Ph.D. in Information Technology
Thesis Defense

April 10th, 2026
at 11:00 am
Alpha Room – building 24

Vick Pierce DINI – XXXVIII Cycle

Reasoning on Architectural Issues for Electric Vehicle Charging Stations of the Future

Supervisor: Prof. Elisabetta di Nitto

Abstract:

The global shift to electric mobility is placing immense pressure on charging infrastructure, making sophisticated software architecture a critical enabler for reliable and scalable operations. However, current centralized software architectures struggle to balance the need for global orchestration with the need for local execution, leading to systems that are fragile during network outages and difficult to evolve. A critical research gap exists in the lack of a comprehensive architectural framework that systematically integrates trustworthiness with specific adaptability mechanisms required to handle volatile market drivers, such as evolving communication protocols, emerging Vehicle-to-Grid (V2G) services, and dynamic grid integration, without requiring fundamental system redesign. This doctoral thesis addresses this gap by answering the question: *How can charging station management software be improved to enhance resilience and adaptability?* The answer is a holistic, multi-faceted solution centered on a novel distributed cloud-edge-IoT architectural framework. The proposed framework strategically distributes intelligence across IoT, edge, and cloud layers. This design empowers individual stations with local autonomy for service continuity during network outages while providing Charge Point Operators (CPOs) with robust centralized management. Built on containerization and microservices, the framework's resilience is validated using formal methods, translating the architecture into a Component & Connector (C&C) model and employing a MaxSAT solver to identify and rectify critical dependencies. This research further contributes a structured catalog of fault-tolerance tactics (Restart, Replacement, Checkpoint, Replication, and Migration) mapped to the architecture's layers. Looking beyond simple fault recovery, this work proposes an evolved MAPE-K model for true component-level self-healing, paving the way for adaptive and antifragile systems. The practical applicability of the architecture is validated through scenario-based analyses, grounded in ethnographic studies with a leading CPO, which use sequence diagrams to model the system's effective mitigation of common operational failures. Finally, a detailed risk assessment of a real-world infrastructure identifies critical security vulnerabilities and provides an actionable roadmap for their mitigation, underscoring that trustworthiness is incomplete without robust security. Ultimately, this thesis delivers a validated architectural blueprint, a catalog of resilience patterns, a forward-looking self-healing model, and a practical risk management strategy. It provides a comprehensive answer to enhancing the resilience and adaptability of EV charging software, offering a robust foundation for the future of electric mobility.

PhD Committee

Prof. Matteo Camilli, Politecnico di Milano

Prof.Patrizia Scandurra, Università di Bergamo

Prof. Vasilios Andrikopulos, University of Groningen