CPS: Synergy: Collaborative Research: Enabling Smart Underground Mining with an Integrated Context-Aware Wireless Cyber-Physical Framework

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Project Details

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Institution(s):	Colorado School of Mines
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Abstract: To reduce reliance on other countries for minerals (e.g., coal, rare-earth metals), the USA has seen an invigoration of mining activity in recent years. Unfortunately, miners often have to work in dangerous environments where there is risk of mine explosions, fires, poisonous gases, and flooding in tunnels. Mine accidents have killed over 500 US and 40,000 mine workers worldwide in the past decade. Most of these accidents occurred in structurally diverse underground mines with extensive labyrinths of interconnected tunnels, where the environment continually changes as mining progresses and machinery is repositioned, complicating search and rescue efforts. In recognition of the severity of the problem, the Mine Improvement and New Emergency Response Act passed in 2006 mandated mines to monitor levels of methane, carbon monoxide, smoke, and oxygen to warn miners of possible danger due to air poisoning, fire, or explosions. The Act also mandated plans to rapidly and safely respond in post-accident scenarios, involving two-way, wired or semi-wired tracking and communication systems that could save lives during entrapment and water inundation emergencies. But the high cost of deploying such a safety infrastructure encourages companies today to meet only the bare minimum required safeguards. This project will involve transformative, foundational, and synergistic research that is necessary to overcome monitoring, communication, and tracking challenges in the underground mining context, to realize a cost-effective safety infrastructure that can be deployed in any type of underground mine. Such a framework will not only minimize the risks facing hundreds of thousands of miners in the USA today, but the foundational research outcomes will also be applicable to a wide range of applications in the realms of Smart and Connected Communities (S&CC) and

Internet of Things (IoT), wherever the emphasis is on creating smart workplaces, sustainably operating in harsh environments, and improving human safety. The principal objective of this proposal is to devise, design, prototype, and test a fundamentally novel wireless cyber-physical framework of low-cost, energy-efficient, and reliable sensor nodes and commodity smartphones for monitoring, tracking, and communication, to improve miner safety in underground mines. This synergy project contributes to the science and engineering principles needed to realize Cyber-Physical Systems and seeks to grow at the intersection of three research thrusts: quality-aware voice and data streaming, mobile computing assisted location tracking, and computational electromagnetics driven wireless signal characterization. These three thrusts (1) introduce novel mechanisms to enable the co-existence of high quality voice streams with environmental sensor data streams in low-power wireless mesh networks of sensor nodes operating in noisy underground environments; (2) develop schemes for energy-efficient scheduling of location queries and error-tolerant indoor localization to locate individual miners and groups of miners underground; and (3) characterize wireless signal behavior with electromagnetic modeling in highly complex and uncertain environments, based on measurements from a real underground mine, to guide optimal placement of wireless nodes in mining tunnels. Not only is the convergence of these thrusts novel as a whole, but also the techniques and insights developed for each thrust are transformative and go beyond conventional approaches. Collaboration with a mining company for technology transfer will enable rapid real-world deployment of the proposed research. The broader impacts of the research will tightly integrate research results into all levels of teaching, including graduate, undergraduate, and K-12 education; broaden the participation of women and minority students in Cyber-Physical research; and integrate research into the syllabi of existing and new courses.

Related Artifacts

Presentations

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Publications

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