Application of Wireless Sensor Network Technology for Miner Tracking and Monitoring Hazardous Conditions in Underground Mines

A RFI Response (MSHA RIN 1219-AB44)

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Introduction

Wireless Sensor Networks (WSN) typically consist of a large number of nodes that are low-power, low-cost autonomous devices with integrated sensing, processing and wireless communication capabilities and small form factor. These networks show great promise for a wide variety of applications (Romer 2004) in areas such as military, homeland security, monitoring environment, remote monitoring and control of devices at our homes, and healthcare. This document presents a high level proposal for using WSN technology for miner tracking and detection of hazardous conditions in underground mines.

Statement of Problem

When underground mine accidents occur, availability of following information could enhance rescue efforts:

- Location of trapped miners
- Two way communication with the miners
- Environment conditions (for example, temperature, carbon monoxide level, presence of methane or other undesirable gases) along the rescue path to the trapped miners

Further, continuous and remote monitoring of miners and environmental factors such as temperature, carbon monoxide level and methane level in underground mines could also help prevent accidents. Communication technologies currently deployed in underground mines have limitations to support the above requirements.

Proposed Solution

The author proposes a multi-hop wireless sensor network to address the above issues. A WSN typically uses IEEE 802.15.4 or ZigBee standards and frequency bands such as 2.4GHz ISM (Industrial, Scientific, and Medical) band, 900 MHz band, 433 MHz band, or 315 MHz band for communication. It could support data rate of up to 1Mbps. A WSN node (called "mote") is typically equipped with a low power battery, a small processor (for example, 10 MHz processor, 10 KB of RAM, 100 KB of ROM), and a transmitter (supporting a radio range of 10 to 100 meters). TinyOS (UC-Berkley, 2004) is a popular operating system for the motes. Many commercial motes have built in sensors and also have the capability to interface with analog or digital sensors. A WSN could also be connected to the Internet or an Intranet through a gateway.

The proposed wireless sensor network for an underground mine requires stationary wireless sensor nodes to be placed at selected locations throughout the mine so that each node could communicate with gateway node(s) (called "sink") using one or

more hops. The network topology typically uses redundancy for reliability. The gateway node(s) are connected to the corporate LAN using Ethernet.

Miner Tracking

For miner tracking, each miner needs to wear mote containing identification information for the miner and the mote broadcasts its code periodically. As a miner moves from place to place within the mine, he/she acts like a mobile node. When a miner comes within the radio range of a stationary WSN node, the stationary node communicates that information to the miner tracking application through a gateway node. As the location of the stationary node is known to the application, the location of the miner could be tracked.

Two-Way Communication

Pre-coded messages could be exchanged efficiently between any miner and the tracking application in the above ground control room through a gateway node. Messages could be conveyed to the miner using color coded LEDs (Light Emitting Diodes). Development could also be done to interface a text display and a keypad to the motes worn by miners.

Monitoring Hazardous Conditions

The stationary wireless sensor nodes could have temperature, carbon monoxide and methane sensors. These nodes could transmit the sensed data periodically to the monitoring application through a gateway node. The monitoring application could analyze the sensor data to predict hazardous conditions. That could help timely evacuation of personnel from unsafe areas.

Future Work

Although WSN technology is commercially available, a prototype for the proposed application needs to be developed and tested in an underground mining environment to prove its feasibility. The following areas also need further investigation:

- Hardware FIT (Failure In Time) rate in underground mining environment
- Reliability and Security
- Network Management

If there is interest from MSHA (Mine Safety and Health Administration), the author and the Ohio University will be glad to submit a detailed proposal for developing a prototype WSN application for miner tracking and monitoring hazardous conditions in underground mines.

References

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UC-Berkeley [2004]. *TinyOS Community Forum*. Retrieved February 28, 2005, from http://www.tinyos.net/