Sara Leccese

# Distributed Control for Cyber-Physical Systems: design and application

Tutor: Prof. Stefania Santini

Cycle: XXXVIII

Year: Second

# Background and Info

- MSc degree in Automation and Robotics Engineering, University of Naples Federico II
- Working team: DAiSy Lab (Prof. Stefania Santini)
- PhD start date: Academic Year 2022-2023
- Scholarship type: PNRR - DM 351 Ricerca

# Summary of study activities

- **Attended the 2024 IEEE American Control Conference (ACC), Toronto Canada and presented the paper "***Prescribed-Time Consensus Control for the Voltage Restoration in Inverter-based Islanded Microgrids***".**

**-Some of the attended seminars are listed as follows:**

- **The Characterization of ISS for time-delay systems: Results and Counterexamples, Prof. Fabian Wirth, Online ISS Seminar**
- **Input-to-State Stability and converse Lyapunov Theorem for Linear Difference Equations and Hyperbolic Partial Differential Equations, Prof. Delphine Bresch Pietri, Online ISS Seminar**
- **Balancing-based model reduction for delay systems, Prof. Nathan van de Wouw, TDS Webinar**
- **From ACE Technologies to Sustainable, Accessible and Equitable Urban Mobility: An Optimization Journey, Prof. Mauro Salazar, ITEE Seminar**

**-Other attended Courses are listed as follows-**

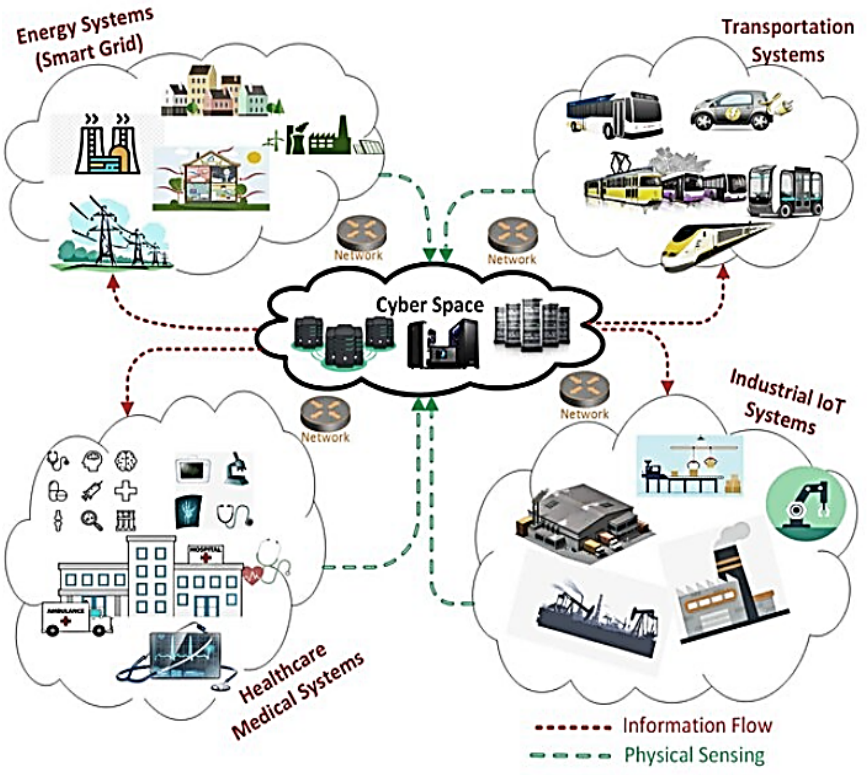
- **Big Data Architecture and Analytics**
- **Smart Roads and Cooperative Driving**

**-Tutorship-**

- **Controlli Automatici, SSD: ING-INF/04, Prof. Stefania Santini**

# Research Area

- **Designing novel distributed control strategies ensuring the efficiency, robustness, and adaptability of multi-agent cyber-physical systems (CPS) on various domains, such as:**
  - **Smart Transportation Systems**
  - **Smart Grids / Micro Grids**
  - **Smart Cities**
- **Hence, it is crucial to explore new control strategies for multi-agent CPS to boost collaboration, efficiency, and adaptability, enhancing system performance in dynamic environments.**

