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Application of the Downhole Monitoring Based on Zigbee Wireless Communication Technology

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Abstract: ZigBee technology is a kind of self organization of short distance, strong anti-interference, low cost, emerging wireless sensor network application that has attracted wide attention. Therefore, this paper studies and designs a real-time positioning system of underground personnel based on ZigBee system, the positioning of the sensor carrying miners through the wireless sensor network. This will help to achieve the attendance management of underground personnel, the real-time location of underground personnel, and effectively improve the monitoring level and efficiency of disaster relief as coal mine safety product to guarantee the life safety of the employees. According to the actual environment, the localization algorithms of popular wireless sensor networks were fully investigated, through the comprehensive demonstration, selection of wireless location algorithm based on RSSI, and deducing the mathematical model of the signal transmission attenuation.

Keywords: Location, localization, received signal strength indicator, wireless sensor network, ZigBee technology.

1. INTRODUCTION

Wireless sensor network (WSN) is a new type of intelligent measurement and control network. It is composed of many micro sensor nodes deployed by self-organized data [1]. These wireless sensors have sensing, communication and computing ability, distributed within or near the monitoring area; with wireless communication, data acquisition and processing, cooperation is possible; communication through specific protocols of sensor network, can obtain the information of environment and work collaboratively to complete specific tasks [2]. Because of its ease of deployment, self-organization, fault tolerance, characteristics of cover range, it is not only applied in the defense industry, intelligent building, modern agriculture, but also has a high application value in the traditional measurement and control field of environmental protection [3].

As countries pay more attention to the safety production in coal mine, automation, information of coal enterprises in China has gradually increased [4]. At present, enhanced monitoring and control capability of the security risks, effectively reduce and avoid the risk of major accidents (Mihir Bellare. *et al.*, 2007). However, enterprises for the detection technology of underground personnel location are still at the exploratory stage. Therefore, Inoue monitors in real-time, the reliable control of underground personnel distribution and operation situation which has always been a bottleneck. It involves location, and trajectory of underground personnel which is difficult to accurately grasp. This is not conducive to the production management and scheduling. Once the accident is occurred, due to the unfavorable underground situation the number of the personnel trapped and specific location cannot be quickly determined, resulting in the delay in launching on time rapid rescue scheme, thus delaying the rescue [5].

The positioning system for underground coal mine is helpful for coal mining enterprises to carry out more reasonable management, play an important role in curbing illegal under the wells, production management and scheduling, attendance and other aspects of daily underground workers. Once the underground tunnel collapses, water, cave and other unexpected danger may be expected, underground personnel positioning system serves as the monitoring center through emergency reporting, Inoue personnel can enter through the system to evacuate personnel under emergency warning. Once the personnel are trapped, rescue personnel act according to the position information of personnel positioning system for the moment, plan for the rapid development of the rescue plan, to avoid the unfavourable situation after the incident even though the number of people trapped, and their location are unknown. Therefore, a substantial increase in the fast and effective emergency rescue work is required.

2. RELATED METHOD AND THEORY

2.1. ZigBee Protocol

Using the development of wireless positioning system, this paper put forward the design of the ZigBee protocol stack [6]. ZigBee protocol stack is based on a 7 layer open systems interconnection model, constructed on the basis of IEEE802, as shown in Fig. (**1**). The application layer can be divided into the application support layer, application framework and ZigBee object [7]. The network layer, application layer, service layer and the underlying security provisions IEEE together constitute the ZigBee protocol. In ZigBee network, data management and service interface for each layer, the transmission network message and data is completed through these interfaces.

