Real Time Location Tracking System for Metal Miners

Lalit Kumar Wadhwa, Vishnu Priye, Reshma Muralidharan, Chitralekha Ruikar, and Venancius Norman

***Abstract*—Safety of underground miners and immediate tracing of them in case of disaster is of prime concern in any mining operation. For successful operation to determine the position of miner is of utmost importance. In this paper we propose a novel method to keep track of a miner position in an underground metal mine. The real time location tracking system is based on wireless sensor network that employs Zigbee as communication platform and ARM processor LPC2148 as the controller. A received signal strength indication (RSSI)-based localization algorithm independent of the environment, a robust localization mechanism to solve the problem of instability and jitter of results and a practical localization algorithm for mobile nodes in the tunnel environment are proposed. The validity of the algorithm is verified experimentally.**

Index Terms—Real time tracking system, target tracking, wireless sensor networks, underground mine safety.

I. Introduction

Wireless communication inside the underground mine is one of the most promising and effective technique that is being used in number of solutions [1].

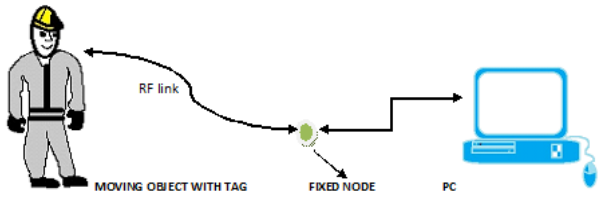

Fig. 1. Working overview.

The limited infrastructure required as compared to the legacy wired communication technology, which is very much susceptible to the disaster itself, has paved the way for ingenious solution development to tackle the mining disaster issue. Several types of mine tracking systems have been developed and many systems have been put into service worldwide [1], [2]. Among them are RFID (radio frequency identification) inertial-based and radio node-based systems [1].

An inertial tracking system relies on its own inertial measurement unit (IMU) to attain the data and complete its own location calculations. A node based system uses the communication linkage of a stationary transceiver (node) and a mobile transceiver (tracking device) to estimate the relative location of the device. Although current tracking systems [2] are functional, none seems capable of correcting for some common errors, such as a tracking device reporting itself inside a metal mine.

Moreover, global position system (GPS) system cannot work in an underground mine, so there is requirement for a new technology [6]. The technologies that are already implemented [1], [2], are somewhat old, outdated and not completely acceptable. The points to be noted are such as the communication system [1], [2], is not completely reliable, transmission rate is low, long time is taken for inspection, the cable networks increase the system cost unduly restricting the extension of coverage through the mine, hence decreasing the security and reliability of data. It cannot implement the real-time control of field equipment very well. So, the design of the monitoring system with higher reliability and accuracy is hence proposed. Wireless sensor networks (WSNs) are recently being investigated due to their remote environment monitoring capabilities. Such a network can easily be used to track the position on miners in underground mine. So we propose design of a Wireless Senor network which can collect data from the nodes via radio frequency waves [2]. In this paper, we propose a network topology to attain high reliability and convenient management of data acquired in a large scale region. We also put forth a special algorithm based on Basic Positioning Algorithm which detects the exact position of metal miners using Zigbee with high reliability. Finally the hardware to realize the location tracing is discussed.

II. Basic Positioning Algorithm

A. Algorithm

The miners working can be handed the mobile node which is small in size and light weight. The fixed nodes are placed equidistant from each other in an organized manner. In our proposed system the accuracy is high which can still be improved via collaboration of a group of sensor node i.e. fixed nodes. Fixed node continuously monitors the activities of mobile node present in its vicinity, and reports the changes in power levels to the host computer or the client PC. The exchange of data between fixed node and mobile node is done with the help of varying power levels and with the help of these power levels position of the mobile node is calculated. The fixed node is placed on the walls of the mine, and mobile nodes are carried by the miners.

