USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES FOR MINING DISASTERS IN UNDERGROUND MINES

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Abstract:

The inherent nature of underground mines and the working environment for the miners provide a daunting challenge to address the safety issue in the mines. The mining industry across the world suffers regular disasters, caused by toxic gas emission, fire or mud slides and other hazards. It takes catastrophic shape due to the fatal effects on the miners trapped inside the mine. Lack of availability of real time positional and environmental information inside the mining zone cripples the ability to react promptly and accurately in case of a mining disaster. In this paper, we propose to investigate the various technology options available to mitigate the disasters in underground mines. The most significant of these options is the Active RFID-based wireless mesh networking technology that provides a sound foundation for establishing real time visibility of mining assets as well as miners that can significantly enhance disaster management capability. The active RFID devices, which support mobility and can be attached to miners, are capable of forming autonomous wireless mesh network and propagate the network information to a central control station in multi-hop, so that the entire network of devices can be viewed centrally. Thus the location of each miner (carrying an active RFID device) is known in real time. The flexibility to attach gas sensors with active RFID devices allows safety monitoring center on the surface to view the poisonous gas level (such as methane, carbon monoxide, carbon dioxide etc) inside the mine on a real time basis. In this way, a combination of Real Time Locating System (RTLS) and Real Time Sensing System (RTSS) applications using active RFID technology in the mining industry will tremendously augment the capacity and effectiveness with which disasters can be foreseen and mitigated in underground mines.

Introduction:

The design and planning of underground mine is aimed at creating an integrated mine system [1] whereby minerals are extracted and processed for a dedicated market at minimum operable cost. Mining system requires an inter-disciplinary engineering structure and coordination for its operation. It is a complex amalgamation of diverse and interconnected technological processes, facilities, integrated with personal skill. This complex array of subsystem includes mining safety as well. And it is beyond doubt that the underground mines present one of the most difficult, tough and challenging environment to work for human beings. Although safety is considered as one of the key issues, limitations in feasible technological solution, cost, and the very nature of underground mine has restricted the genesis of a unified mechanism to ensure full-proof safety for the miners.

In light of numerous underground mining disasters across the world, substantial research work had been taking place in academics as well as in industries for the last couple of decades. The disastrous situations and accumulated experience has opened up new horizons of technologies that are being analyzed for applicability in the mines for improving safety. Through the course of the next sections of this paper we investigate the mining problems and compare the available technologies and their evolution in addressing the safety concern and advance our paper by explaining the preeminent mechanism for ensuring a sustainable and feasible solution for mine safety.

Safety Problem in Mining:

The physical and geographical complexity of tunnels in underground mines impairs the visibility of environment and operating assets, including human beings. Irrespective of the acuteness of locating mineral though proper mining design and planning, the hazards of the sub-terrestrial world remains unpredictable. This increases the vulnerability of the miners. Most of the available technologies are restricted in being reactive rather than proactive, which means that it can not predict an imminent disaster situation. And, once the disaster strikes sub-terrestrially, it leaves very little window of opportunity to control the disaster from getting worse. At the heart of the majority of these technologies there is a mining information system, which is used as a reference to deduce the latest situation upon periodic availability of information from the underground. The quality and accuracy of mine information varies greatly depending on the source, type, and age of the mine. The various causes of mine disaster, such as mud slides, breaking into old mines [2], active faults in geological structure, water breakage [3], toxic gas emissions, fire, roof collapses, suffocations etc. all lead to catastrophic proportions because of the loss of human lives as trapped miners. The prolonged time it takes for the rescuers to reach the victims claims more life than the disaster itself.

