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A Sustainable IoT-Based Monitoring Architecture for Radioactive Waste Management Across Its Lifecycle

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The safe and sustainable management of radioactive waste across all phases — including conditioning, storage, transportation, and disposal — requires reliable, autonomous, and long-term monitoring solutions. This work presents a novel integrated system developed by the University of Pisa within the H2020 PREDIS project, aiming to address the operational challenges posed by sensor heterogeneity, regulatory compliance, and long-term data management. The architecture combines a Django-based metadata framework for structured representation of facilities, waste packages, and measurement records, with ThingsBoard for IoT device provisioning, telemetry handling, and real-time data processing. Wireless sensor nodes, equipped with solid-state micro-power gamma and thermal neutron detectors, perform continuous in-situ measurements directly from cemented waste drums. Data are autonomously transmitted via long-range LoRaWAN connectivity, ensuring robust wireless coverage over extended distances, even within complex storage and transportation environments.

A key element of the system is its sustainability-oriented design, which incorporates ultra-low power electronics combined with energy harvesting solutions to enable long-term autonomous operation, minimizing maintenance and infrastructure requirements. The middleware layer provides secure communication, metadata enrichment, and ensures full traceability of monitoring data throughout the entire lifecycle of radioactive waste. The proposed modular and scalable architecture lays the foundation for integration into future frameworks such as EURAD-2 (Work Package 5 - ICARUS), supporting not only long-term monitoring but also enabling advanced functionalities such as predictive analytics, anomaly detection, and automated decision-making, ultimately reinforcing the safety, sustainability, and resilience of radioactive waste management infrastructures.

Technical Track

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Primary authors: CHIERICI, Andrea (University of Pisa); Prof. D'ERRICO, Francesco (University of Pisa); Prof. CIOLINI, Riccardo (University of Pisa); Prof. LO FRANO, Rosa (University of Pisa)

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