- Let two circles of radii R and r and centered at (0, 0) and (d, 0) intersect in a region shaped like an asymmetric lens. The equations of the two circles are

$$x^2 + y^2 = R^2 \quad (1)$$

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$$(x - d)^2 + y^2 = r^2 \quad (2)$$

- Subtracting (1) from (2) gives

$$(x - d)^2 + (R^2 - x^2) = r^2] \quad (3)$$

- Expanding and rearranging gives

$$x^2 - 2dx + d^2 - x^2 = r^2 - R^2 \quad (4)$$

- Solving for x results in

$$x = (d^2 - r^2 + R^2)/ 2d \quad (5)$$

- y can be found by substituting x back in Equation (1) to obtain $y^2 = R^2 - x^2$

$$= R^2 – ((d^2 - r^2 + R^2)/2d)^2 \quad (6)$$
$$= 4d^2R^2 - (d^2 - r^2 + R^2)^2 /4d^2 \quad (7)$$

- Thus substituting the values of x and y in the equation: $(x + x')^2 + (y + y')^2 = r^2$ (Smaller circle).
- Thus, the co-ordinates of mobile nodes i.e. X and Y are obtained.

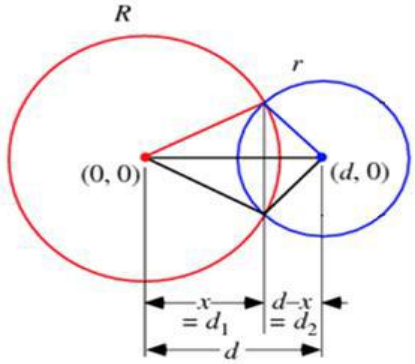

Fig. 2. Circle to circle intersection.

B. Programming Steps

1) Start
2) Pair stationary node 1 (s_1) with mobile node (m).
3) Send the signal from s_1 to m
4) Save the RSS value as ms_1.
5) Pair stationary node 2 (s_2) with mobile node (m).
6) Send the signal from s_2 to m
7) Save the RSS value as ms_2.
8) Pair stationary node 3 (s_3) with mobile node (m).
9) Send the signal from s_3 to m
10) Save the RSS value as ms_3.
11) When all the three RSS values are received by m then look for the look up table and convert them into their respective distance as a_1, a_2 and a_3.
12) Find the coordinates of m i.e. x and y using following formula:
$(x + x')^2 + (y + y')^2 = a^2$: generic formula
13) Send the location information to the stationary node s_1(which is connected to PC)
14) Display the location information of m on the screen.

III. HARDEWARE IMPLEMANTATION

A. Zigbee Technology

Zigbee is based on the 802.15.4 wireless personal area network (PAN) and it is suitable for low –data-rate wireless network technology [4]. Zigbee's data rate is between 10Kbps and 250 kbps. Zigbee network is primarily used for the automatic control and establishment of the data transmission [3]. Zigbee which is based on the 802.15.4 protocol stack posses a improved and powerful networking capability. The use of routing enables more nodes to communicate and greater distance to be covered by the use of intermediate nodes. There are three different network topologies that are supported by Zigbee, namely the star, mesh and cluster tree or hybrid networks. But mesh topology is preferred because of its high reliability. The system is specified to operate in one of the three licenses free bands at 2.4 GHz, 915 MHz for North America and 868 MHz for Europe. At PHY layer, IEEE 802.15.4 defines 27 channels in three carrier band [2]. At 2.4 GHz there are a total of sixteen different channels available, and the maximum data rate is 250 kbps. For 915 MHz there are ten channels and the standard supports a maximum data rate of 40 kbps, while at 868 MHz there is only one channel and this can support data transfer up to 20 kbps.

IEEE802.15.4 defines two types of Zigbee network devices: full function device (FFD) and reduced function device (RFD) [4]. They communicate each other but RFD cannot communicate with itself. In fact system operate in heavily congested environments, and in areas where levels of extraneous interference is high, the 802.15.4 specification has incorporated a variety of features to ensure exceedingly reliable operation. These include a quality assessment, receiver energy detection and clear channel assessment. CSMA (Carrier Sense Multiple Access) techniques are used to determine when to transmit, and in this way unnecessary clashes are avoided. The standard supports 64 bit IEEE addresses as well as 16 bit short addresses. The 64 bit addresses uniquely identify every device in the same way that devices have a unique IP address. Once a network is set up, the short addresses can be used and this enables over 65000 nodes to be supported.

It also has an optional super frame structure with a method for time synchronization. In addition to this it is recognized that some messages need to be given a high priority. To achieve this, a guaranteed time slot mechanism has been incorporated into the specification. This enables these high priority messages to be sent across the network as swiftly as possible.

