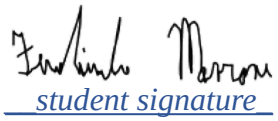
PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Ferdinando Marrone

Cycle: XXXIX

Training and Research Activities Report

Academic year: 2024-25 - PhD Year: Second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Tutor: Prof. Stefano Avallone


tutor signature

Date: October 31, 2025

1. Information:

- **PhD student: Ferdinando Marrone** **PhD Cycle: XXXIX**
- **DR number: DR997215**
- **Date of birth: 01/04/1981**
- **Master Science degree: Telecommunications Engineering**
- **University: University of Naples Federico II**
- **Scholarship type: no scholarship**
- **Tutor: Prof. Stefano Avallone**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Conversazioni su Etica e Intelligenza Artificiale	Course	8	1,6	02-05-09-12/12/2024	Prof. Lucio Franzese	Y
Perché l'Intelligenza Artificiale crede di fare a meno della teoria linguistica, ma in realtà non potrà farlo	Seminar	2	0,4	20/11/2024	Prof. Francesco Cutugno	Y
Strutture basate su regole e strutture basate su approssimazioni	Seminar	1,5	0,3	10/12/2024	Prof. Francesco Cutugno	Y
Study on the Adaptive Time-Excess Round Robin (ATERR) slicing mechanism for performance comparison with implemented SlicingScheduler. Further simulations and performance verification of the implemented algorithm.	Research		5	1/11/2024 - 31/12/2024		
How to boost your PhD	Course	18	5	08-15-22-29/01/2025 - 05-12/02/2025	Prof. Antigone Marino	Y

IoT Data Analysis	**Course**	**16**	**4**	**28-31/01/2025 - 4-7-11-14-25/02/2025**	**Prof. Raffaele Della Corte**	**Y**
Opportunità e Prospettive dell'AI Generativa nel mondo del Lavoro e della Ricerca	**Seminar**	**5**	**1**	**29/01/2025**	**Centro Ricerche ENEA Portici**	**N**
Optimisation-based Control of Flexible Resources in Sustainable Energy Networks	**Seminar**	**1**	**0,2**	**05/02/2025**	**Prof. Luigi Glielmo**	**Y**
Emergent behaviors and collective decisions in cyber-physical-human systems	**Seminar**	**1**	**0,2**	**13/02/2025**	**Dr. Alessandro Della Pia (SSM)**	**Y**
Explainable Scientific Machine Learning: Theoretical and Practical Perspectives	**Seminar**	**1**	**0,2**	**20/02/2025**	**Dr. Francesco Bajardi (SSM)**	**Y**
Further simulations and performance verification of implemented algorithm SlicingScheduler. Review of an article on NOMA-Enabled 6G IoT Networks for the journal "Computer networks". Preparation of the conference paper "Wi-Fi Network Slicing Through Multi-User Transmissions" submitted to IEEE International Symposium on Modeling and Optimization in	**Research**		**4**	**1/01/2025 - 28/02/2025**		

Mobile, Ad Hoc, and Wireless Networks (WiOpt)						
Nonlinear Spectral Modeling from Data	**Seminar**	**1**	**0,2**	**06/03/2025**	**Dr. Francesco Bajardi (SSM)**	**Y**
5G & digital transformation: a view from an unconventional perspective	**Seminar**	**4**	**0,8**	**14/03/2025**	**Prof.ssa Antonia Maria Tulino**	**Y**
Robot Autonomy among Decision-Making Agents	**Seminar**	**1**	**0,2**	**15/04/2025**	**Prof. Fabio Ruggiero**	**Y**
Safety of highly automated driving systems	**Seminar**	**1**	**0,2**	**23/04/2025**	**Prof. Marcello Cinque**	**Y**
Study on the design and implementation of Uplink Wi-Fi network slicing in ns-3. Study on ns3-ai module. Review of an article on NOMA-Enabled 6G IoT Networks for the journal "Computer networks". Preparation of the conference paper “Smart Resource Allocation to Enable Network Slicing” submitted to IEEE International Mediterranean Conference on Communications and Networking (IEEE MEDITCOM 2025). Preparation of the paper “Network Slicing Through Buffer Aware Multi-User	**Research**		**8**	**1/03/2025 - 30/04/2025**		

