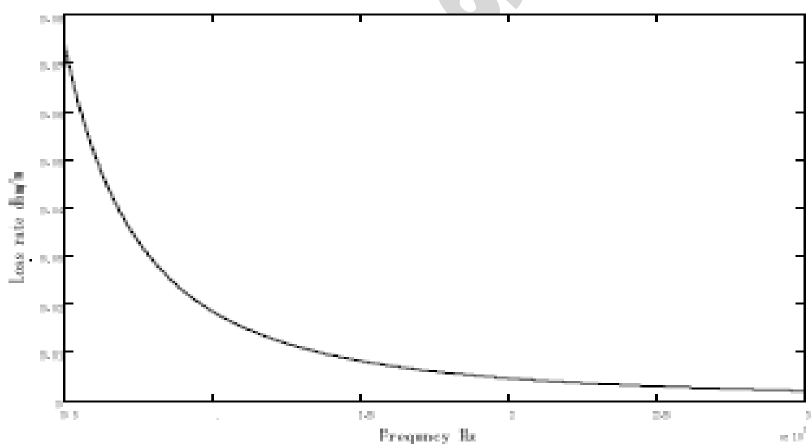

Figure 2. Relationship between attenuation and frequency in rectangular tunnel

We also take tests in the coalmine tunnel. The test environment is shown in figure 3. The results are showed in table 1. We can find that according the increasing of frequency, the attenuation is decreased in the straight tunnel.

Figure 3. Test environment

Table 1. Attenuation in straight tunnel

Frequency (MHz)	40	60	150	470	900	1700	4000
Attenuation ($dB \cdot km^{-1}$)	301	217	113	9.8	2	1.6	0.7

So, 2.4GHz was chose as the working frequency of WSN under the coal mine.

B. Node Coverage

Test under the coal mine shows that when the RF transmitting power is 100mW (maximal transmitting power of 2.4GHz set by the state), it can cover 100–150 m by using omni-directional antenna. But if using directional antenna, the cover range's radius can reach 300m in the straight main tunnel. IEEE 802.15.4 specifies that each device shall be capable of transmitting at least 1 mW . Typical devices (1mW) are expected to cover a 10–20 m range.

As radio propagation along the coalmine tunnel has a strong waveguide effect, we can confirm that the cover range is at least 10-100 m in the coalmine tunnel. A ZigBee device can be divided to a full-function device (FFD) or reduced function device (RFD). A ZigBee network shall include at least one FFD, operating as the personal area network (PAN) coordinator. An FFD can talk to RFDs or FFDs, while an RFD can only talk to an FFD. While in the coalmine tunnel, the monitor devices are only put in the places that need monitor, so the ZigBee nodes are not need to full occupy in the coalmine tunnel. We can adjust the RF power of FFD and RFD to make the different transmitting range and form the topology of cluster-tree as shown in figure 4. Each cluster is composed by cluster head (CH) and the cluster nodes (CN). CH is as Full function device (FFD) which can become the network coordinator, while CN is as reduced function device (RFD) which can only function as a network device. In Figure 4, the CH nodes are deployed to chain-type for the length much larger than the width of tunnel.

Figure 4. Topology of cluster-tree in coalmine tunnel However, WSN technology used in coalmine has limitations such as routers and co-coordinators that are permanently connected to the mains supply and it has not enough bands to take mobile telecommunication and transfer video data, etc. So, how to overcome the limitations and make the technology practicability has a big meaning for the safety production in the coalmine.

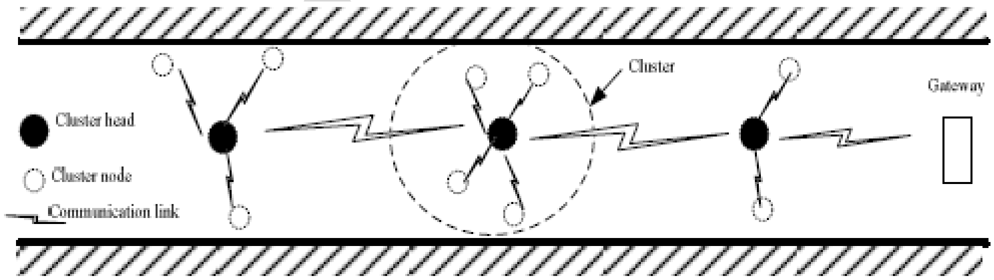

Figure 4. Topology of cluster-tree in coalmine tunnel

III. HYBRID SYSTEM USING ZIGBEE AND WIFI TECHNOLOGY

Aiming at solving the limitation of ZigBee technology using in the coalmine tunnel, under the support of ministry of information industry development fund and national science and technology support program project, we have successfully invented a set of multifunction wireless system using ZigBee and WiFi technology that can achieve the functions of gas monitoring, wireless communication, personnel management, video surveillance and strong anti disaster, etc.

