# Ph.D. in Information Technology
# Thesis Defense

**March 28th, 2025**
**At 2:00 p.m.**
**Room Alpha – Building 24**

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**6G NETWORKS: A COVERAGE ENHANCEMENT STUDY**
Supervisor: Prof. Umberto Spagnolini

**Abstract:**

The increasing demand for higher capacity in future wireless communication networks drives the exploration of new frequency spectrums, including Frequency Range 2 (FR2) and Frequency Range 3 (FR3). For FR2, the primary challenge is high path loss, which often necessitates network densification. However, densification introduces problems such as increased cost and high aggregated interference. Paradigms like Integrated-Access-and- Backhauling (IAB), Cell-free massive MIMO (CF-MIMO) architectures, and Smart Radio Environments (SREs) have been proposed to address these issues. This thesis focuses specifically on SREs as a promising solution.

For cellular networks, the thesis develops a comprehensive physical propagation model to evaluate SRE-enabling devices such as Reconfigurable Intelligent Surfaces (RISs) and Network-Controlled Repeaters (NCRs), under realistic urban scenarios. This analysis reveals that RIS provides superior flexibility in wide-open areas due to its reconfigurability, while NCR is more effective in corridor-like environments where its amplification compensates for higher path loss. These insights are extended to an optimal planning framework for Heterogeneous SRE (HSRE), balancing cost and coverage through strategic device placement and configuration. This study highlights that optimal planning can significantly reduce network deployment costs while maintaining high coverage performance, showcasing the practicality of HSRE in dense urban scenarios.

In the vehicular domain, the thesis proposes fully passive Conformal Intelligent Reflective Surface (CIRS) to mitigate signal blockage in Vehicle-to-Vehicle (V2V) communication. In the first approach, CIRS are designed to mimic flat surfaces, achieving mirror-like reflections to improve signal reliability. This design reduces blockage probability by approximately 20% compared to the case where reflections (metasurfaces) are not used, effectively mitigating signal blockage. Building on this, the second approach introduces advanced optimally designed CIRSs to maximize both coverage and Spectral Efficiency (SE) by leveraging traffic patterns and vehicular dynamics. This design reduces block age probability by up to 70% compared to bare surfaces, significantly outperforming the specular CIRS approach and enhancing vehicular communication reliability.

Interference analysis is another cornerstone of this work. The thesis introduces a scalable and adaptable Stochastic Geometry (SG)-based framework to analyze aggregated interference using the characteristic function of interference. This framework is easily adaptable for various network architectures, such as classical Coordinated MultiPoint (CoMP), CF-MIMO networks, and potentially SREs in future work. This thesis also applies interference analysis in the context of satellite and cellular coexistence in the Upper 6GHz (U6G) band. The analysis considers both direct and reflected interference paths toward geostationary satellites, proving that aggregated interference levels, under typical International Mobile Telecommunications (IMT) parameters, remain safely below the Interference-to-Noise Ratio (INR) protection thresholds set for geostationary satellites, even in dense terrestrial deployment scenarios.

By bridging theoretical advancements and practical deployment strategies, this thesis provides a cohesive framework to tackle coverage challenges and interference issues, offering robust, scalable, and cost-effective solutions for 5G and beyond.

**PhD Committee**

Dr. Francesco Linsalata, **Politecnico di Milano**

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