A Practical Model for LoRa Propagation in Underground Mines

N. Udugampola[1], *A. Seneviratne*[2], *B. Li*[3], *and X. Ai*[4]

1. Postgraduate Researcher, UNSW, Sydney NSW 2052. Email: n.udugampola@unsw.edu.au
2. Professor, UNSW, Sydney NSW 2052. Email: a.seneviratne@unsw.edu.au
3. Associate Professor, UNSW, Sydney NSW 2052. Email: binghao.li@unsw.edu.au
4. Postdoctoral Fellow, UNSW, Sydney NSW 2052. Email: x.ai@unsw.edu.au

Keywords: RF propagation, modelling, LoRa, underground mining, wireless mesh networks, ray tracing, network simulation

ABSTRACT

With the evolution of mining technology, wireless communication is increasingly utilized in underground mining operations. Due to the long tunnel structures and highly constrained environments, wireless mesh networks based on Low Power Wide Area Network (LPWAN) technologies such as LoRa are more desirable for underground mines. When designing such a network for an underground mine, the efficient and precise deployment of wireless repeater nodes is crucial. This necessitates the characterization of radio wave propagation behaviour in the underground mine. Although there is significant research on measurements and models of radio wave propagation in underground mines and tunnels, most of the existing propagation models are either theoretical models analysing certain straight or curved mine tunnels as dielectric waveguides or empirical formulas specifically derived for basic shapes of mine tunnels with rough walls. Applying such models to an actual complex underground mine with multiple main tunnels, cross tunnels, and intersections may be very difficult, requiring an extensive number of complicated calculations. In this paper, we introduce a propagation model that can be practically utilized to estimate the optimal locations for the deployment of wireless nodes in a complex underground mine structure. It is a generalized model that can estimate the signal strengths when any random layout of an underground mine structure is given. The proposed model is also implemented as a software tool that can be easily used for the planning of mesh network node deployment in an underground mine. The model was verified by comparing its results with existing publicly available radio propagation measurements in underground mines. Furthermore, we created a 3D model of a complex mine structure to study the radio wave propagation behaviour using ray tracing. The results obtained by ray tracing also aligned with those derived from our proposed empirical model.