UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

DOTTORATO DI RICERCA / PHD PROGRAM IN
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

Activities and Publications Report

PhD Student: Annalisa Navarro

Student DR number: DR996622

PhD Cycle: XXXVIII
PhD Chairman: Prof. Stefano Russo

PhD program student's start date: 01/11/2022
PhD program student's end date: 31/10/2025

Supervisor: Roberto Canonico

e-mail: roberto.canonico@unina.it

PhD scholarship funding entity: Università Federico II

General information

Annalisa Navarro received in 2022 the Master Science degree in Computer Engineering from the University of Napoli Federico II. She attended a curriculum in Network Engineering within the PhD program in Information Technology and Electrical Engineering. She received a grant from Università Federico II.

Study activities

Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1st	Using Deep Learning Properly	Ad hoc course	4	Prof. Andrea Apicella	ITEE
1st	Scientific Programming and Visualization with Python	Ad hoc course	2	Prof. Alessio Botta	DiSt
1st	Statistical Data Analysis for Science and Engineering Research	Ad hoc course	4	Prof. Roberto Pietrantuono	ITEE
1st	Virtualization Technologies and Their Applications	Ad hoc course	5	Prof. Luigi De Simone	ITEE
1st	Big Data Architecture and Analytics	Ad hoc course	5	Prof. Giancarlo Sperlì	ITEE
2nd	Artificial Intelligence and Natural Language Processing	Ad hoc course	3	Prof. Francesco Cotugno	ITEE
2nd	Hands-on Network Intrusion Detection via Machine Learning and Deep Learning	Ad hoc course	4	Prof. Antonio Montieri	ITEE
2nd	Strategic Orientation for STEM Research & Writing	Ad hoc course	5	Chie Shin Fraser	ITEE

Attended PhD Schools

Year	School title	Location	Credits	Dates	Organization
1st	RESTART Tech Camp on 5G and Open RAN	University "La Sapienza", Rome	3	13-14-15/09/2023	CNIT
3rd	20th TAROT Summer School on Software Testing, Verification & Validation	Napoli, Italy	4	06/30/2025 – 04/07/2025	University of Napoli Federico II

Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1st	Connecting the Dots: Investigating an APT Campaign Using Splunk	0.4	Antonio Forzieri	Splunk	University of Napoli Federico II
1st	Stabilizer Renyi Entropy and Quantum Complexity	0.2	Prof. Alioscia Hamma	University of Napoli Federico II	University of Napoli Federico II
1st	Cybercrime and Information Warfare: National and International Actors	0.4	Dr Pierluigi Paganini	Università Telematica Pegaso	University of Napoli Federico II
1st	Privacy and Data Protection	0.4	Dr Stefano	Gianni & Origoni	University of Napoli