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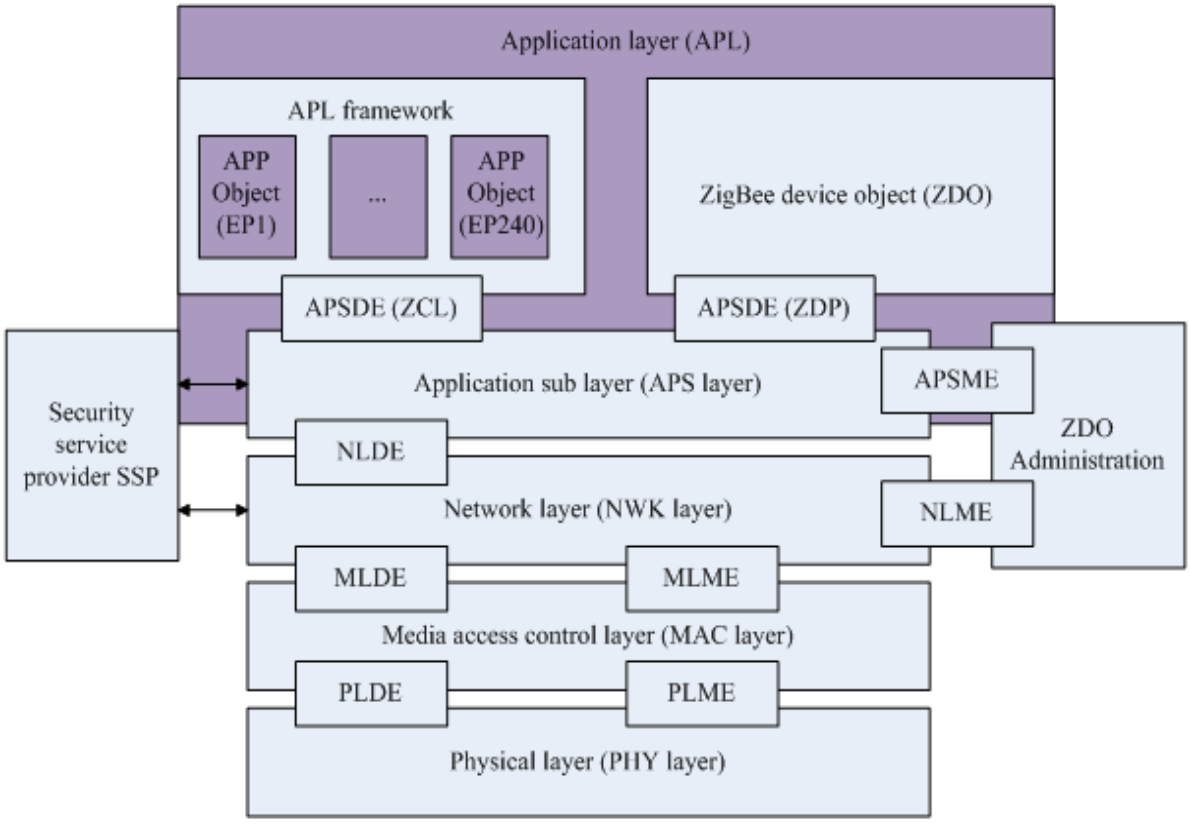

Fig. (1). The model constructed on the basis of IEEE802.

Table 1. The methods of modulation and data transmission.

Channel frequency (MHz)	Channel bandwidth (MHz)	Data transmission speed (Kbps)	Receiving sensitivity (dBm)	Modulation mode
868	868-868.6	20	-92 or more higher	Double phase shift keying
915	906+2(K-1)	40	-92 or more higher	Double phase shift keying
2400	2401+5(K-11)	250	-85 or more higher	Offset quadrature phase shift keying

2.2. The Physical Layer of IEEE802.15.4 PHY

The communication frequency of physical layer is mainly responsible for the specification of ZigBee, the transmission rate of each band, the relevant requirements of transmission power and modulation of the definition, in addition to some technical indicators, there are hardware receiver and transmitter standard, with which a two node communication path is formed underlying the network [8-10].

The channel number defines the mean frequency and the corresponding channels are as follows:

$$\begin{aligned} p &= 763.3\text{MHz} && (k=1) \\ p &= 906\text{MHz}+2(a-3)\text{MHz} && (k=1,2,3,\cdots,10) \\ p &= 2405\text{MHz}+5(a-9)\text{MHz} && (k=1,2,\cdots,26) \end{aligned} \quad (1)$$

Three kinds of frequency modulation and transmission parameters are described in Table. **1**.

2.3. Localization Algorithm for WSN

LEACH algorithm is the cluster topology MIT WSN, a cyclical low power adaptive designed by Chandrakasan *et al*. LEACH defines "wheel (round)" concept, which comprises the following two stages:

Firstly, a general coordinator PC is connected directly through the cable as a serial port, *i.e.* the establishment of a new network in the commands received from the host computer, is responsible for the new distribution system for other subsequent sub node number. On the other hand, according to the coordinator, node will request their number to send back to the host computer. Therefore, coordination plays a pivotal role in the network, which is the key part. In communication with the upper computer to complete the work, the coordinator node also has a reference node. The position of the reference node is fixed in the positioning process, the coordinates by people are determined in advance, and during