B. Working Overview

To reduce the delay to a minimum, we are developing a metal miner's tracking system based on Zigbee technology. A wireless tracking system consists of two separate hardware components:

- Signal transmitter/receiver
- A measurable unit which usually carries the major part of system intelligence (ARM LPC2148).

The metal miners tracking system detects the signals transmitted by or received at known reference point using radio sensing technologies. The sensing technique is based on signal strength level that converts sensed signal into received signal strength (RSS).Given a set of reference point, relative position of the mobile station can be derived from the signal characteristics of RSS. The signal characteristics of RSS are unique for a location.

Then finally microcontroller processes the position algorithm and estimates the position of the object and displays it on the PC. This system will operate by recording

and processing signal strength information at multiple base stations positioned to provide information. It will combine **Circle-circle intersection technique** with **signal strength matrix** obtained during offline measurement to determine the location of the miners.

Packets are received by Zigbee transceiver & it sends the signal to ARM7 via MAX232. Electrical signal is transmitted to ARM via MAX232 Ic.MAX232 is used to maintain the voltage compatibility between ARM7 & RS232 cable. Signal is processed by ARM7. It sends this signal to its UART1. UART1 converts parallel data to serial data & sends it PC via RS232.

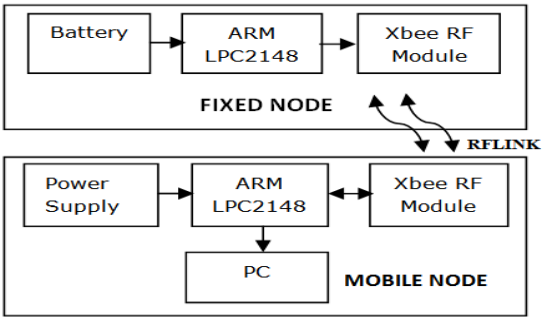

Fig. 3. Block diagram of system.

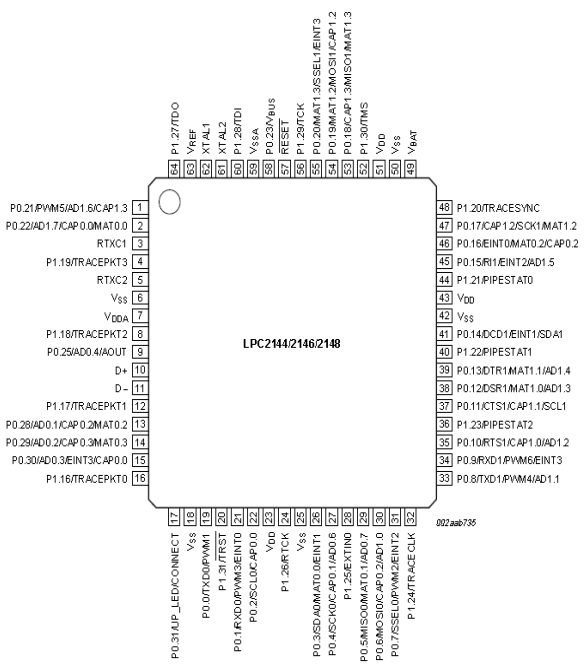

Fig. 4. Pin diagram of LPC2148 [7].

C. Hardware Implimentation Design

1) ARM7 processor (LPC2148)

This processor embeds many features enhancing its usage in our proposal, A few can be listed as 16/32-bit ARM7TDMI-S microcontroller in a tiny LQFP64 package, 8 to 40 kB of on-chip static RAM and 32 to 512 kB of on-chip flash program memory, 128 bit wide interface/accelerator enables high speed 60 MHz operation. It has USB 2.0 Full Speed compliant Device Controller with 2 kB of endpoint RAM. In addition, the LPC2148 provides 8 kB of on-chip RAM accessible to USB by DMA, Low power real-time clock with independent power and dedicated 32 kHz clock input. Multiple serial interfaces including two UARTs (16C550), two Fast I2C-bus (400 kbit/s), SPI and SSP with buffering and variable data length capabilities and Vectored interrupt controller with configurable priorities and vector addresses[7]. There are up to 45 of 5 V tolerant fast general purpose I/O pins in a tiny LQFP64 package. 60 MHz maximum CPU clock is available from programmable on-chip PLL with settling time of 100 µs. The Power saving modes include idle and Power-down and the Individual enable/disable of peripheral functions as well as peripheral clock scaling for additional power optimization. The Processor wake-up from Power-down mode via external interrupt, USB, Single power supply chip with Power-On Reset (POR) and BOD circuits: – CPU operating voltage range of 3.0 V to 3.6 V (3.3 V ± 10 %) with 5 V tolerant I/O pads [7].