			Mele	Law Firm	Federico II
1st	Optimizing Video Transport Over IP	0.4	Dr Alessandro Breccia	Cisco	University of Napoli Federico II
1st	Automated Offensive Security	0.4	Prof S.P. Romano	University of Napoli Federico II	University of Napoli Federico II
1st	Machine Learning for CPS Security: Limitations and Novel Attack Discovery Techniques	0.6	Chuadhry Mujeeb Ahmed, Muhammad Azmi Umer	University of Strathclyde (UK), DHA Suffa University (Pakistan)	IEEE LATINCOM Conference 2022
1st	Feature Extraction Leveraging Programmable Data Planes for Traffic Analysis Based on Machine Learning	0.6	Sergio Gutierrez, Juan Felipe Botero, Adrian Lara	Universidad Autonoma Latinoamericana, Colombia, University of Antioquia, Colombia, University of Costa Rica	IEEE LATINCOM Conference 2022
1st	From Cyber Situational Awareness to Adaptive Cyber Defense: Leveling the Cyber Playing Field	0.4	Prof. Massimiliano Albanese	George Mason University	University of Napoli Federico II
1st	Game Theory for Information Engineering	0.6	Prof. Leonardo Badia	University of Padova	University of Napoli Federico II
1st	Entangled Relativity	0.2	Prof. Oliver Minazzoli	Observatoire de la Côte d'Azur	Scuola Superiore Meridionale (SSM)
1st	(5G Seminar Series) Principi Architetturali – TOGAF I	0.6	Alberto Curcio, Pietro Boscolo	Capgemini Invent	University of Napoli Federico II
1st	(5G Seminar Series) Data Strategy	0.6	Lorenza Catalano, Angela Taglialatela	Intesa Sanpaolo, Capgemini Invent	University of Napoli Federico II
1st	(5G Seminar Series) Blockchain and 5G in Business	0.6	Conforto Luca, Mutarelli Gabriele	Capgemini Invent	University of Napoli Federico II
1st	(5G Seminar Series) Il Cloud e gli Hyperscaler	0.6	Giovanni Vendramel	Capgemini Invent	University of Napoli Federico II
1st	Embracing Data Imperfections Via Domain Enriched Visual Task Learning	0.2	Vishal Monga	Pennsylvania State University, USA	ITEE
1st	Using Fuzzing to Detect Network Vulnerabilities	0.2	Multiple	Multiple	IEEE ComSoc
1st	AI for Networking, Networking for AI	0.4	Kyunghan Lee, Michael Schapira, Ness Shroff, Noa Zilberan	Seoul National University, University of Jerusalem, Ohio State University	IEEE ComSoc
1st	Security for IoT Networks and Devices in 6G	0.6	Multiple	Multiple	IFIP Networking Conference
1st	Impact of IT/OT Convergence on the Resilience of Critical Infrastructure	0.8	Multiple	Multiple	IFIP Networking Conference
1st	From Data Plane Programmability to Slicing Automation for Softwarized	0.8	Multiple	Multiple	IEEE NetSoft Conference

	Infrastructures Towards 6G				
1st	Intent-Based Networking	0.6	Multiple	Multiple	IEEE NetSoft Conference
1st	Measuring Routing Performance, a P4 Practice with Source Routing	0.48	Pascal Mérindol	University of Strasbourg	TMA Conference (PhD School)
1st	Privacy-Preserving Data Processing	0.72	Luca Vassio	Politecnico di Torino	TMA Conference (PhD School)
1st	Research and Education in the Digital Transition Society	1	Nicola Blefari Melazzi	Politecnico di Milano	PNRR RESTART
1st	Research with Amazon Web Services: Opportunities and Tools	0.4	Dario Regazzoni	AWS Education and Research	Unina CSI
1st	Lessons Learned from 40+ Years of the Internet	0.2	Prof. H. Schulzrinne, Prof. J. Kurose	Columbia University, University of Massachusetts	TheNetworkingChannel
2nd	Introduction to Multi-Agent Reinforcement Learning	0.4	Prof. Stefano V. Albrecht	University of Edinburgh	University of Campania "Luigi Vanvitelli"
2nd	Large ISPs: How do they work? What are the challenges they face and the Engineering/CS skills needed	0.2	Jason Livingood, Amreesh Phokeer, Yong Cui	Comcast, Tsinghua University	IEEE Comsoc
2nd	Energy-Efficient Data Science	0.2	Dr. Carlos Ordonez	University of Houston, USA	UNINA
2nd	Mobility Support in Slice-based Network Control for Heterogeneous Environments (Workshop)	0.8	Multiple	Multiple	IEEE NFV-SDN Conference 2023
2nd	Computing in Communication Networks (Tutorial)	0.8	Multiple	Multiple	IEEE NFV-SDN Conference 2023
2nd	RESTART Plenary Dissemination Workshop	3	Multiple	Multiple	PNRR RESTART
2nd	Machine Deception	0.2	Dr. Henrik Skaug Sætra	University of Oslo	University of Naples Federico II
2nd	Generative, Incremental, Adversarial, Explainable AI/ML in Distributed Computing Systems (Workshop)	0.6	Multiple	Multiple	ICDCS 2024 Conference
2nd	Digital Twin-Enabled 6G Multi-Tier Distributed Computing Systems (Workshop)	0.6	Multiple	Multiple	ICDCS 2024 Conference
2nd	From ACE Technologies to Sustainable, Accessible and Equitable Urban Mobility: An Optimization Journey	0.4	Prof. Mauro Salazar	Eindhoven University of Technology	University of Naples Federico II
2nd	LLMs: Teaching and Learning (Networking)	0.2	Keith Ross, Bruce Davie, Cristel Pelsser, Qiao Xiang, Vishal Misra	NYU Abu Dhabi UAE, Systems Approach LLC Australia, Université Catholique de Louvain Belgium, Xiamen University	TheNetworkingChannel

