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MINING VEHICLE SAFETY USING WIRELESS COMMUNICATION SYSTEMS

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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—*wireless communication, RFID, multi-hop protocol, Voice over sensor network, PED, SIAMnet, TeleMag*

I.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.

Communication is the activity related to the transmission of signals (data) for the sake of information exchange. In underground (U/G) mines communication is a crying need both from safety and productivity point of view [1,2].The need to keep pace with the market and lifestyle of the miners, demands more reliable communication methods, and hence more and more research has been done for improving the technology from the beginning of 20th century.Underground communication methods are lagging behind the surface level communication which has seen huge advancements, the lates being the 4G technology. The less improved communication inside U/G mine is not only due to general lack of interest in this area but also for the unfavorable and hazardous environment inside the same. Communication is mainly comprised of transmission of data from the sender to receiver which may be in groups or from a miner to another miner, in which transmission deals with the amount and speed of the data through the transmitting medium. This seems very simple above ground, as a huge amount of data can be sent at a very high data rate through

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cables or optical fibres, which can be be conveniently installed, in which noise can be easily eliminated without using any special techniques. However, wired communication in fails in situations where connectivity is imperative e.g fire outbreak, roof fall, power or battery failure, explosions etc. This is the reason, wireless communication has a key role in underground mines.

II. TYPES OF COMMUNICATION SYSTEMS FOR UNDERGROUND MINE

Conventional systems or the wired system is comprised of magneto phones, paging phones, voice powered phones etc. Magneto phones are the oldest crank ringer phones of 20th century operated by DC batteries and AC signals [3]. Paging phones are partly line wired phone for voice communication with no tracking capability [4]. When high voltage trolley line is used as signal path only for voice communication then it is called as the trolley carrier phones system. Hoist rope system is nearly same as trolley carrier phones except that the hoist radio signal is inductively coupled to hoist rope through use of capacitor as coupling device with the trolley carrier phones. TTE or Through The Earth system is a well known system providing alarming, tracking and messaging with the help of loop antennas on surface of mine which transmit low frequency signal to receivers, integrated into cap lamps[5]. Whereas, wireless network system deals with WiFi (IEEE 802.11), bluetooth (IEEE 802.15) and WiMax technologies. Ultra Wide Band system is the another radio system for short range communication with very low power at a very high data rate[6-10]. RFID System is comprised of radio frequency identifier tags, RFID readers, routers and a host station. RFID tags are very small chips which store a specified amount of data in its circuitry. RFID tags are of two types, active and passive; in underground mine active tags should be used as the signal range is nearly 100 metre for active tags whereas for passive tag's the range is practically 6-8 metres. In each level of the underground mine routers are placed for a specified region and these routers act as intermediate for host station and RFID tags. Routers give the information about the tags which are in its coverage-region and the RFID Reader reads the tag information and sends it to the host station. By this way miners position can be located and monitored by tracking and monitoring software. Attendance of miners can also be taken by this method and in the event of an undesirable situation the miners can be saved from the trapped zone [11, 12]. ZigBee is new wireless technology guided by IEEE 802.15.4 Personal Area Network standard. It is primarily designed for the wide ranging controlling applications and to replace the existing non-standard technologies. It currently operates in 868MHz band at a data rate of 20Kbps in Europe, 914MHz band at 40kbps in USA, and the 2.4GHz ISM bands Worldwide at a maximum data-rate of 250kbps. The sensor nodes in the underground section will send the collected data to the wireless network and then to the host or database for further analysis. For through the earth communication radio wave attenuation creates the main problem. Attenuation is dependent on frequency of radio wave, earth conductivity, transmission power, antenna type and noise over the surface and in the underground [13-15]. To decrease the attenuation, low or very low frequency radio waves should be used. According to MSHA rules more power can't be transmitted through the earth due to the risky conditions and noxious gases present in the mine environment. In such conditions Helical ferrite antennas are very much helpful for a long range duplex voice communication and text messaging at very low power transmission. These low cost antennas are also small in size which can be mounted or wound around the pipes or pillars present in the underground mine. It also enables the communication in case of roof fall. Multi-hop Protocol technology is developed to provide long range wireless communication inside the mine (through the air) by using portable relay nodes. These nodes carry the data in packet form and this is a half-duplex communication method. By implementing this method instructions can be given to the rescue robots with a certainty of guaranteed data transmission [16]. Voice over Sensor Network in underground mine works for the data communication between the sensors and the host station [17]. But now a day's wireless sensor network is developed to use the wireless network for real time voice streaming in a TDMA based bidirectional communication. Audio signals are compressed and then modulated in the carrier radio wave as the wireless network works for low frequency bandwidth

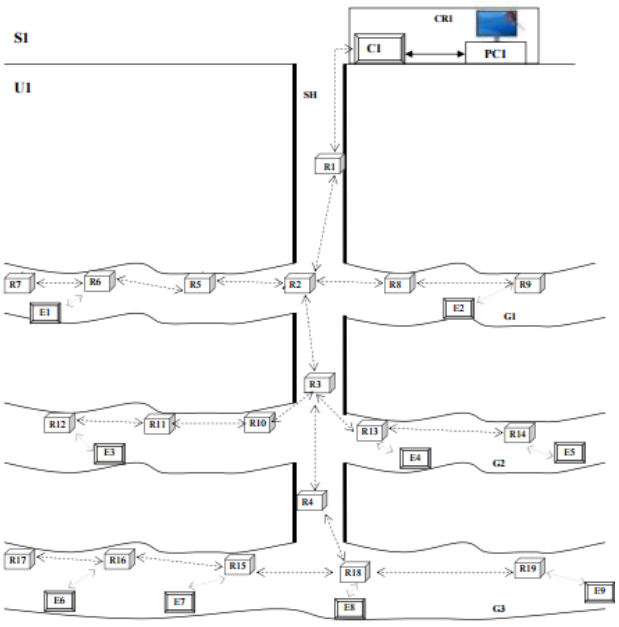

Fig. 1 Layout of wireless network in an underground mine having shaft entrance

III. 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.

3.1. 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.

IV. 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 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.

V. SYSTEM CAPABILITIES

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

- 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.
- Capable of identifying the miners entering in underground mine to keep the track of the miners and maintaining computerized attendance.
- Capable of monitoring equipment locations and their operation to improve productivity and reduce fatal collision accident.
- 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.
- Capable of real-time monitoring environmental parameters in underground mine.
- Capable of sending coded message to the concerned person in underground mine.
- 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.
- Capable of monitoring movement of dumpers in opencast mine, which ultimately helps in optimum shovel-dumper performance and improving productivity.
- Enables a low-powered, intrinsically safe, easy to install and cost-effective miners' information and safety system for underground mine.

VI. CONCLUSION

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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