Optimization and Reconfiguration of Wireless Communication Network in Mine Environments

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The design of wireless communication systems in mine environments greatly benefits from tools capable of synthesizing wireless network configurations and reconfiguring networks in response to changing operating conditions. Oftentimes, such tools are used to determine transmitter locations that yield desired coverage inside electrically large mine environments (e.g. signal levels at a fixed set of receivers). The problem of determining these transmitter locations is complicated by the fact that the mine environments of interest oftentimes are geometrically complex and possibly obstructed by cave-in debris. Hence, network synthesis tools cannot simply rely on heuristic design rules; instead, they involve an electromagnetic (EM) simulator and a global optimizer that together are capable of accurately and rapidly evaluating many candidate transmitter constellations. Unfortunately, few existing EM simulators are up to this task. Those employing approximate techniques are fast but restricted to simple geometries and restricted frequency bands, while full wave simulators are prohibitively expensive when repetitive execution is called for. An additional problem consists in the choice of optimizer, which should be minimally intrusive and converge rapidly to minimize the cost of execution of the computationally expensive forward EM simulator.

In this work, an efficient optimization framework that addresses the aforementioned challenges is proposed. The framework combines the DIRECT (Dividing RECTangles) global optimization algorithm (Jones et. al., *J. Optim. Theory Appl.*, 1993) with a domain decomposition (DD) based surface integral equation (SIE) simulator (Sheng et. al., *Proc IEEE Int. Symp. Antennas Propagat.,* 2016) that provides path loss estimates in realistically modeled mine environments. The DD-based SIE simulator first divides mine tunnels and galleries into subdomains using equivalent surfaces and computes wave input-output relationships for each of them. It next constructs and solves an inter-domain system that comprises wave propagation information of all subdomains using significantly fewer degrees of freedom compared to conventional full wave simulators. The DIRECT algorithm constitutes an effective approach for solving global optimization problems with simple constraints. The algorithm executes a series of moves that explore the behavior of the objective function at a set of points carefully picked in the multidimensional search space. Here, the DIRECT scheme is used on objective functions first proposed by Sherali et al. (Sherali et al., *IEEE J-SAC*, 14, 662–672, May 1996) that consist of minisum and minimax components, comprising the average and maximum of the weighted path loss measured at receivers, respectively. A penalty term applies to the objective function if the maximum tolerated path loss is exceeded at certain receivers. The efficiency and applicability of the proposed framework are demonstrated via optimization of transmitter placements and reconfiguration of optimized networks after catastrophic events inside electrically large mine tunnels and galleries.