				China, Columbia University USA	
2nd	AI-RAN and Open RAN: Exploring Convergence of AI-Native Approaches in Future Telecom Technologies	0.2	Pedram Johari, Salvatore D'Oro, Michele Polese	Northeastern University, ZTouch Networks	TheNetworkingChannel
3rd	Challenges and Opportunities of Distributed Learning	0.2	Giovanni Neglia, Peter Kairouz	Inria, Google	EPFL - Swiss Federal Technology Institute of Lausanne
3rd	Infrastructure Security: Threat- and Model-based Automated Penetration Testing	0.2	Prof. Massimiliano Rak	University di Napoli Federico II	University of Napoli Federico II
3rd	Research Infrastructures and Tools for Collaborative Networked Systems Research	0,2	Georg Carle, Serge Fdida, Kate Keahey, Henning Schulzrinne	Technical University of Munich	Technical University of Munich, Sorbonne Université, University of Chicago, Columbia University
3rd	Emergent behaviours and collective decisions in cyber-physical-human systems	0,2	Prof. Karl H. Johansson	KTH Royal Institute of Technology, Stockholm, Sweden	University of Napoli Federico II
3rd	Start Getting Telecoms Ready for the Transition to FRMCS and AI Era	0,2	Anne-Marie Ntibazonkiza, Zineb El Aissaoui, Benoît Leridon	Infrabel, Egis Rail, Nokia	Global Railway Review
3rd	From Automation to Orchestration: The New Frontiers of Network Softwarization	0,4	Gianluca Davoli	Università di Bologna	RESTART Foundation
3rd	Cloud Networking	0,4	Cristian Perissinotto	Cisco Spark	University of Napoli Federico II
3rd	Reinforcement Learning for Next-Generation Networks: The Road to Trustworthiness	0,6	Ahmad M. Nagib	Queen's University, Canada	IEEE International Conference on Machine Learning for Communication and Networking
3rd	IoT Edge Computing with Hierarchical Federated Learning for Smart City Applications	0,2	Mohsen Guizani	Machine Learning Department, MBZUAI, UAE	IEEE International Conference on Machine Learning for Communication and Networking 2025
3rd	Realizing an AI-native, virtualized RAN for 6G	0,2	Christian Ibars	NVIDIA, US	IEEE International Conference on Machine Learning for Communication and Networking 2025
3rd	10 things I wish my advisor had told me	0,2	Jim Kurose	University of Massachusetts Amherst, US	PhD School at Traffic Measurement and Analysis 2025
3rd	From PhD to Industry: on navigating the dynamics of scientific research within the (global) cellular ecosystem	0,2	Andra Lutu	Ericsson Research, Sweden	PhD School at Traffic Measurement and Analysis 2025
3rd	Inferring performance of	0,4	Simone Ferlin-	Ericsson Research,	PhD School at Traffic

	container orchestration platforms in the edge		Reiter	Germany	Measurement and Analysis 2025
3rd	Cybersecurity and privacy in mobile systems: challenges and opportunities in the age of AI and 5G/6G	0,6	Maria Christopoulou; George Xilouris	National Centre for Scientific Research "Demokritos", Greece	PhD School at Traffic Measurement and Analysis 2025
3rd	Internet data analysis with the Internet Yellow Pages	0,6	Romain Fontugne	IIJ Research Lab, Japan	PhD School at Traffic Measurement and Analysis 2025
3rd	Digital Sovereignity: What It Is and What Are the Main Threats to National Cyberspace	0,4	Roberto Baldoni	Embassy of Italy in the United States	ITEE
3rd	Network Softwarization at the Edge with SD-WAN	0,2	Sebastian Troia, Guido Maier	Politecnico di Milano	RESTART foundation