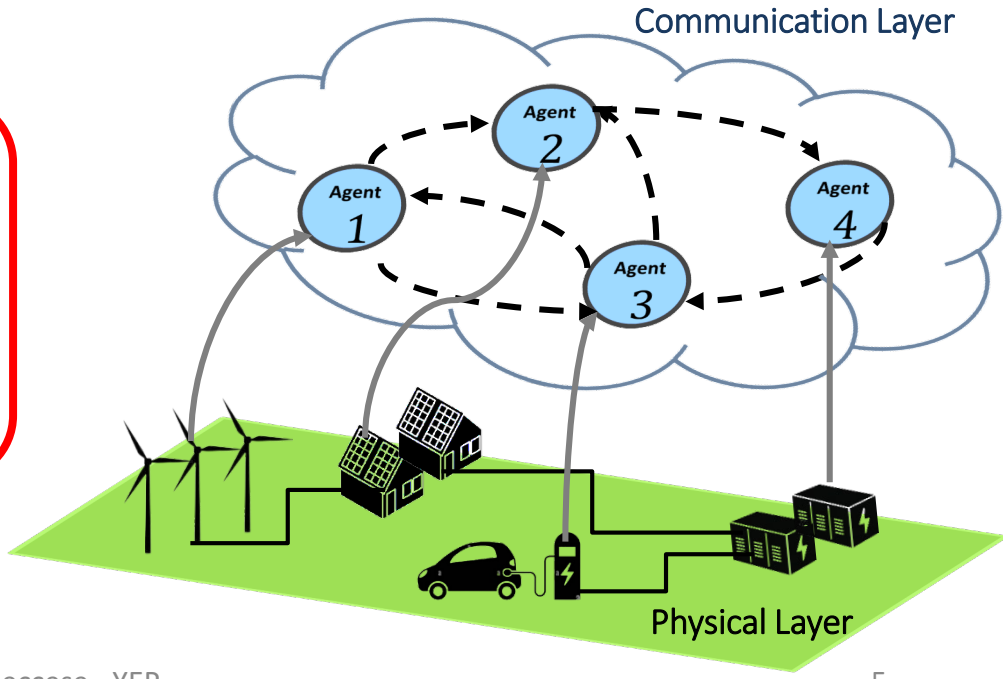


# 2nd Year Research Activity: Problem Statement

- The current environment of cyber-physical systems (CPS) poses a variety of challenges, such as communication delays, digitalization, the requirement for timely decision-making, and issues related to robustness, scalability, and resilience.

- The paradigm is shifting towards distributed control, ensuring efficient and resilient operation in interconnected environments.

The aim of the research is to design and validate distributed and fully decentralized cooperative control strategies for CPSs in a Multi-Agent Systems (MASs) fashion.



# 2nd Year Research Activity : Objectives

- The objective of the PhD thesis is twofold:

  i. From theoretical perspective: develop distributed control algorithms to address the consensus problem in multi-agent CPS, focusing on reducing communication load to enhance Networked Control System (NCS) efficiency

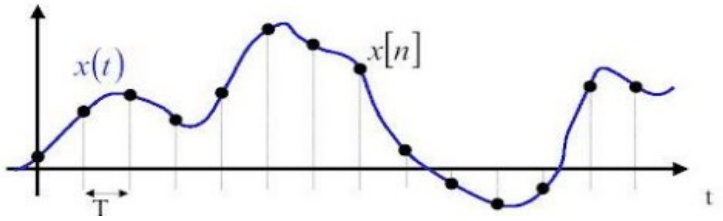
  ii. From the applied side: to tailor theoretical results to solve real-word CPSs applications control problem. Specifically, the one that can be met in power systems and the intelligent transportation systems.