2) Working and design of stationary unit

In stationary unit, ARM7 is interfaced with Zigbee module as well as computer through its two UART provided.UART1 is connected to computer via RS232 cable and UART0 is connected to Zigbee module.

Following Fig. 1- Fig. 6 shows Hardware implementation of Stationary Unit.

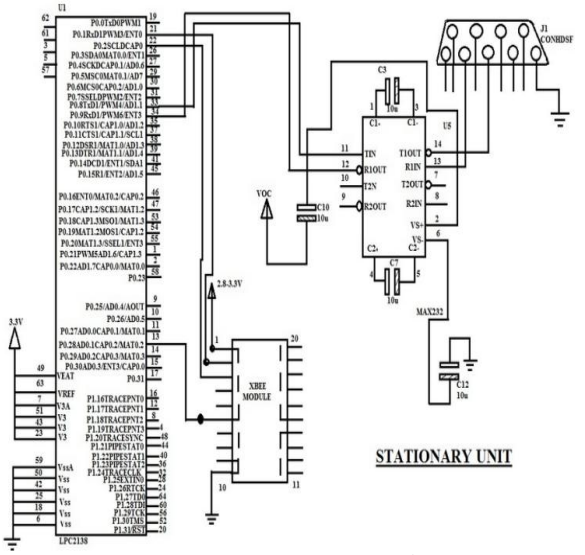

Fig. 5. Hardware implementation of stationary unit.

3) Working and design of mobile unit

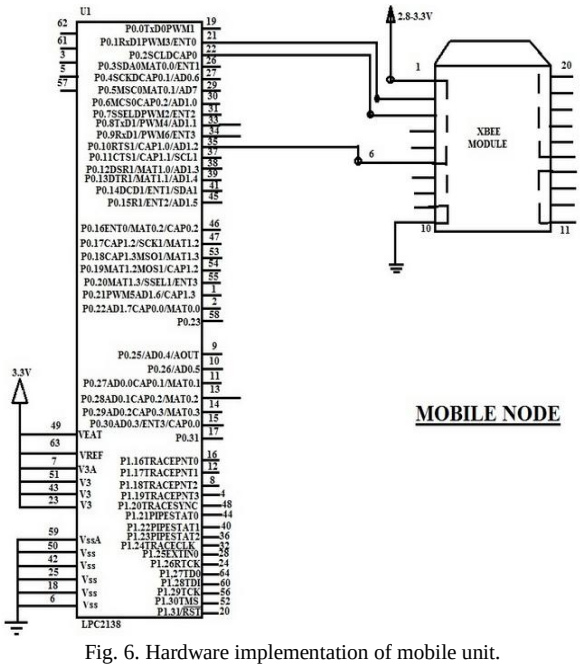

Fig. 6. Hardware implementation of mobile unit.

Step 1: Packets is received by Zigbee transceiver & sends the signal to ARM7 via MAX232.

Step 2: Electrical signal is transmitted to ARM via MAX232 Ic.MAX232 is used to maintain the voltage compatibility between ARM7 & RS232 cable.

Step 3: Signal is processed by ARM7.it sends this signal to its UART1.UART1 converts parallel data to serial data & sends it PC via RS232.

In mobile we have used an ARM7 which is interfaced to Zigbee transceiver. Zigbee Transceiver receives radio signal from other Zigbee modules, pass the signal to ARM, ARM processes the signal and calculates the required miners $X \times Y$ co-ordinates.

IV. Conclusion

Therefore, compared to any other device, Zigbee provides the most prominent features to suffice its usage in the extreme environmental conditions with a satisfactory performance. Hence with this we have proposed a real time tracking system which performs a localization algorithm to achieve the exact location.

The system is composed of hardware and software platform. This design works using general principles of position estimation using position estimating sensors which provide us the information of the desired location module. This design work focuses on accuracy and precision. As designed for position estimation, RSSI in the device is used for position estimation. Our study found that the minimum distance between two adjacent positions also affects the positioning performance. This is due to the randomness of RSS patterns induced by the ever changing indoor environment. Using the real time tracing system for miners we can hope to increase the safety of the miners.

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