Research activities

The research of Annalisa Navarro focused on automated network management and orchestration in next-generation programmable networks, including SD-WAN, O-RAN, and 5G Core Network, leveraging Machine Learning and Reinforcement Learning (RL) techniques.

In SD-WAN, a scalable multi-agent RL framework was developed for policy-based traffic control across multi-site networks, achieving significant reductions in QoS violations and cost while ensuring compliance with global policies. An Explainable AI technique (i.e., surrogate models through decision trees) was integrated to provide transparent insights into RL decision-making.

In O-RAN, a reliable RL-based handover strategy using offline training and off-policy evaluation was implemented, improving throughput, fairness, and load balancing while minimizing deployment risks. Lightweight predictive models were developed for proactive latency management in resource-constrained edge environments.

For 5G Core and edge-cloud networks, orchestration and resource allocation challenges in cloud-native architectures were addressed. Data-driven scaling algorithms and RL-based task offloading mechanisms were designed to dynamically allocate workloads between edge and cloud resources, optimizing latency, energy efficiency, and user experience for URLLC applications.

I also investigated network security aspects, conducting a comprehensive survey on the security of Low Power Wide Area Networks (LPWANs) for IoT. Furthermore, in the context of Cyber-Physical Systems, an integrated anomaly detection approach combining network and sensor data was proposed to identify deviations from normal behaviour, enabling the detection of both network-level and physical cyber-attacks.

Tutoring and supplementary teaching activities

- Practical Kubernetes demo based on Minikube for a lesson of the "Cloud and Network Infrastructure" course (by Prof. Roberto Canonico). (2h)
- Explanation of the theoretical background of Software Defined Wide Area Networks (SD-WANs), for the course of "Cloud and Network Infrastructure" by Prof. Roberto Canonico (2h).

- Explanation about network simulation and emulation tools with practical exercises based on Cisco Packet Tracer, for "Computer Networks" course by Prof. Giorgio Ventre. (2h)
- Explanation about Wireless technologies, for "Computer Networks" course by Prof. Giorgio Ventre. (2h)
- Tutorship activity (Type B) for "Fondamenti di Informatica" courses (by Prof. Alessio Botta and Prof. Giuseppe Aceto) for the grant "Didactic-Integrative Tutoring Activities, Propaedeutic, and Recovery" (Academic Year 2023-2024) (32h)
- Tutorship activity (Type B) for "Calcolatori Elettronici" course (by Prof. Roberto Canonico) for the grant "Didactic-Integrative Tutoring Activities, Propaedeutic, and Recovery" (Academic Year 2023-2024) (28h)
- Practical demo lesson on switching, static/dynamic routing, NAT and DHCP for the "Computer Networks" courses by Prof. Roberto Canonico and Prof. Antonio Pescapé (date: 23/11/2023) (2h)

Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1st	23.0	13.4	26.2	0.32
2nd	12.0	7.6	44.0	2.36
3rd	4.0	4.8	65.0	0.16
Total	39.0	25.8	135.2	2.84

Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
2nd	Technische Universität Dresden, Germany	Prof. Frank Fitzek and Prof. Giang Nguyen	15.05.2024 15.10.2024	Research on Reinforcement Learning for connection management in O-RAN under mobility scenarios. Experimentation was conducted on the NS-O-RAN simulator for evaluation. Publication of a joint paper.

