Optimization of Wireless Network Configurations in Mine Environments

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Wireless communication and tracking systems are essential to ensuring the safety and efficiency of mining operations. The design of these systems greatly benefits from tools capable of synthesizing wireless network configurations (locations of transmitters, repeaters, and access points), and rapidly reconfiguring networks in response to changing operating conditions and catastrophic events. These tools typically hybridize an electromagnetic (EM) simulator and an optimization engine. Ideally, the simulator is capable of accurately accounting for the presence of miners, mining equipment, as well as roughness on the tunnel walls. A full-wave simulator readily fulfills these requirements but oftentimes may become prohibitively expensive when the tool's optimization engine requires the simulator's repetitive execution. The design of a wireless network synthesis tool for mine environments therefore requires the careful matching of a complementary simulator and optimizer, and endowing the latter with an objective function that permits rapid convergence to highly performant network configurations.

In this work, an efficient optimization framework that addresses the above-mentioned challenges is proposed. The framework combines a Hooke and Jeeves pattern-search optimization engine (Sherali et al., in IEEE J-SAC, 14, 662–672, May 1996) and a 3D domain decomposition (DD) based surface integral equation (SIE) based simulator that provides path loss estimates in realistically modeled environments. The simulator divides the mine environment (tunnel or gallery) into subdomains and computes wave input-output relationships for each of them. The simulator next characterizes the global system comprising all subdomains by enforcing field continuity across subdomain boundaries. The simulator only re-solves the inter-domain system during each execution and is very efficient for network optimization. The Hooke and Jeeves technique optimizes the network configuration by minimizing a convex combination of minisum and minimax objective functions, comprising the sum and maximum of the weighted path loss measured at receiver locations, respectively. A penalty term applies to the objective function if the maximum tolerated path loss is violated at certain receiver locations. The proposed framework is applied to the optimum placement of nodes in a partial mesh wireless network operated at 455 MHz and 915 MHZ inside electrically large mine galleries, which are formed by the intersection of 2 or 3 rectangular tunnels of the same dimensions. The signal coverage throughout the mine gallery before and after the optimization will be demonstrated during presentation.