Different Available Technologies and Limitations:

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

Ultra low frequency text messaging using Personal Emergency Device, also known as PED System [4], is an effective communication means for underground mine. The PED System operates as a through-the-earth communication system with substantially low bandwidth used for paging, control and centralized blast initiation. The use of ultra low frequency (ULF) electromagnetic signals enables the PED signal to propagate through several hundreds of meters of rock strata. The signal can therefore be received at any location throughout the mine with an antenna on the surface only or a small underground antenna. For this reason, PED is an extremely effective emergency communication system. The ability to transmit actual messages is vitally important in allowing, not only a warning to be issued, but specific information regarding the situation to be sent; such as where a fire is, which evacuation route to take, which would be the most effective exit to find help, etc. The PED system can communicate with 1) Belt PED - personal receiver worn by miners; 2) Auto PED - vehicle mounted receiving units; 3) Control PED - remote control of underground equipment; 4) Blast PED - a centralized blasting system, where the blasts can be initiated remotely. Similarly, the Canary 2 system [5] uses un-modulated very low frequency (VLF) for voice communication in the underground mine. The Canary 2 also enables through the earth communication in presence of high-density ore bodies, metal and rock environment. But, as the depth of the mine increases so do the tunnel complexity, and eventually these types of technologies fail. Disasters such as those at the Consol Mine, in Sunshine Mine and the Sago Mine (2006) has brought to light the glaring failures of these mine communications systems. Radio signals fail to penetrate rock, ore bodies and debris. They fail to penetrate shielded or complex environments such as mines. These incidents have highlighted the lack of robustness of communication technology in emergency situations. They are susceptible to power blackouts causing dangerous downtime, putting the lives of miners and emergency rescue teams at risk.

Rapid-deploy Seismic location system is rapidly deployable and effective in detecting minute vibrations. The vibrations generated from trapped miners are captured and transmitted through wireless signals to anywhere in the terrestrial surface. The system includes a set of geophones sub array pods, each containing a high resolution digitizer, digital signal processor, and interfaced with a WiMax wireless network. A small base station computer receives signals from the pods, and stores in database for signal processing and micro-seismic search. However there are numerous problems associated with this kind of system, such as miss alignment of pods with the geophone, WiMax base station installation limitation in underground mine.

Inertial Sensor Tracking System also offers similar solution, where small surface mount technology, powerful microprocessor chips and improved battery technology forms the basis. Micro-Electro-Mechanical Systems (MEMS) Inertial Sensors consist of miniature devices that combine electrical and mechanical inertial sensing components. Wearable battery operated MEMS device transmits position data via wireless telemetry. Telemetry receivers are located throughout the mine at strategic locations. And the information is relayed back to monitoring station which employs charting software.

Radio Frequency Identification (RFID) based tracking system is another effective mechanism to track underground asset and miners. The small RFID devices can be attached to the miners as well as assets to reliably track the location and movement of resources, including personnel, vehicles and goods, for underground mines and tunnels. This type of system consists of active RFID tags, networked readers and central software running at a remote PC. The active RFID readers placed at strategic locations forms a wireless network between them and propagates the network information generated by the mobile tags attached to the miners or assets to that central PC, where the software can visually represent the real time location of the tagged objects. This kind of system is known as Real Time Locating System (RTLS).

One of the common and major drawbacks of the technologies discussed above is that they are not proactive. These technologies do not provide any preemptive mechanism to avert a disaster or provide a reliable warning system to alert the miners and subsequently evacuate. Because, once the disaster hits the mine itself, there remains very limited opportunity to suppress the calamity. To overcome these severe limitations a combination of these technologies seems to be the right answer. And, active RFID technology integrated with sensors for real time location monitoring and sensing emerges to be the obvious solution which has the capability to address the mining disaster handling issue competently. In the following section we explore and analyze active RFID based integrated sensing and tracking system in an underground mining environment.

Active RFID based Integrated Sensing and Tracking System:

Active RFID based Real Time Locating System (RTLS) and Real Time Sensing System (RTSS) [6], consists of small wearable active RFID tags, intelligent network of routers, a central coordinator and a system software suite which enable real time location and environment monitoring visually. If the central monitoring and control station, where the software suite runs, is internet enabled then the whole underground mining environment and operation can be viewed globally, giving anytime anywhere visibility as well control. The RFID tags attached to the miners or assets are capable forming a network between them even under constant mobility. Highly effective and small sensors can be integrated with these tags. The flexibility to attach gas sensors, capable of sensing toxic gasses such as carbon monoxide, carbon dioxide, methane, sulphur dioxide etc. and to subsequently transmit that information in real time to a monitoring station on the surface creates the

absolute critical visibility of the sub-terrestrial mining world. This smart active RFID tags are capable of communicating in both directions, so the miners can also communicate with the control station and vice versa.

