



UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

itee_{PhD}
information technology
electrical engineering



Annalisa Navarro

Machine Learning For Networking: the Traffic Engineering Use Case

Tutor: Roberto Canonico

Cycle: XXXVIII

Year: I

My background

- MSc degree in Computer Engineering
- Research Group: Architectures and Computer Networks Laboratory (ARCLAB)
- PhD Start Date: 01/11/2022
- Scholarship type: UNINA

Research field of interest

- Data-driven approaches - including Machine Learning and Deep Learning - for enhancing *performance*, *security*, and *availability* of complex networks.



- Case studies: Traffic Engineering in Software Defined Wide Area Networks (*SD-WANs*), Anomaly Detection in Industrial Cyber Physical Systems (*ICPSs*), and Security in Low Power Wide Area Networks (*LPWANs*).

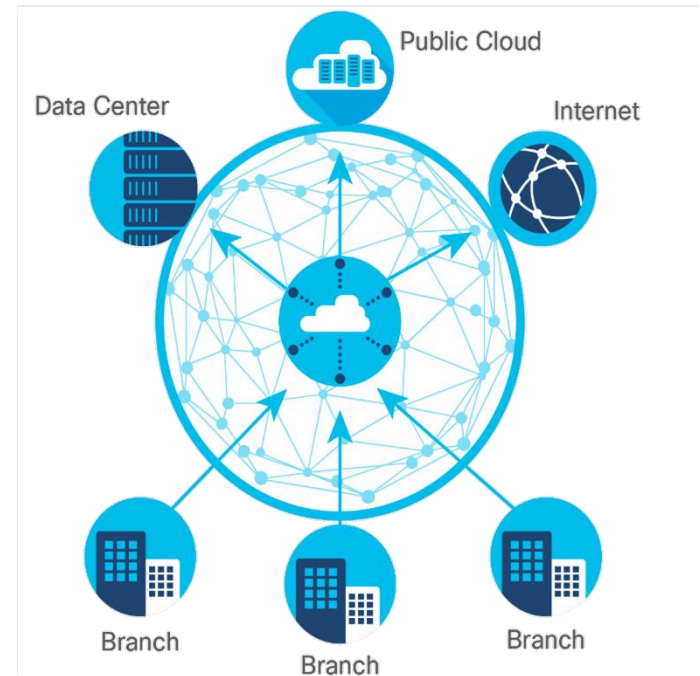


Summary of study activities

- Ad hoc PhD courses
 - Using Deep Learning Properly
 - Scientific Programming and Visualization with Python
 - Statistical Data Analysis for Science and Engineering Research
 - Virtualization Technologies and their Applications
 - Big Data Architecture and Analytics
- School
 - TMA Conference PhD School
 - RESTART Tech Camp on 5G and Open RAN
- Conferences attended
 - IEEE Latin-American Conference on Communications (LATINCOM)
 - International Federation for Information Processing (IFIP) Networking 2023 Conference (NETWORKING 2023)
 - IEEE International Conference on Network Softwarization (NETSOFT)

Research activity: Overview

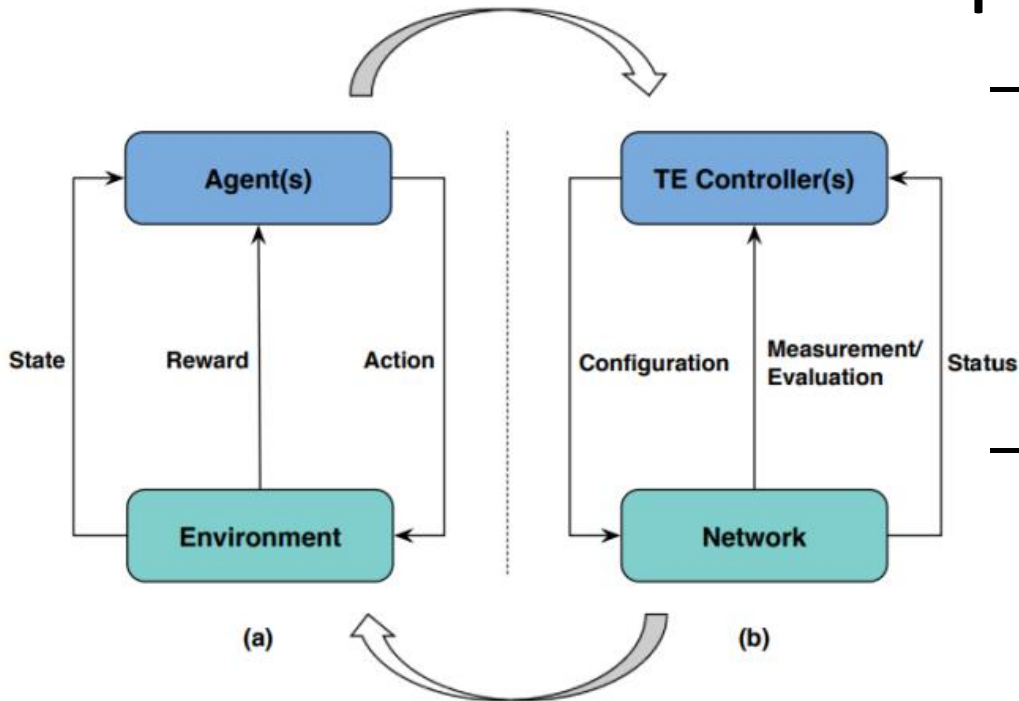
- Objective
 - SD-WAN builds interconnections between sparse geographical sites through diverse overlays (MPLS, Internet, ...).
 - How to exploit the available connections to improve latency and availability while at the same time reducing transit cost is still an open problem.