PhD Thesis

Next-Generation Networks (NGNs), including 5G and the upcoming 6G, mark a paradigm shift in telecommunications by introducing unprecedented requirements in terms of throughput, latency, scalability, and reliability. To meet these challenges, networks must evolve into programmable, adaptive, and autonomous infrastructures, enabled by paradigms such as Software-Defined Networking (SDN), Network Function Virtualization (NFV), and the integration of Artificial Intelligence (AI) and Machine Learning (ML). Among ML approaches, Reinforcement Learning (RL) has emerged as particularly promising for dynamic network resource management. However, the inherent complexity and lack of trustworthiness have hindered its widespread adoption in real-world telecom systems.

This thesis addresses the challenge of designing scalable, trustworthy, and safe RL-based frameworks for the automated management and control of advanced communication networks. This thesis proposes an RL-powered SD-WAN traffic engineering framework that dynamically enforces network policies over heterogeneous overlays. Then, this approach is extended by introducing a decentralized Multi-Agent RL (MARL) architecture to tackle scalability in multi-site scenarios, and further enhanced with cooperative strategies to improve overall policy compliance. Furthermore, an explainability layer for RL-based network control is introduced by employing surrogate models to provide interpretable insights into RL decisions, thereby fostering trust and operational adoption. Finally, a novel framework for safe RL deployment in the Radio Access Network (RAN) is presented that, by leveraging offline training and evaluation, ensures performance improvements in handover management while mitigating risks associated with online learning and testing.

Research products

Research results appear in *5* papers published in international journals, *9* contributions to international conferences.

List of scientific publications

International journal papers

A. Botta, R. Canonico, A. Navarro, G. Stanco, G. Ventre,
Adaptive overlay selection at the SD-WAN edges: A reinforcement learning approach with networked agents,
Computer Networks,
vol. 243, p. 110310, Apr. 2024, DOI: 10.1016/J.COMNET.2024.110310.

G. Stanco, A. Navarro, F. Frattini, G. Ventre, A. Botta,
A comprehensive survey on the security of low power wide area networks for the Internet of Things,
ICT Express,
vol. 10, no. 3, pp. 519-552, 2024, DOI: 10.1016/j.icte.2024.03.003.

R. Canonico, G. Esposito, A. Navarro, S.P. Romano, G. Sperlì, A. Vignali
An Anomaly-based Approach for Cyber-Physical Threat Detection using Network and Sensor Data,
Computer Communications,
vol. 234, pp. 108087, 2025, DOI: 10.1016/j.comcom.2025.108087.

R. Canonico, G. Esposito, A. Navarro, S.P. Romano, G. Sperlì, A. Vignali,
Empowered Cyber-Physical Systems Security using both Network and Physical Data,
Computers & Security,
vol. 152, pp. 104382, 2025, DOI: j.cose.2025.104382.

R. Canonico, F. Lista, A. Navarro, G. Sperlì and A. Vignali,
Threat Detection in reconfigurable Cyber Physical Systems through Spatio-Temporal Anomaly Detection using Graph Attention Network,
Computers & Security,
vol. 156, pp. 104509, 2025, DOI: 10.1016/j.cose.2025.104509.

International conference papers

R. Botta, A. Canonico, A. Navarro, S. Ruggiero, G. Ventre,
AI-enabled SD-WAN: the case of Reinforcement Learning,
IEEE Latin-American Conference on Communications (LATINCOM),
Rio de Janeiro, Brazil, November 30 – December 2, pp. 1-6, DOI: 10.1109/LATINCOM56090.2022.10000667

A. Botta, R. Canonico, A. Navarro, G. Stanco, G. Ventre,
Scalable Reinforcement Learning for Dynamic Overlay Selection in SD-WANs,
IFIP Networking Conference,
Barcelona, Spain, June 12-15, 2023, pp. 1-9, DOI: 10.23919/IFIPNetworking57963.2023.10186399

