



Mobile Sensor Networks: What Can Underground Electric Transport Vehicles do in Underground Mine Monitoring?

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

According to our previous work, we have found that the ZigBee WSN technology and sensors are actually suitable for the underground monitoring, but there are still many problems. So in this viewpoint paper, we showed our viewpoint that the underground driver-less electric transport vehicles could also play an important role in the underground monitoring, that is, underground electric transport vehicles running in the mine roadway could carry mobile sensors to monitor the environmental conditions in the transport roadway. If it could be realized, it will save the number of sensors installed around the mine so as to reduce costs. If it could be realized, the monitoring of underground mines will become more convenient.

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In previous studies, many experts have found ZigBee WSN technology and sensors suitable for the monitoring of underground mines.

M. A. Moridi et al. [1-3] found in two experimental explorations in 2014 and 2018 that ZigBee WSN, as a short-distance communication tool, could play a greater advantage in narrow environment of underground mines. ZigBee WSN and sensors were used to monitor environmental conditions in underground mines, such as temperature, humidity, gas concentration, and the concentration of various gases. In addition, they found that the power consumption of ZigBee WSN technology is very low which implies affordability for small and medium-sized mines in terms of operating costs.

A lot of researchers such as C. Ba [4] did the same research as M. A. Moridi et al. they also agreed that the ZigBee WSN is well suited to operate in the monitoring of underground mines.

In our last concept paper [5], we designed ZigBee WSN and sensors system for application in the monitoring of underground mines environment. For instance, , we tried to monitor the environmental conditions of underground mines in real time through ZigBee WSN technology and sensors. Once a rollover accident or emergency occurs, we will judge the environmental conditions where the accident or emergency occurs, especially the concentration of harmful gases, so as to determine whether the conditions of the underground environment is suitable for vehicle or personnel rescue otherwise further considerations and measures will be put forward, such as regulating underground ventilation and purifying underground air.

However, the method of installing a large number of sensors in the underground mine to monitor the environment conditions is undoubtedly very costly. Therefore, in order to save cost further and enhance performance, we have improved design compared to our original design with the following views for monitoring underground mine environment:

- Mobile sensors can be placed on driver-less electric transport vehicles so that if there is a roll-over accident or emergency, we can use the sensors on the roll-over

vehicles to get the environmental conditions of the underground mine and make a rescue plan.

- If the mobile sensors can be installed on the driver-less vehicles, the monitoring of the roll-over accident site environment conditions can be achieved without the need to install a large number of sensors in the underground mine, thus greatly reducing operating cost.

Besides our point of view, ZigBee WSN and mobile sensors can also play a positive role in the prevention and monitoring of mine fire. In metal mines, the main cause of fire is the spontaneous combustion of sulfide minerals. At present, the fire prediction is mainly based on the sensors to obtain the information of temperature, humidity and the concentration of various gases in the sulfur-containing area to judge whether the fire may occur.

As expected, sensors have become more and more popular for the monitoring of the underground environment since 2012, especially the mine fire monitoring. M. Huang [6] proposed that about 20% of mine fires are caused by belt conveyor according to U.S. statistics from the National Bureau of Mines and so he developed a new method for monitoring and predicting the ignition of mine belt conveyors with sensors. In 2018, L. Muduli, P. K. Jana and D. P. Mishra [7] deployed sensor nodes in underground mines to collect various environmental data, such as temperature, relative humidity, concentration of different gases, etc. and send these data to the base station (receiver) directly connected to the ground monitoring center. They proposed a underground mine fire monitoring system based on WSN, which uses fuzzy logic method to improve the reliability of the decision-making process in order to reduce the hidden danger of coal mine fire.

The concept of “mobile sensors or mobile sensor networks” was proposed in the mid-2000s.

In 2004, P. Ogren, E. Fiorelli and N. E. Leonard [8] proposed a stable control strategy that allows groups of vehicles to move and reconfigure in concert in response to a perceived distributed environment, and they used each car in the group as a mobile sensor. They were among the first researchers to propose and apply mobile

sensors. And in 2006, during the 4th international conference on embedded networked sensor systems, B. Hull et al. [9] introduced Cartel which is a mobile sensor computing system designed to collect, process, deliver, and visualize data from sensors located on mobile units such as automobiles. The system, which treats each car as a mobile sensor, has been used to analyse commuting times, urban Wi-Fi deployments and car diagnostics.

In 2010, M. S. Stankovic and D. M. Stipanovic [10] applied and optimized mobile sensors and related algorithms in the study of noise source localization with good research results. In the same year 2010, S. He et al. [11] found that mobile sensors have the ability to dynamically capture information and applied it to capture information on energy consumption per unit. In 2013, J. Du et al [12] made some optimization to the mobile sensor networks.

Subsequently, mobile sensors and sensor networks have been used in other fields, for example, sensing technology for biomedical

applications [12,13]. During IEEE 2nd ICBAIE Conference 2021, IEEE Fellow Professor Guo Yong-xin [14] announced the Fall Sensors project they were working on. It is a kind of mobile sensors for old people. As more unnatural deaths occurred, falls accounts for the large percentage of death and Guo's team has now completed a new study of Fall Sensor LKCNN-1 and based on experimental data, the sensor performed better than other existing fall sensors.

However, vehicle monitoring and control aspects requires a comprehensive application, for example, urban air monitoring with high spatial resolution using mobile vehicle sensors [15].

On IEEE 2nd ICBAIE Conference 2021, Professor Liu Kai [14] raised the importance of Internet of Vehicles for future urban transport systems, particularly the promotion of driver-less technology and thus reiterated that, the realization of Internet of Vehicles(IoV) would require mobile sensors.