# 2nd Year Research Activity : Methodology (1/2)

- To address objective $i$)

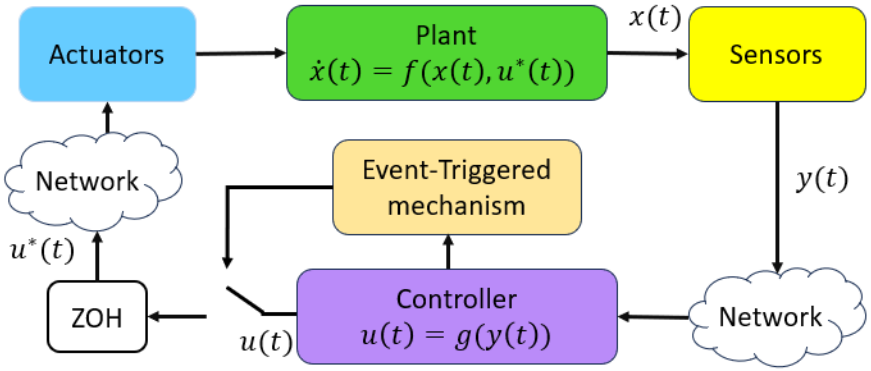
→ **sampled-data control**

- ✓ Periodic rather than continuous communication
- ✓ Control design in continuous time via time-delay approach
- ✓ Optimal sampling conditions by means of Lyapunov-Krasovskii stability theory




→ **event-triggered control + sampled-data**

- ✓ Aperiodic communication
- ✓ Further reduction of network workload
- ✓ Stability conditions analytically derived by means of Lyapunov-Krasovskii theory
- ✓ Zeno behaviour automatically excluded

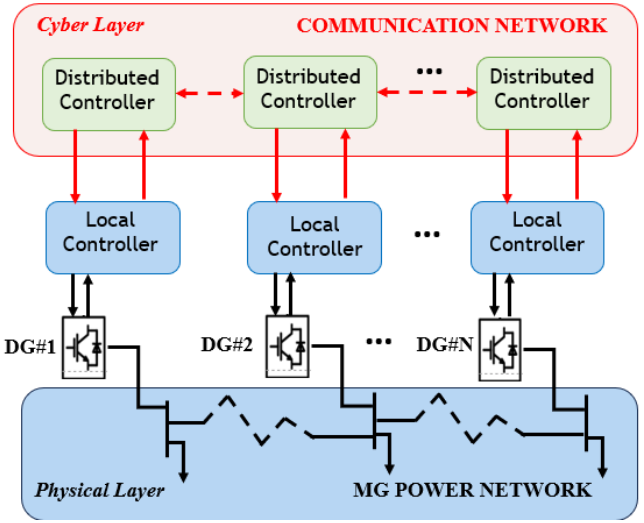


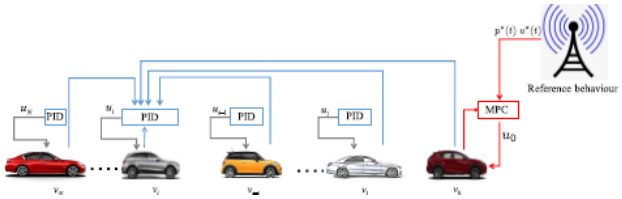
# 2nd Year Research Activity : Methodology (2/2)

- To address objective $ii$)

→ **Theoretical results applied to :**

- Power Systems
  - ✓ Solve secondary control for frequency and voltage regulation problem in a Micro-grid.
- Intelligent Transportation Systems
  - ✓ Solve the formation control problem in Intelligent transportation Systems field.
- Develop co-simulation platform exploiting *MATLAB/Simulink and/or MATLAB/Simscape*, and real-time hardware such as dSPACE or Speedgoat.




