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PREREQUISITE SAFETY SYSTEM USING WIRELESS SENSOR NETWORK FOR UNDERGROUND MINES

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Abstract:

Underground mine operations are associated with severe safety problems and due to the high attenuation of radio frequency waves in mines the application of wireless communication systems are highly restricted. To overcome these problems a RFID based wireless information and safety system has been developed at Central Institute of Mining and Fuel Research, Dhanbad, India. The hardware components of the system are ZigBee compliant active radio frequency identification (RFID) devices/ transceivers. The devices can be programmed to act as end device (tag), router or coordinator that enables them to form an IEEE 802.15.4-based mesh network. It uses a unified wireless mesh-networking infrastructure to locate, trace and manage mobile assets and people as well as monitor different environmental conditions using sensors. The associated software has been developed for tracking of underground miners and moveable equipment by wireless sensor networking in mines. The paper describes the developed system and its applications.

Keywords: RFID, Underground, Wireless, sensors.

1. INTRODUCTION:

In an underground mine, huge number of miners are generally enter into underground in a shift for exploitation of coal/mineral from different working faces. As per the current practice, the tracking of miners working in underground mine is not possible. In case of disaster, it is very difficult for the mine management to identify the actual person trapped, their number and exact location. Occasionally, some miners are coming out from underground mine before completion of the scheduled shift time. In case of disaster during that period, there is no track of early adjourns of duty by such miners and the mine managements are always in doubt about how many persons are trapped. Some miners come out of the mine before the scheduled shift time and/or joins duty in late.

However, those miners get full wages in spite of the fact that they are not performing their scheduled duty.

Therefore, the identification and coding of the miners is a vital need for underground mine management in case of disaster as well as normal operating conditions. Further, mining industry is generally capital intensive, and numbers of equipment related to production and transportation are deployed in the underground. It has been reported in many situations that the cost of maintenance at mechanized mines comes to about 35% of the operating cost of the system and it goes as high as 50-60% when both direct and indirect costs are taken into account [1]. Sometimes it constitutes 30% of the total production cost. In today's globally competitive market scenario, efforts to reduce production cost have awaked the mining industry for automation and optimum utilization of equipment by increasing its availability and performance [2,3]. Therefore, continuous monitoring of equipment location and their

operation with respect to dynamic working places is necessary to make the underground mines viable, competitive and profitable. To achieve these goals, Central Institute of Mining and Fuel Research (CIMFR), erstwhile Central Mining Research Institute, Dhanbad, India, has developed a "Wireless Information and Safety System for Mines".

The paper briefly describes the developed system.

2. THE SYSTEM:

The core system component is ZigBee-compliant active RFID device. The devices can be programmed to act as tag (end device), router or coordinator (Fig. 1) that enables them to form an IEEE 802.15.4-based mesh network4. It uses a unified wireless mesh-networking infrastructure to locate, trace and manage mobile assets and people as well as monitor different environmental conditions using sensors [5-7]. The ZigBee devices have numerous advantages, namely, unlicensed 2.4 GHz industrial, scientific and medical (ISM) band; ultra low power (ideal for battery operated system); operates for years on inexpensive batteries; large number of nodes/sensors; reliable and secure links between network nodes; easy deployment and configuration; low cost system; very fast transition time; digital battery monitor facility; and smaller in size (system on chip). The specification of ZigBee devices are as follows: High performance low power 8051 Microcontroller core; Operating voltage is 2 V to 3.6 V; Operating ambient temperature range is –40 ºC to 85 ºC; Frequency band is 2.4GHz ISM; Current consumption in micro-controller active receiving mode is 26.7 mA and transmitting mode is 26.9 mA; System clock frequency is 32 MHz; Time delay is 10 ns; Radio bit rate is 250 kbps; Flash memory is 128 kb; and Receiver sensitivity is –92 dBm.

2.1 System Software

The software is developed for tracking of underground miners and moveable equipment by wireless sensor networking in mines. The complete software is menu driven, self-explanatory, user friendly and does not require any prior sophisticated computer training. The software is developed in Visual Basic (VB) under windows environment as front-end tool and SQL-Server as back end support. VB is an object oriented based software package, therefore various objects available in VB are used. Moreover, few functions and classes are designed in VB to integrate the software. For reporting very powerful and extensive software, Crystal Report is used.

The software operates in two modes, namely on-line and off-line. In on-line (real-time) mode the CPU (central processing unit) is connected to the coordinator by a serial port, and read the periodic tag's data through various routers by multi-hoping technique. Coordinator receives signal from different routers, which are placed in strategic locations. The active RFID devices are attached to the underground miners. Each device can transmit/receive signal to/from the neighbouring devices. The devices are having ZigBee-complaint network interfaces and can autonomously form network among themselves and with other static devices. The locations of the tagged personnel are displayed numerically or graphically on the system and data is automatically saved in a database file. In this mode of operation, location of miner is detected for each router and draws a complete miner path chart as per the request. The software keeps the record of time when the respective miner is going inside the mine and coming back.

It also helps the mine management to keep the record of attendance. Ultimately this software helps in preparing computerised reporting on the actual duty hours of each miner. In off-line mode, one can display the stored data by simply selecting the file of the required date. Graphical location of the particular miner can also be displayed on the screen. In both the operating modes, the software supports hard copy printing of data (numerical or graphical as desired). Administrator can change the software configurations, like working area of mine plan, unit of scale, router locations, router status and different essential parameters. Enough security has been maintained using password.

