Annalisa Navarro

Data-driven Automated Management and Control for Next-Gen Programmable Networks

Tutor: Roberto Canonico

Cycle: XXXVIII

Year: second

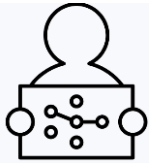
My background

- MSc degree: Computer Engineering
- Research Group: Architectures and Computer Networks Laboratory (ARCLAB)
- PhD Start Date: 01/11/2022
- Scholarship type: UNINA
- Period abroad: 15/05/24 – 15/10/24 at Technische Universität Dresden (Germany)

Research field of interest

- Automated Management and Control of Communication Networks.
- Focus on:



performance *security* *availability* *explainability*

- Case studies: Software Defined Wide Area Networks (*SD-WANs*), Open Radio Access Networks (*O-RAN*), Cyber Physical Systems (*CPSs*), Low Power Wide Area Networks (*LP-WANs*)




Summary of study activities

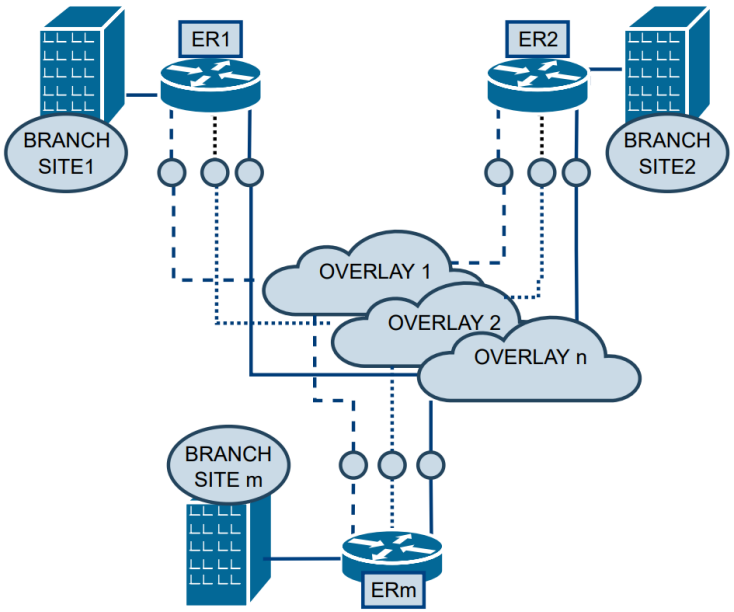
- Ad hoc PhD courses
  - Artificial Intelligence and Natural Language Processing
  - Hands on Network Intrusion Detection via Machine Learning and Deep Learning
  - Strategic Orientation for STEM Research and Writing
- Conferences attended
  - IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN 2023)
  - RESTART Plenary Dissemination Workshop 2024
  - IEEE International Conference on Distributed Computing Systems (ICDCS 2024)

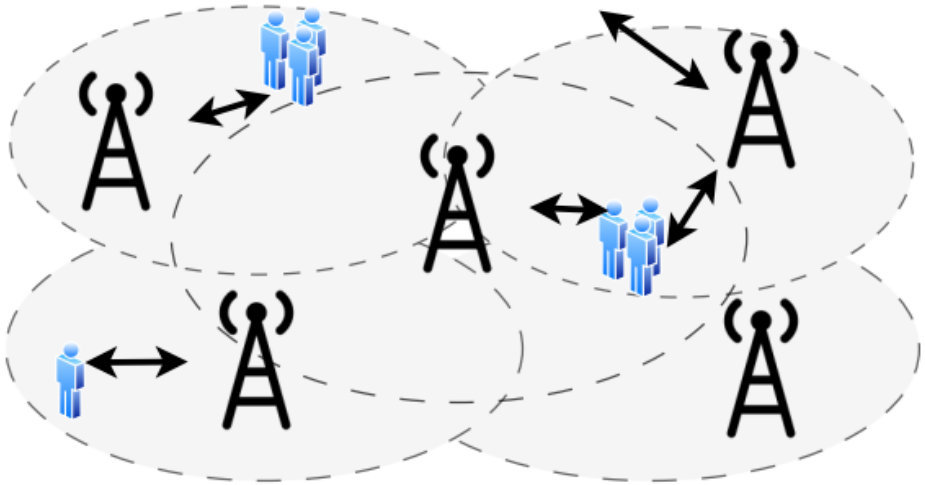
Problem

Automatically manage and control next-gen telecom networks under dynamic conditions to meet cost constraints and achieve network intents.

- **SD-WAN** traffic orchestration: selection of the most suitable overlay to connect geographically sparse sites based on variable network state and cost requirements to reduce delay.

O-RAN connection management: handover a UE from the current base station to a target base station in a mobility scenario or in overload situation to improve overall throughput.