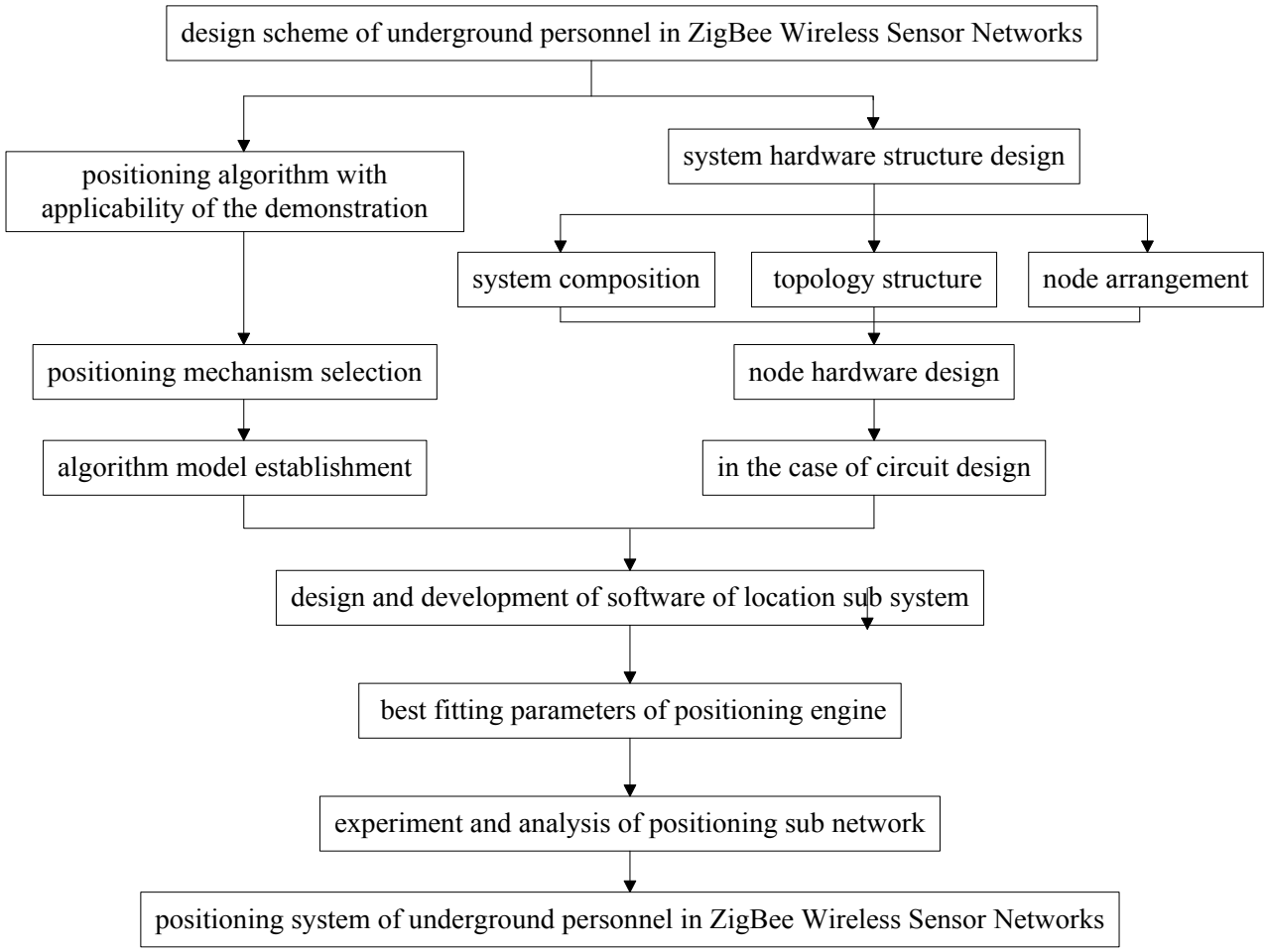

Fig. (2). The technical route.

assignment "in positioning" in the process, it is responsible for receiving and transmitting data packets to the other nodes, and according to the location within the package, for providing relevant parameters such as RSSI value and average value of the parameter, then by positioning node in data package, and finally sent to the coordinator node [11].

Reliable and fast signal transmission is the guarantee for the whole system to work effectively. In the system design, not only it needs to attach to the network location for a reliable data transmission path, in order to avoid unnecessary loss of signal; but also it requires designing a suitable network topology structure that can ensure the reliable data transmission, and a small transmission time delay, i.e. the relative real time increase in the system efficiency.

3. EXPERIMENTAL RESULTS

3.1. Technical Route

Underground wireless positioning system through real-time arrangement in a large number of reference nodes to locate the underground mobile node and positioning for the data transmission and processing, provides managers to achieve a real-time monitoring of underground mobile personnel, to achieve rapid alert in the event of an accident, and the location information for the trapped personnel. The technical route is shown in Fig. (**2**).