3. System Application

There are a number of scopes for application of the developed technology that will help the mining industry to improve productivity and miners' safety with the means of accurately monitoring various dynamic activities, people and assets. An integrated system with different modules has been developed to overcome the existing problems in the mines.

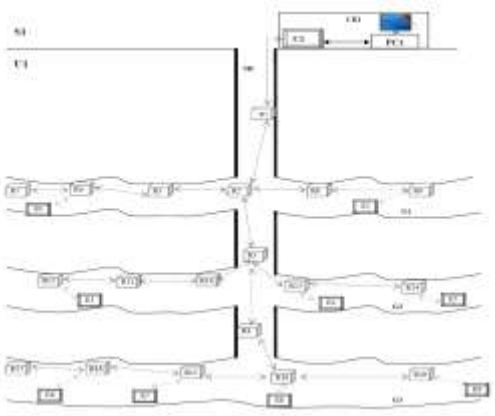

Fig-1 : Layout of Wireless Network in an Underground mine having Shaft Entrance

Fig. 1 illustrates the wireless sensor network in an underground mine having shaft entrance. The sensor
network consists of a personnel computer (PC1), coordinator (C1), router (R1 to R19) and end devices (E1 to E9).

The computer (PC1) is connected to the coordinator (C1) using RS232 cable in the surface (S1) control room (CR1).

The routers (R1 to R4) are wirelessly connected with the said coordinator (C1) at a distance of around 60 m apart in an underground (U1) shaft (SH). The routers (R5 to R7) and routers (R8 to R9) placed in the left and right sides of the first gallery (G1), respectively at distance of around 50 m are wirelessly connected to the said router (R2). The end devices (E1 and E2) attached with the miners/moveable equipment are wirelessly communicated with routers
(R6 and R9), respectively. The routers (R10 to R12) and routers (R13 to R14) placed in the left and right sides of the second gallery (G2), respectively are wirelessly connected to the said router (R3). The end devices (E3, E4 and E5) attached with the miners/moveable equipment are wirelessly communicated with routers (R12, R13 and R14), respectively. The routers (R15 to R17) and routers (R18 to R19) placed in the left and right sides of the third gallery (G3), respectively are wirelessly connected to the said router (R4). The end device (E6 to E9) attached with the miners/moveable equipment are wirelessly communicated with routers (R16, R15, R18 and R19), respectively.

4. System Capabilities

The developed wireless information and safety system for mines has following capabilities:

(i) Capable of tracking and monitoring miners and equipment in underground mine using ZigBee-enabled active RFID devices forming a wireless network among them and other static and mobile ZigBee devices placed at strategic locations.

(ii) Capable of identifying the miners entering in underground mine to keep the track of the miners and
maintaining computerized attendance.

(iii) Capable of monitoring equipment locations and their operation to improve productivity and reduce fatal collision accident.

(iv) Capable of locating and tracking the miners in case of disaster for speedy rescue operation.

(v) Capable of monitoring miners' unsafe practice and providing warning to the respective miner.

(vi) Capable of real-time monitoring environmental parameters in underground mine.

(vii) Capable of sending coded message to the concerned person in underground mine.

(viii) Capable of automatically forming alternative network among the undisturbed and reachable routers in case of disaster (like roof fall, collapse of entrance/ gallery side, inundation, mine fire and explosion) in particular area in underground mine so that communication does not get disturbed in the whole mine.

(ix) Capable of monitoring movement of dumpers in opencast mine, which ultimately helps in optimum shovel-dumper performance and improving productivity.

(x) Enables a low-powered, intrinsically safe, easy to install and cost-effective miners' information and safety system for underground mine.

5. Conclusions

To overcome the above mentioned day-to-day problem faced by the mine management, installation of wireless information and safety system is a vital need for mining industry. With the help of central processing unit at the pit top, it will be possible to keep the track of miners and machines moving in the underground. It will also be possible to keep the record of time when the respective miner is going inside the mine and coming back. The implementation of the system will also help the mine management to keep the record of the attendance and to identify the persons who are delaying to start his scheduled duty and/or coming back early. This would help in preparing computerized pay roll based on the actual duty hours of each individual. In case of disaster, the system will help in identifying the trapped miner along with their location and numbers, and this will improve the safety of the miners. Therefore, it may be concluded that implementation of the developed system in the mine can fulfill following purposes:

(i) The risk of fatal accidents can be greatly reduced; (ii) The efficiency and productivity can be measured and improved;

(iii) Safety of miners can be enhanced by continuously monitoring and tracking of miners and vehicles movement;

(iv) Collision can be prevented to reduce the risk of accidents, loss and machine downtime period;

(v) Locating and tracing of trapped miner is possible for speedy rescue operation;

(vi) Improving the output per man shift (OMS);

(vii) Reducing the idle time by tracking and monitoring the equipment operating in underground mines;

(viii) Saving the wages for miners who does not perform his duty as per his scheduled shift;

(ix) Tracking of the miners going inside the mine in normal operating hours;

(x) Monitoring miners' unsafe practice and providing warning; and

(xi) Enhancing the safety of the miners.

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