Research activity: Overview

- Problem

- Reinforcement Learning (RL) is the main approach proposed for the dynamic overlay selection problem.
- Unfortunately, RL suffers the explosion of action and state spaces when the environment gets too complex.



Research activity: Overview

- Methodology
 - We modelled the overlay selection problem with Multi Agent Reinforcement Learning (MARL) reducing complexity significantly.
 - Lack of cooperation among agents prevented the achievement of global network policies.
 - For this reason, we are now proposing a Cooperative version of MARL – namely Multi Agent Reinforcement Learning With Networked Agents – to promote agents' cooperation without impacting complexity.
 - Preliminary results show improvements in SLA violations: this approach seems to meet global intents even in case of conflicting and heterogeneous policies regarding QoS and cost.

Products

- [P1]** A. Botta, R. Canonico, A. Navarro, S. Ruggiero and G. Ventre, "AI-enabled SD-WAN: the case of Reinforcement Learning," 2022 IEEE Latin-American Conference on Communications (LATINCOM) [PUBLISHED]
- [P2]** A. Botta, R. Canonico, A. Navarro, G. Stanco and G. Ventre, "Scalable Reinforcement Learning for Dynamic Overlay Selection in SD-WANs," 2023 IFIP Networking Conference (IFIP Networking), 2023 [PUBLISHED]
- [P3]** A. Navarro, R. Canonico and A. Botta, "Software Defined Wide Area Networks: Current Challenges and Future Perspectives," 2023 IEEE 9th International Conference on Network Softwarization (NetSoft)[PUBLISHED]
- [P4]** A. Botta, R. Canonico, A. Navarro, G. Stanco and G. Ventre, "Towards a Highly-Available SD-WAN: Rapid Failover based on BFD Protocol" 2023 9th IEEE Conference on Network Functions Virtualization and Software-Defined Networking (IEEE NFV-SDN 2023) [ACCEPTED]
- [P5]** R. Canonico, G. Esposito, A. Navarro, S.P. Romano, G. Sperli, A. Vignali, "CPS Security Unleashed: Anomaly Detection for Cyber-Physical Threats in Critical Infrastructures". IEEE Transaction on Dependable and Secure Computing, [UNDER REVIEW]
- [P6]** R. Canonico, G. Esposito, A. Navarro, S.P. Romano, G. Sperli, A. Vignali, "Network and Physical Data Fusion for Cyber-Physical Systems Protection", IEEE Transaction on Industrial Informatics [UNDER REVIEW]
- [P7]** 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 [UNDER REVIEW]
- [P8]** A. Botta, R. Canonico, A. Navarro, G. Stanco and G. Ventre, "Adaptive Overlay Selection at the SD-WAN Edges: A Reinforcement Learning Approach with Networked Agents", Computer Networks [SUBMITTED]

Next Year

- Introduce network policy support that encompasses not only latency and transit cost but also throughput, availability, and security.
- Expand the experimentation scope to a larger and more realistic scenario involving multiple SD-WAN sites and various alternative overlays between them.
- Evaluate the proposed approach in case of conflicting policies and/or greedy agents.