A. Navarro, R. Canonico, A. Botta,
Software Defined Wide Area Networks: Current Challenges and Future Perspectives,
IEEE 9th International Conference on Network Softwarization (NetSoft),
Madrid, Spain, June 19-23, pp. 350-353, DOI: 10.1109/NetSoft57336.2023.10175458

Botta, R. Canonico, A. Navarro, G. Stanco, G. Ventre,
Towards a Highly-Available SD-WAN: Rapid Failover based on BFD Protocol,
IEEE Conference on Network Functions Virtualization and Software-Defined Networking (NFV-SDN),
Dresden, Germany, Nov. 7-9, 2023, pp. 153-158, DOI: 10.1109/NFV-SDN59219.2023.10329617

Navarro, A. Botta, A. Canonico, R. Stanco, G. Ventre, G. Buonocunto, A. Fresa, A. Gentile, V. Scommegna, L. Vicario, E.
Edge to Cloud Network Function Offloading in the ADAPTO Framework,
in *Advanced Information Networking and Applications* (proceedings of AINA 2024),
Apr. 9, 2024, pp. 69-78, Springer Nature Switzerland, DOI: 10.1007/978-3-031-57931-8_7.

Botta, R. Canonico and A. Navarro,
Explainable Reinforcement Learning for Network Management via Surrogate Model,
2024 IEEE 44th International Conference on Distributed Computing Systems Workshops (ICDCSW),
Jersey City, NJ, USA, July 2024, pp. 35-40, doi: 10.1109/ICDCSW63686.2024.00012.

A. Botta, R. Canonico, A. Navarro, G. Stanco, G. Ventre, A. Buonocunto, A. Fresa, V. Gentile, L. Scommegna, E. Vicario, E. Mingozzi, A. Virdis, M. Cucurachi,
ADAPTO: Scaling and Offloading Cloud-Native Network Functions in Future Mobile Networks,
Advanced Information Networking and Applications
Barcelona, Spain, Apr. 2025, pp. 337-346, Springer, DOI: 10.1007/978-3-031-87778-0_33.

A. Navarro, A. Botta, R. Canonico, Y. Wang, F. H. P. Fitzek and G. T. Nguyen,
2OffRAN: Offline Off-Policy Reinforcement Learning for Safe Handover in O-RAN,
IEEE International Conference on Machine Learning for Communication and Networking
Barcelona, Spain, May. 2025, pp. 1-6, IEEE, DOI: 10.1109/ICMLCN64995.2025.11140172.

Zinno, S., Navarro, A., Rotbei, S., Pasquino, N., Botta, A., & Ventre, G.,
A lightweight deep learning approach for latency prediction in 5G and beyond,
1st Workshop on Integrated Wireless Networking and Computing (IWNC),
IEEE Conference on Network and Service Management (CNSM)
Bologna, Italy, October. 2025, pp. 27-31, IEEE, [YET TO APPEAR]

Awards and Prizes

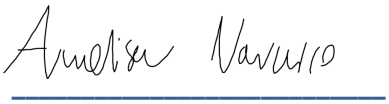
13th TMA PhD School Best Poster Awards
"2OffRAN: Offline Off-Policy Reinforcement Learning for Safe Handover in O-RAN"
Annalisa Navarro, Roberto Canonico, Alessio Botta

IEEE ComSoc CSIM TC Conference Best Paper Award 2023
A. Botta, R. Canonico, A. Navarro, G. Stanco and G. Ventre, "Towards a Highly-Available SD-WAN: Rapid Failover based on BFD Protocol," 2023 IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN), Dresden, Germany, 2023, pp. 153-158, doi: 10.1109/NFV-SDN59219.2023.10329617.

Travel Grants

- 2023 IEEE 9th International Conference on Network Softwarization (NetSoft)
- 2024 IEEE 44th International Conference on Distributed Computing Systems (ICDCS)
- 2025 Network Traffic Measurement and Analysis Conference (TMA)

Date ___27/10/2025_____

PhD student signature 

Supervisor signature