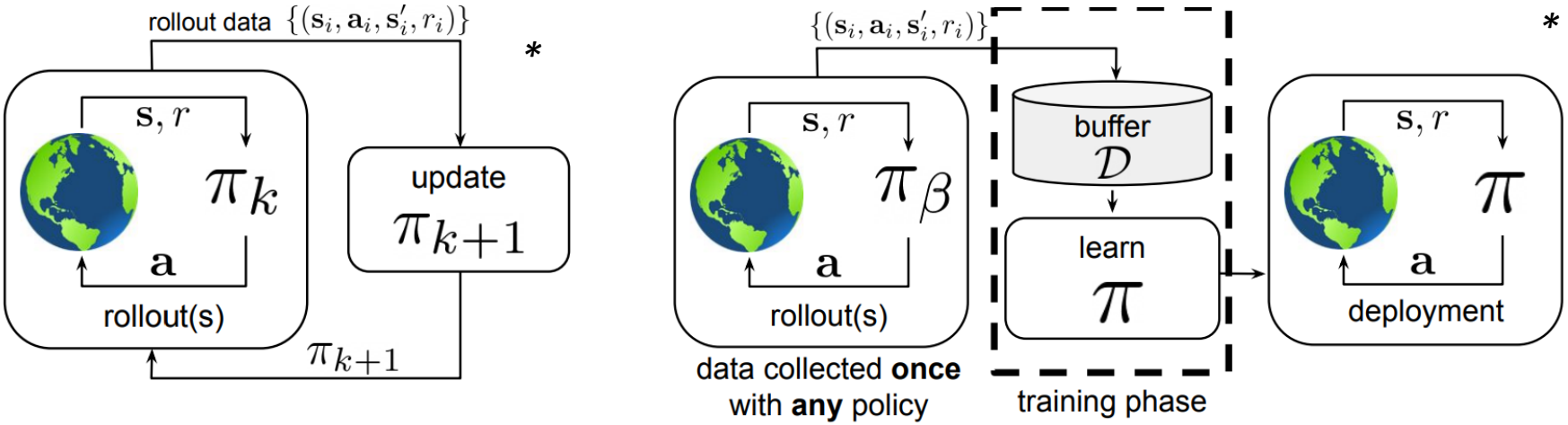




Methodology: offline Reinforcement Learning

Online Reinforcement Learning: the policy is learned while interacting with the environment.

Offline Reinforcement Learning: the policy is learned using pre-collected, static datasets from past experiences



** Levine, S., Kumar, A., Tucker, G., & Fu, J. (2020). Offline reinforcement learning: Tutorial, review, and perspectives on open problems.*

SD-WAN

Methodology: online Reinforcement Learning

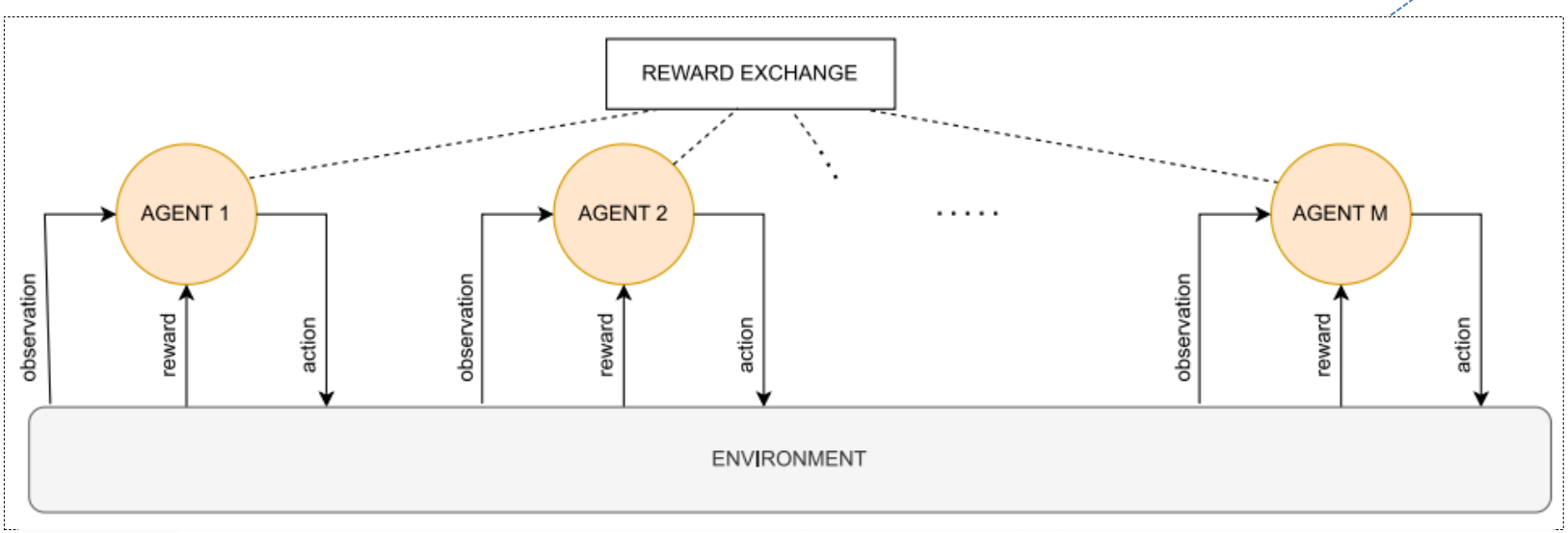
Single Agent Reinforcement Learning: state action spaces explosion