MATLAB & SIMULINK

speedgoat real-time simulation and testing

dSPACE

# Research products

| | |
|---|---|
| [P1] | Basile, G., **Leccese, S.**, Petrillo, A., Rizzo, R., & Santini, S.<br>*Sustainable DDPG-based Path Tracking for Connected Autonomous Electric Vehicles in extra-urban scenarios*<br>**IEEE Transactions on Industry Applications,**<br>2024, pp. 1-13, 2024 |
| [P2] | Caiazzo, B., **Leccese, S.,** Pepe, P., Petrillo, A., Santini, S.<br>*From piece-wise constant to continuous time-varying delays: Global Exponential Stability Preservation for Nonlinear Systems Under Sampling*<br>**IEEE Conference on Decision and Control (CDC)**<br>Milan, Italy, Dec. 2024, accepted |
| [P3] | Andreotti, A., Caiazzo, B., **Leccese, S.,** Lui, D. G., Petrillo, A., & Santini, I. S.<br>*Prescribed-Time Consensus Control for the Voltage Restoration in Inverter-based Islanded Microgrids*<br>**IEEE American Control Conference (ACC)**<br>Toronto, Canada, Jul. 2024, (pp. 1783-1788). IEEE. . |
| [P4] | Andreotti, A., Caiazzo, B., **Leccese, S**., Petrillo, A., & Santini, S.<br>*A Unified Distributed Digital Control Architecture for Secondary Control in Islanded Microgrids*<br>**IFAC Control of Power and Energy Systems (CPES)**<br>Rabat, Morocco, Jul. 2024, IFAC-PapersOnLine, 58(13), 74-79. |

Legend
- 2nd Year
- 1st Year

# Research products

| | |
|---|---|
| [P5] | Andreotti, A., Caiazzo, B., **Leccese, S.,** Petrillo, A., Santini, S., & Vaccaro, A.<br>*Assessment of a Dynamic Event-Triggered Voltage Control for Islanded Microgrids Using High-Fidelity Cyber-Physical Platform*<br>**International Conference on Smart Energy Systems and Technologies (SEST)**<br>Torino, Italy, Sept. 2024, (pp. 1-6), IEEE. |
| [P6] | B. Caiazzo, E. Fridman, **S. Leccese,** A. Petrillo, S. Santini «<br>*Voltage Recovery in SOA-based Virtual Microgrids via Time-Delay Approach to Averaging*<br>**IFAC, 22nd World Congress 2023 of the International Federation of Automatic Control**<br>Yokohama, Japan, IFAC-PapersOnLine, vol 56 (pp 905-910), Elsevier |
| [P7] | G. Basile, **S. Leccese**, A. Petrillo, R. Rizzo and S. Santini,<br>*Sustainable DDPG-based Path Tracking For Connected Autonomous Electric Vehicles in extra-urban scenarios*,<br>**2023 IEEE IAS Global Conference on Renewable Energy and Hydrogen Technologies (GlobConHT),**<br>Male, Maldives, 2023, (pp. 1-7), IEEE |

Legend
- 2nd Year
- 1st Year

# Year Three: My Period Abroad

**The period abroad has started on September 28, 2024.**

- **The hosting institution is the Department of System Engineering at the University of Seville (US), Spain; the supervisor is Prof. Alexander Seuret.**
- **The research aim is to keep on working on distributed sampled-data and event-triggered control for MAS by leveraging different tools such as hybrid systems theory.**
- **For the next third year, it is planned to stay at US until the end of March 2025.**


# Year Three: Open Challenges

**The focus of my third year will be:**

- **Network Optimization: design of novel event-triggered mechanisms to reduce network congestion in Networked Control Systems (NCSs), optimizing bandwidth and stability.**

- **Applications and Validation: different applications fields will be considered including distributed control of CPSs (e.g. connected autonomous electric vehicles (CAEVs) and, more in general, other applications belonging to the smart cities paradigm). Experimental validation in realistic simulation environment will be carried out to validate theoretical results in realistic scenarios.**

# THANKS FOR THE ATTENTION !

**Get in touch:**
**sara.leccese@unina.it**
*https://daisylab.dieti.unina.it/*

Questions?