Improving Emergency Response in Cyber-Enabled Underground Mines

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Thousands of miners die from mine accidents each year, especially in underground mines. The explosive vapour, poisonous gases, unsafe structures, fires, and flooding in underground mines threaten trapped miners' lives, and force the rescue team to move slowly with extreme caution. Sometimes survivors die before help reaches them. For instance, a coal mine explosion in Jan 2006 in the Sago Mine in West Virginia, USA killed 12 miners [1]. 40 hours after the Sago Mine disaster, rescue team found 12 dead trapped miners who were only a few kilometres away from the mine entrance. However, the rescue team failed to identify the location of the miners and did not reach them in time. To save trapped miners more efficiently, a rapid notification and communication system is highly demanded to improve the emergency response.

Some techniques [1] have been developed to locate or communicate with miners in underground mine environment. One common strategy is to drill a narrow hole from the ground to the mine tunnel and drop a microphone, camera and air quality sensors at different locations. However, this method is time-consuming and provides limited access to the mines. Another method to locate miners is based on the source of seismic signal. When a trapped miner hits the wall, seismic signal is generated and sent up to the receiver. Once the seismic source is pinpointed, rescue teams are able to locate the miners. When the seismic signal becomes weak or the underground structure attenuates the signal significantly, this method does not work well. Yet another method is to deploy loop antenna on the surface of the mine to broadcast one-way messages to miners underground, but it is unable to get any information from the underground to the surface.

Wireless sensor networking is a promising technique for end-to-end rescue communication network. They can be deployed in inhospitable environments and remain functional over a long period without human attendance. In addition to performing sensing tasks, sensor nodes are able to disseminate the information via muti-hop communication, and perform network control and quality assurance essential to emergency responses. However, mobility is inherent in the context of emergency responses, since both trapped miners and rescuers move around in the tunnel to either evacuate safely or reach a certain point in the mine. The unpredictable nature of mobility makes it challenging to maintain effective communication in extreme environments like underground mines in emergency situation.

In our work, we consider a system consisting of a set of mobile nodes and fixed infrastructure nodes. The first step is to support real-time voice communication in this challenging environment. This involves the development of an effective routing and forwarding design strategy for high data-rate voice application in mobile environment, the support of voice streams with desired voice quality, and the support of co-existence of other types of sensing data with the limited bandwidth. We will use the Edgar Mine[1], an experimental mine owned by the Colorado School of Mines, to validate and evaluate our ideas.

References

[1] Raj Rajkumar and Rahul Mangharam and Anthony Rowe and Ryohei Suzuki. Voice over sensor networks. In *Proceedings of the 27th IEEE International Real-Time Systems Symposium*, pages 291–302, 2006.

[1] `http://mining.mines.edu/edgar_mine.html`