→

Multi Agent Reinforcement Learning (MARL): suboptimal performance due to lack of cooperation

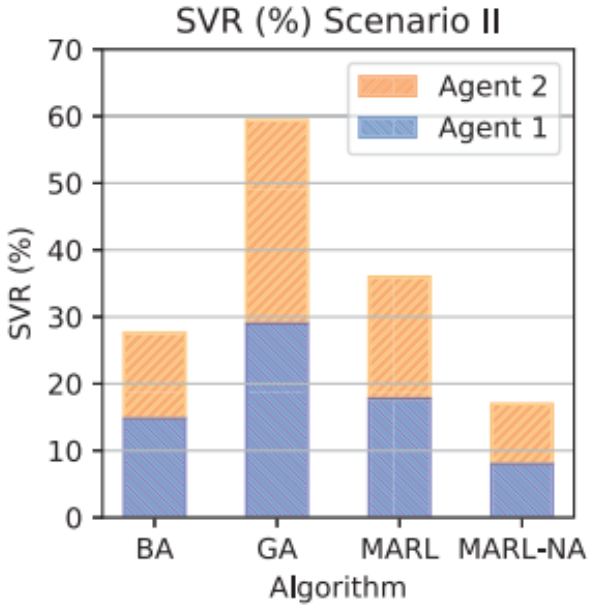
→

Cooperative Multi Agent Reinforcement Learning with networked agents (MARL-NA)

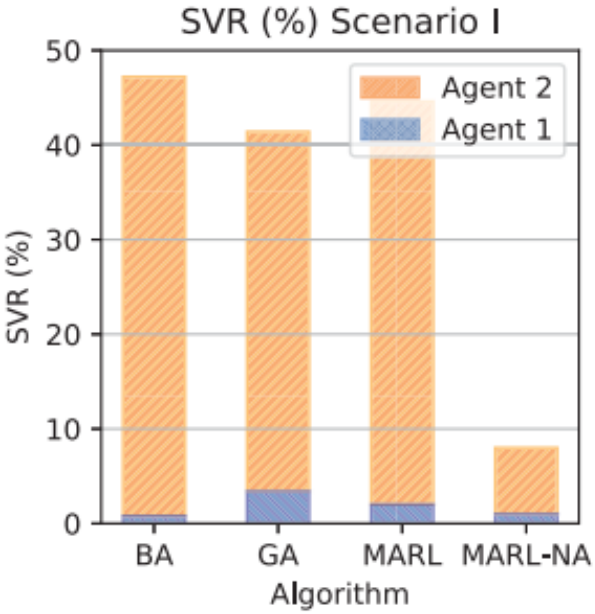


SD-WAN

Results



Network Intent:
A1, A2: "Traffic must experience a maximum delay of 300 ms"



Network Intent:
A1: "Traffic must experience a maximum delay of 400 ms";
A2: "Traffic must experience a maximum delay of 200 ms"

SVR: SLA violation ratio
BA: Blind Algorithm, GA: Greedy Algorithm

Products

[P1]	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) [PUBLISHED]
[P2]	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”, 2024, ICT Express [PUBLISHED]
[P3]	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, 2024 [PUBLISHED]
[P4]	A. Botta, R. Canonico, A. Navarro, G. Stanco, A. Buonocunto, … , E. Vicario, “Edge to Cloud Network Function Offloading in the ADAPTO Framework”, International Workshop on Cloud-Edge Continuum Projects and Initiatives (CCPI 2024) [PUBLISHED]
[P5]	A. Botta, R. Canonico & A. Navarro “Explainable Reinforcement Learning for Network Management via Surrogate Model”, International Conference on Distributed Computing Systems Workshops (ICDCSW 2024) [PUBLISHED]
[P6]	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, [UNDER REVIEW]
[P7]	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 [UNDER REVIEW]
[P8]	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”, Engineering Applications of Artificial Intelligence [UNDER REVIEW]

Next Year

- **I year:**
  - Design of a Multi Agent Reinforcement Learning Algorithm for SD-WAN network management and control

- **II year:**
  - Adding Cooperation to the Multi Agent Reinforcement Learning framework for SD-WAN and overall framework Evaluation
  - Design of an Offline Reinforcement Learning Algorithm for O-RAN network management and control

- **Plan for III year:**
  - ***Evaluation of the Offline Reinforcement Learning Algorithm for O-RAN management and control***