Transmissions" submitted to journal "Computer networks".						
Superconducting Radio Frequency Cavities for Quantum Computing and Communication	**Seminar**	**1**	**0,2**	**24/06/2025**	**prof. Edo Giusto**	**Y**
Trusted Execution Environments for QPUs	**Seminar**	**1**	**0,2**	**27/06/2025**	**prof. Edo Giusto**	**Y**
Study on the design and implementation of Uplink Wi-Fi network slicing in ns-3. Revision of the paper "Network Slicing Through Buffer Aware Multi-User Transmissions" with new simulations and performance check of the implemented algorithm.	**Research**		**8**	**1/05/2025 - 30/06/2025**		
Study on Python, ns3-ai and Rllib. Presentation of the paper "Smart Resource Allocation to Enable Network Slicing" to the Conference IEEE MEDITCOM 2025. Preparation of the conference paper "Toward Latency Isolation through Adaptive Network Resource Allocation" submitted to International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM 2025). Revision	**Research**		**10**	**1/07/2025 - 31/08/2025**		

of the paper “Network Slicing Through Buffer Aware Multi-User Transmissions” submitted to journal "Computer networks". Revision of the paper “A Study of 802.11be EMLSR: Exploiting Multiple Links by Using a Single Radio” submitted to journal "Ad Hoc Networks".						
PhD school, 2025 Spring School on Transferable Skills	**Course**	**9**	**2**	**30-31/10/ 2025**	**Department of Pharmacy University of Naples Federico II**	**Y**
Security Summit Napoli 2025	**Seminar**	**5**	**1**	**23/09/2025**	**CLUSIT**	**Y**
IEEE Authorship and Open Access Symposium: Tips and Best Practices to Get Published from IEEE Editors	**Seminar**	**1,5**	**0,3**	**15/10/2025**	**IEEE Xplore**	**Y**
Radar Cross-Section Estimation and Measurements	**Seminar**	**4**	**0,8**	**17/10/2025**	**Prof. Amedeo Capozzoli**	**Y**
Guardians or Threats? AI at the Frontlines of Cybersecurity	**Seminar**	**4**	**0,8**	**17/10/2025**	**Prof.ssa Antonia Maria Tulino**	**Y**
AI Powered User Interface design	**Seminar**	**4**	**0,8**	**24/10/2025**	**Prof.ssa Antonia Maria Tulino**	**Y**
Quality of services	**Seminar**	**4**	**0,8**	**28/10/2025**	**Prof.ssa Antonia Maria Tulino**	**Y**
Study on reinforcement learning and Rllib. Revision of the paper	**Research**		**5**	**1/09/2025 - 31/10/2025**		

"Network Slicing Through Buffer Aware Multi-User Transmissions" submitted to journal "Computer networks". Preparation of the conference papers "Flexible Network Slicing to Meet Latency and Reliability Requirements" and "Reinforcement Learning for Efficient Link Scheduling in Multi-Link Networks" submitted to the International Conference on Communications (IEEE ICC 2026).						

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	**1,6**	**0,7**	**5**	**0**	**7,3**
Bimonth 2	**9**	**1,6**	**4**	**0**	**14,6**
Bimonth 3	**0**	**1,4**	**8**	**0**	**9,4**
Bimonth 4	**0**	**0,4**	**8**	**0**	**8,4**
Bimonth 5	**0**	**0**	**10**	**0**	**10**
Bimonth 6	**2**	**4,5**	**5**	**0**	**11,5**
Total	**12,6**	**8,6**	**40**	**0**	**61,2**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

During the second year of my PhD, the research activity evolved from the initial study of Time-Sensitive Networking (TSN) concepts toward their extension and implementation in wireless environments.

Building upon the foundations laid in the first phase, the work focused on consolidating and expanding the Wi-Fi network slicing framework to enable deterministic and time-critical communication. Following the initial development of the *SlicingScheduler* and its evaluation in downlink scenarios, the

research activity was further extended to consolidate and broaden the network slicing framework for Wi-Fi. In this phase, I focused on a deeper comparative analysis of the proposed approach against existing state-of-the-art solutions in the literature. In particular, I evaluated the Adaptive Time-Excess Round Robin (ATERR) mechanism, a recently proposed strategy designed to differentiate latency in Wi-Fi networks and support slicing. The comparison highlighted that the proposed solution distributes resources proportionally across slices and dynamically reuses unused resources, effectively addressing the limitations of existing approaches, such as ATERR, that fail to manage excess resources.