The system consists of two parts: under the ground and above the ground. Under the ground mainly consists of base station (BS), wireless sensor, dual-mode mobile phone, identity card (ID card), video camera, etc. all these devices must be intrinsic safe or explosion-proof. The devices on the ground mainly in the monitor room, they include console and varies servers. Figure 5 gives the monitor image that can be seen in the monitor room.

Figure 5. The actual pictue in the monitor room

The BS is the core device of the system. Figure 6 show the BS installing under the coalmine tunnel. Figure 6.

Figure 6. Base station installation on site

To satisfy the different band need, it uses ZigBee/IEEE 802.15.4 and IEEE 802.11 b/g (WiFi) protocols. Any equipment use these two protocols can connect to the base station. In our system, dual-mode mobile phone and video camera connect to the BS use WiFi technology, while wireless sensor and ID card use ZigBee technology. When using ZigBee technology, the BS is FFD and CH, and the sensors and ID cards are RFD and CN. The sensor and ID card only send signals to the BS and the BS read these data by poll method. Two BSs are connected by the optical cables. The BS's power was supplied by the underground grid. The base station also has backup power that can sustain more than 2 hours.

The sensor and ID card use battery. The battery life T can be calculated as follows:

$$T = C\times(T1 + T2 + T3) / (T1\times I1 + T2\times I2 + T3\times I3)$$

In this formula, T1: data sending time, I1: working current, T2: waiting time, I2: waiting curent, T3: active time, I3: active current. C: battery capacity.

Take ID card as an example, we use the battery CR2450, its capacity is 550mAh. T1 is 450μs, I1 is 12.5mA, T2 is 500ms, I2 is 1μA, T3 is 600μs, I3 is 1.5 mA,so we can calculate T= 39149.8 h, that is about 4.5 years. Considering real factors, we can confirm that the ID cards can normal work for 3 years.

This system supports the functions of multi-ring and multi-routing network redundancy. If any point in the BS, optical cable and other equipment is failure or damaged by the disaster, System has the ability of self-healing with realtime reconstruction, so it ensure the reliability of the network Under the disaster or the interruption of the network, the linked BSs can composite of network automatically. One mobile phone in these linked base stations' radio propagation area can find other mobile phones, display phone numbers and communicate with them through the function of broken network communication. So, it can achieve emergency communications under the broken network condition. Rescue person can get one terminal into the coverage and can find the number of mines and communicate with these people. In the same time, all the information in the coverage of the BSs can be stored in the near base station. Once the network is recovered, the information can be send to the ground. Through the ID cards bring by the miners, we can get the miner's information of his location and his walking path, and the sensor data can also be sent to the ground.

IV. CONCLUSIONS

This paper studied the wireless sensor network used in the coalmine tunnel. Through our study, we get that the working frequency should adopt 2.4GHz and the network structure should adopt cluster-tree topology in the coalmine tunnel.The multifunction wireless system that we designed has been used in several coal mines. The user's feedback shows that this system has achieved our expected purpose and gets a good economic benefit.

REFERENCES

[1] Prasant Misra, Salil Kanhere, "Safety Assurance and Rescue Communication Systems in High-Stress Environments: A Mining Case Study," IEEE Communications Magazine, 2010, 4: 66-73.

[2] M. Li and Y. Liu, "Underground Coal Mine Monitoring with Wireless Sensor Networks," ACM Trans. Sensor Net, 2009, 5: 1-29.

[3] A. Chehri, P. Fortier, and P. M. Tardif, "UWB-Based Sensor Networks for Localization in Mining Environments," Ad Hoc Network, 2009, 7: 987-1000.

[4] Z. Xuhui and W. Sunan, "Design of a Wireless Sensor Network for Methane Monitoring System," 6th IEEE Int'l. Conf. Industrial Informatics, 2008. 614-618.

[5] R. Mangharam, A. Rowe, and R. Rajkumar, "Firefly: A Cross-Layer Platform for Real-Time Embedded Wireless Networks," Real-Time System, 2007, 37:183-231.

[6] X. D. Wang, X. G. Zhao, Z. Z. Liang, and M. Tian, "Deploying a wireless sensor network on the coal mines," Proceedings of the IEEE International Conference on Networking, Sensing and Control. London. UK, 2007. 324-328.

[7] IEEE standards 802.15.4, 2006.

[8] Sun Jiping, Cheng Lingfei, Zhang Changsen, "Influence of transverse dimensions on electromagnetic waves propagation in rectangular tunnels," Journal of China University of Mining &Technology, 2007, 34:596-599.(in Chinese)

[9] LK Bandyopadhyay, SK Chaulya, PK Mishra, "Wireless Communication in Underground Mines: RFID-based Sensor Networking," Springer: New York, 2009.