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A Data-Driven Optimization Framework for Joint Reliability and Energy Efficiency in 5G Smart Factory Monitoring

Ensuring both the safety and operational continuity of smart factories requires reliable real-time hazard detection and energy-efficient predictive maintenance. This work addresses the joint challenge of guaranteeing ultra-reliable, low-latency communication for safety-critical sensors (Factory Safety Detectors - FSDs) while minimizing energy consumption for a large-scale network of equipment health monitors (Equipment Monitoring Units - EMUs). We propose the Factory Resource Optimization (FRO) framework, a data-driven iterative algorithm that dynamically allocates 5G network and edge computing resources. By decomposing the problem into optimal channel pairing and power allocation, FRO ensures that stringent latency bounds for safety-related data are never violated, thereby enhancing system reliability and safety. Simultaneously, it significantly extends the operational lifespan of EMUs by minimizing their transmission energy, directly supporting sustainable predictive maintenance cycles. Simulation results demonstrate that our approach achieves over 40% energy savings for monitoring units while fully meeting sub-millisecond latency targets for safety detectors. This work provides a scalable model for integrating communication optimization into data-driven reliability and maintenance strategies for Industry 5.0.

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