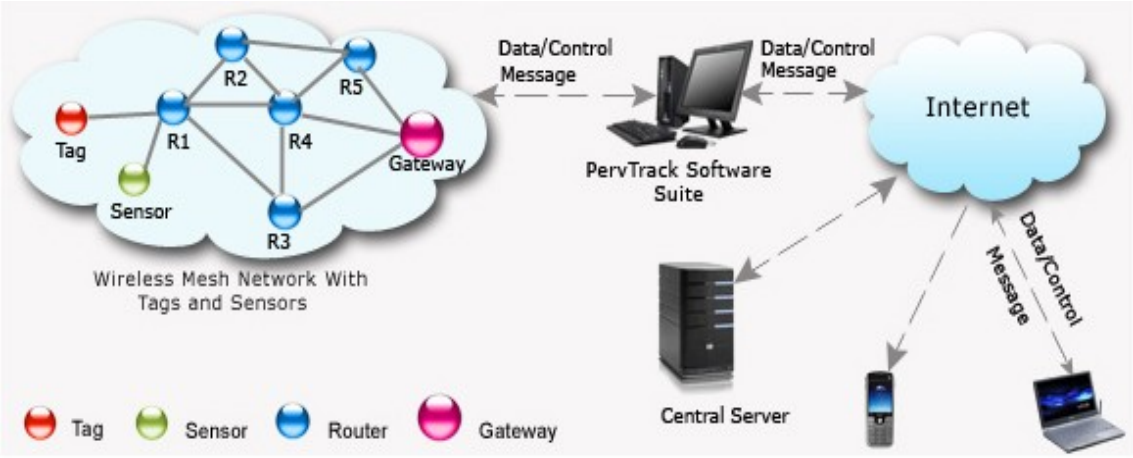

Figure 1: Architecture of Integrated Platform for Real Time Locating and Sensing System.
(Courtesy PervCom Consulting, India)

Figure 1 shows the complete system architecture of this active RFID based integrated real time locating and sensing solution. The routers are placed in strategic locations in the various mining tunnels and they are capable of forming autonomous, fault tolerant and robust wireless network. Specific sensors, such as vibration sensors, soil moisture sensor, smoke sensors for fire detection can be placed in critical locations and they can detect the environmental parameters continuously to predict immanent disasters. The integrated nature of the system enables the location tracking of every individual tagged object as well as miner in time of immenent disaster and subsequently sends alarms to warn the miners to take necessary actions, such as evacuation. Even in case of disaster recovery, this real time location information is critical for prompt and effective rescue operation. Thus, we can see the completeness and effectiveness of such integrated real time location tracking and sensing system in improving the mine safety tremendously.

Conclusion:

In view of regular mining disasters across the world, there have been plenty of technologies tried out to address the mining disaster issue over a long period of time. Throughout the paper we have discussed the most effective available technologies and their limitations. Even if the recently developed active RFID based integrated real time location tracking and sensing system seems by far the most effective technology available, its use and application has not yet become very wide spread. Proper mining safety standardization with regard to this specific technology could tremendously augment the capacity and effectiveness with which disasters can be mitigates and even averted. There is no doubt that the right technological solution is here, it is just that

the awareness and eventual acceptability of this solution in the mining industry would change the underground mining safety paradigm for good and forever.

References:

[1] http://www.mine-engineer.com/mining/coal/undergnd_mining.htm

[2] http://igs.indiana.edu/survey/news/newsMineMapping.cfm

[3] "Mining problems caused by the presence of underground water in a mining site and possible solutions: An example from Iran", A. Kamkar-Rouhani, Geophysical Research Abstracts, Vol. 9, 01409, European Geosciences Union 2007.

[4] http://www.minesite.com.au/coal_mines_ped_system

[5] Canary 2 System, Los Alamos National Laboratory, www.lanl.gov

[6] www.pervcomconsulting.com