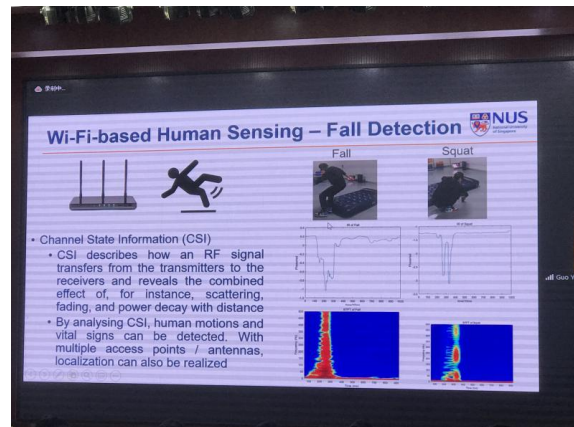
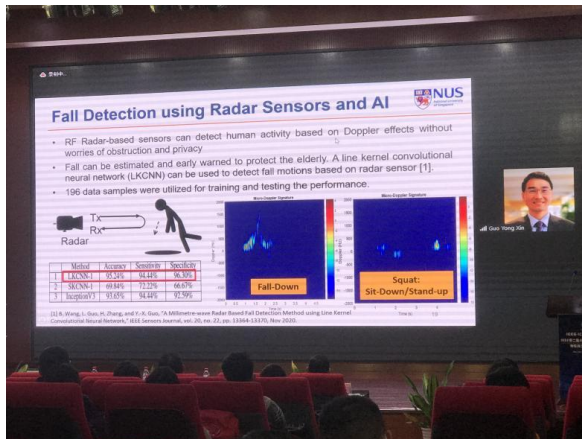


Fig. 1. Fall Sensors for the old which is the research project of Professor Guo Yong-xin

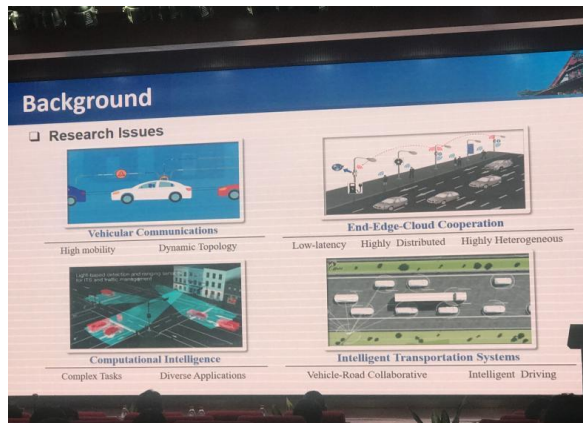


Fig. 2. Prof. Liu Kai's introduction to IoV

Therefore, if we apply the mobile sensors to the driver-less vehicles for underground mine monitoring, the environmental conditions of the transport road in the underground mine can be obtained, and mine fire can easily be detected:

- If mobile sensors are installed on driver-less vehicles, there is no need to install a large number of sensors for monitoring the underground environment in the main transport road with frequent transport operations in the mine saving operational costs
- In the event that fire accident occurs along and around the transport road, the production efficiency of the mine will be significantly affected. Therefore, if the environmental conditions in the mine can be monitored by the mobile sensors on the unmanned transport vehicle for potential fire risks with corresponding prevention and control measures. Such measures and risk mitigations makes mine transport road safer.

Therefore, combination of mobile sensors with driver-less vehicles in underground mines will be very beneficial to mine operations and production.

However, in recent years, there have been many researches on underground communication. S. Basu et al [8] and L. Muduli [17] did a research on advanced technology for underground monitoring around 2020. Also, in 2021, some experts [18,19,20,21] utilized 5G technology, GIS(Geographic Information System), WAMC(Wide Area Monitoring and Control) system, CBTC(Communication-based Train Control) system and other advanced technologies for underground mine monitoring.

Although, there are lots of research on wireless(mobile) sensor networks and other technologies ongoing for underground monitoring in recent years, we believe that the ZigBee WSN technology and sensors are currently the most suitable technology for the underground monitoring in most underground mines particularly small and medium-sized mines . The reasons are as follows:

- Although some advanced technologies can better solve the problem of mine fire monitoring, such advanced technologies are obviously not suitable for all mines, especially some backward mines in China. And most of these advanced technologies

have high operating costs, such as the operation of 5G technology requiring the establishment of a large number of base stations on the contrary, the operation of ZigBee WSN technology in underground mines does not require complex conditions, and the operating costs and energy consumption of ZigBee WSN technology are lower compared to other communications technologies according to related research [22,23].

- As a short-distance information transmission tool, ZigBee WSN technology is considered suitable for the underground narrow environments. Both M. A. Moridi [1-3] and C. Bai [4] agree that the ZigBee WSN technology is very suitable for the underground monitoring, and D. Wei and H. Wu [24] revealed that most underground mines in China are equipped with ZigBee WSN technology as monitoring networks in 2015.

As researchers and engineers, we should not only pursue the research of frontier technology, but also choose appropriate underground monitoring system in accordance suitability requirements of mines. Therefore, we believe that, ZigBee WSN technology still has the superiority in underground mine monitoring, and has the potential for further development. In our previous work, we have emphasized the superiority of ZigBee WSN technology in environmental monitoring of underground mines. in addition, underground electric transport vehicles could actually help monitor underground environment.

CONCLUSION

Our future research work entails developing the potentials of ZigBee WSN technology and mobile sensors in underground mine monitoring including engagements of interested experts and scholars in the field.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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