Chapter 14

Wireless Robotics Networks for Search and Rescue in Underground Mines:
Taxonomy and Open Issues

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ABSTRACT

To ensure the safety of miners, reliable and continuous monitoring of underground mine environment plays a significant role. Moreover, such a reliable communication network is essential to provide speedy rescue and recovery operations in case of an emergency situation in a mine. However, due to the hostile nature and unique characteristics of underground mine workings, emergency response communication and disaster management are very challenging tasks. This chapter presents an overview of evolving technology wireless robotics networks (WRN) which may be a promising alternative to support search and rescue (SAR) operation in underground mine emergencies. The chapter first outlines the introduction followed by a detailed discussion on the current state of the art on WRNs and their development in the context of underground mines. Finally, this chapter provides some insights on open research areas targeting the current wireless research design community and those interested in pursuing such challenging problems in this field.

1. INTRODUCTION

Underground mining occupation is considered as *high-stressed* work environment, compared to a normal work environment, which consists of several unique features such as narrower work space, high humidity, poor visibility, dusty and hazardous gas concentration, etc. (Bandyopadhyay, Chaulya, & Mishra, 2010; Misra et al., 2010). The miners working underground are highly exposed to health hazards and risks of either fatal injuries or minor causalities. Therefore, to provide a safe work environment to the mine personnel is of paramount importance for the mine management. However, reliable operation of mine communication and monitoring systems are *restricted* in performance due to the unique features of underground mines. The different challenges to achieve wireless communication with particular reference to Wireless Robotics Networks (WRN) is discussed later in the chapter.

Disasters either natural or man-made have always been a matter of concern and are hard to predict. It can affect a large number of people, causing loss of lives and serious injuries, infrastructure damages, and also hampers our environment and surroundings. In the context of underground mines, *unforeseen disasters* have been a challenge to the mine management. Moreover, providing a timely rescue support to the affected persons in the working districts is another significant concern to the management (Ranjan, Sahu, & Misra 2016). Though several mine accidents have been reported and remained in news headlines, there are many small injuries and events which remained unnoticed across the world. For example, in the year of 2006-2007, there were around11,800 minor injuries and 69 fatal injuries in US mines (Kamruzzaman, Fernando, Jaseemuddin, & Farjow, 2017). Every year miners die due to serious injuries. A comparative illustration of mine accidents in coal and metal mines of India can be seen in the Figures 1 and 2. It is reported that a miner in routine operation is five times more exposed to occupational hazards than a person working in the normal industry (Kamruzzaman et al., 2017). In case of any emergency situation in underground mine workings, the first ever question in front of mine management and rescue team is, *where exactly are the miners trapped?* In addition, there are few more questions which have to be answered in the aftermath of mine disaster to support timely rescue operation and are as follows (Alok Ranjan, Sahu, & Misra, 2016):

- How many miners have been trapped?
- What are the different mine environmental parameters such as temperature, noxious gas concentration, and humidity percentage?
- Is there any communication infrastructure working?
- And knowledge of escape route plans.

Hence, locating the miners' positions, mine asset and explosives tracking and environmental monitoring are crucial tasks for the mine management for both routine operations and during any emergency scenario. Following are some of the major causes that have led to the frequent occurrence of accidents in underground mines and need to be monitored in a timely manner (Forooshani et al., 2013; Ranjan, Sahu, & Misra, 2015).

Mine Fire

Every day for carrying out mining activity, several mine equipment is used such as drilling machine, surface miner, belt conveyors, mine trucks, shuttle car, load haul and dump (LHD), etc. Proper main-

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