3.2. Experiment and Analysis

The experimental environment for building a layer was selected corridor, wide 2.1m, high 3.6m. Nodes arranged in the channel on the ground. Considering the limited number of nodes, laboratory density should not be too large. The reference node layout interval is 5m. The experimental area is 2mX10m, the length of corridor to the X axis, Y axis width, 6 reference node coordinates are: (0,0), (0,2), (5,0), (5,2), (10, 0), (10,2).

From the geometric center location area gradually to the edge of the way of positioning in the process of the experiment, the center and the edge of each point have been taken into account, the comparison between experimental coordinates and the actual coordinates are shown in Table **2**.

Analysis of the experimental results, the following conclusions can be drawn:

Excluding the two bad values, pay attention to the actual coordinates and the coordinates of the measurement error is small, the X axis of the maximum error is less than LM, the Y axis is mostly on 1m.

Note that the Y axis coordinates, even if the Y axis changes, but due to the calculated coordinate positioning engine, this change is obviously not sensitive. Changes in the range of 0-2m, the Y axis are basically maintained at 0.25m.

Table 2. The comparison between experimental coordinates and the actual coordinates.

Actual value (m)	Measured value (m)	Error value (m)	Actual value (m)	Measured value (m)	Error value (m)
(0,1)	(14.5,1.25)	bad value	(5,0)	(6,0.25)	(1,0.25)
(3,0)	(2.5,0.5)	(0.5,0.5)	(7,1)	(7.25,0.25)	(0.25,0.25)
(3,1)	(2.75,0.25)	(0.25,0.25)	(7,2)	(7.25,0.25)	(0.25,1.75)
(4,1)	(3.25,0.25)	(0.75,0.75)	(8,1)	(8.25,0.25)	(0.25,0.75)
(5,1)	(5.25,0.25)	(0.5,0.25)	(10,1)	(13.25,0.25)	bad value

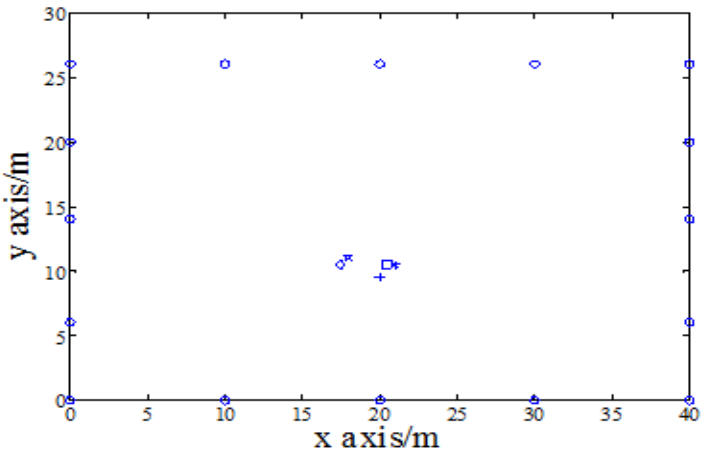

Fig. (3). Nodes for positioning.

At the edge of the position area, positioning vector is really phenomenon.

The positioning effect significantly enhanced the number of reference nodes, and when the six points increases to seven points after the positioning performance is not obvious. At the same time it is reasonable to assume, when the reference node number is more than seven, the performance will continue to rise slightly. But in the actual project, simply increasing the number of reference nodes sometimes is not the best solution for positioning node performance. We can see from Fig. (**3**), the least squares method using six point positioning can smoothly complete positioning, in the range of thirty to forty meters in the precision is about 1-3 meters.

Node hardware mainly includes the wireless transceiver module, power supply circuit, and data download circuit. Coordinate sensor nodes should also include serial communication circuit in order to transmit data with PC. In addition, the system is still the coordinator node design a dot matrix liquid crystal display, embedded with convenient pedestrian machine interaction. In the above mentioned system, hardware part of each node is basically the same, but coordination and other nodes may vary based on a slight increase in nodes. So, this paper introduces a coordinated design of sensor nodes and the remaining nodes designed based on the required function.

CONCLUSION

The society and the government proposed the safe production of coal mine underground personnel positioning system in real time. As an important part of the six systems, it is the construction of many coal enterprises on the agenda that has become a hot research issue of the industry. Aiming at the problems existing in the personnel positioning function of coal mine safety monitoring system at present, combined with the development trend of ZigBee wireless communication technology and wireless sensor network technology. A comparison based research on the existing underground positioning system embedded with several kinds of wireless communication technologies, combined with the special application for environment of underground mine, this paper puts forward the real-time positioning ZigBee WSN technology. This is based on the principle of several common wireless sensor network localization algorithms, underground space wireless signal transmission, to determine a low cost, easy positioning algorithm.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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