After completing the downlink analysis, I extended the investigation to the uplink direction, which remains largely unexplored in the literature. While most existing studies on Wi-Fi slicing have focused exclusively on downlink transmissions, the uplink plays an equally critical role in modern applications such as augmented reality, industrial control, and interactive services. To address this gap, I designed and implemented a buffer-aware OFDMA scheduling framework within the ns-3 simulator to enable slice-level resource differentiation for both downlink and uplink traffic in Wi-Fi networks. The approach is fully standard-compliant, relying on Buffer Status Report (BSR) frames to estimate uplink buffer occupancy without protocol modifications. Moreover, it allows stations to access the channel using contention-based mechanisms while still enforcing effective slice-level differentiation. As in the previous year, the research activity on this topic is conducted in collaboration with Intel Labs/ Network Simulation Solutions LLC and Samsung researchers. According to the available literature, this represents the first solution that enables network slicing in both downlink and uplink Wi-Fi transmissions. The integration of these two directions provides a unified and consistent framework for enforcing proportional resource distribution across slices and achieving deterministic performance in Wi-Fi networks. The next step of the research will focus on integrating Reinforcement Learning (RL) algorithms into the slicing framework to dynamically adjust scheduling decisions to meet application-specific *Key Performance Indicators (KPIs)* such as latency, throughput, and reliability. This evolution aims to create an adaptive and intelligent scheduler capable of autonomously optimizing network performance under varying traffic and channel conditions.

Recently, I investigated the potential of Multi-Link Operation (MLO), introduced in the IEEE 802.11be amendment, as an additional means to reduce latency and improve reliability. The analysis initially focused on the Enhanced Multi-Link Single Radio (EMLSR) configuration. It demonstrated that MLO can substantially reduce end-to-end delay by enabling simultaneous transmissions across multiple channels. The study was then extended to evaluate the impact of transport layer dynamics on MLO performance, focusing on TCP traffic and the Simultaneous Transmit and Receive Enhanced Multi-Link Multi-Radio (STR-EMLMR) configuration. The experiments revealed that the interaction between TCP congestion control and MLO mechanisms can degrade performance when one link experiences moderate to high UDP interference. To mitigate this effect, I explored the Transmission Opportunity (TXOP) Random Discard mechanism, a probabilistic approach in which stations intentionally relinquish TXOPs for Best Effort traffic. Building upon this concept, an RL-based adaptive strategy was developed to dynamically adjust the discard probability on each link according to network conditions. Simulation results show that this approach improves TCP throughput and latency, enabling the multi-link configuration to outperform the single-link setup even under moderate and heavy loads, while preserving UDP performance and ensuring more balanced operation.

4. Research products:

F. Marrone, P. Imputato, S. Avallone, “Smart Resource Allocation to Enable Network Slicing”, IEEE International Mediterranean Conference on Communications and Networking (IEEE MEDITCOM 2025), 7-10 July 2025, Nice, France (published, 2025, indexed in Scopus and ISI Web of Science)

F. Marrone, P. Imputato, S. Avallone, “Network Slicing Through Buffer Aware Multi-User Transmissions” in *Computer Networks* (published, 2025, indexed in Scopus and ISI Web of Science) https://doi.org/10.1016/j.comnet.2025.111717

S. Avallone, P. Imputato, F. Marrone, “Exploiting multiple links with a single interface: A performance study” in *Ad Hoc Networks* (published, 2025, indexed in Scopus and ISI Web of Science) https://doi.org/10.1016/j.adhoc.2025.104029

F. Marrone, P. Imputato, S. Avallone, M. R. Kanagarathinam, J. M. Ppallan, “Flexible Network Slicing to Meet Latency and Reliability Requirements” IEEE International Conference on Communications (IEEE ICC 2026), 24 - 28 May 2026, Glasgow, Scotland (submitted)

N. D’Ambra, F. Marrone, P. Imputato, S. Avallone, “Reinforcement Learning for Efficient Link Scheduling in Multi-Link Networks” IEEE International Conference on Communications (IEEE ICC 2026), 24 - 28 May 2026, Glasgow, Scotland (submitted)

5. Conferences and seminars attended

IEEE International Mediterranean Conference on Communications and Networking (IEEE ICC 2026) Nice, France, 7-10 July 2025. I presented a paper, “Smart Resource Allocation to Enable Network Slicing”

Security Summit Napoli 2025, Napoli, Città della Scienza, 23/09/2025

6. Periods abroad and/or in international research institutions

7. Tutorship

8. Plan for year three

- Continue the collaboration with Network Simulation Solutions LLC and the Samsung researcher to validate and consolidate the slicing framework.
- Explore the integration of RL into the Wi-Fi Slicing Framework to dynamically adapt the slice ratios based on the performance requirements and the performance that is actually experienced by the different slices.
- Examine additional network scenarios and RL algorithms to further enhance the effectiveness and robustness of the TXOP Random Discard mechanism.