Alberto Petrillo

Tutor: Stefania Santini

XXXI Cycle - I year presentation

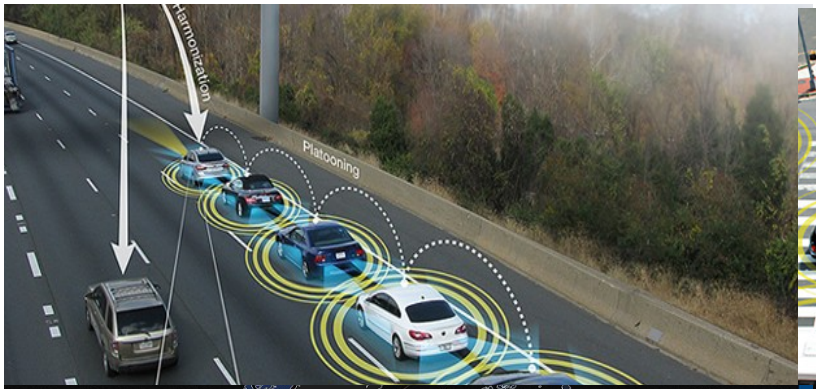
Cooperative Synchronization of multi-agent systems in the presence of multiple communication time-varying delays: theory and applications

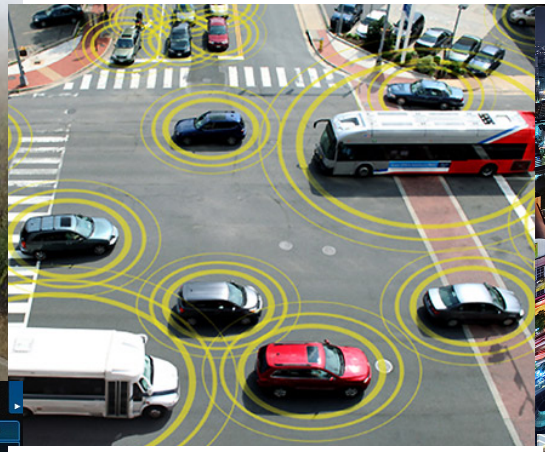
Background & Info

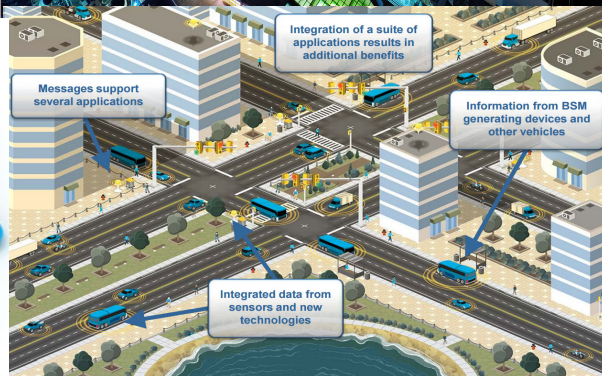
- M.Sc. Degree in Automation and Control Engineering from University of Naples Federico II.
- Working team: SINCRO group (Prof. Stefania Santini).
- Fellowship program: “Borsa di ateneo”.

Research Topic (1/2)

- Distributed Cooperative Control in the presence of communications impairments, such as multiple communication time-varying delays and network vulnerabilities .
- Application to ITS, e.g. autonomous ground vehicles in urban and extra-urban scenario, smart cities, communication infrastructures, cloud vehicular networks and their cyber-security.







Research Topic (2/2)

- Collaborative Control of agents, sharing information through communication links (wired or wireless), is usually solved by neglecting communication delays or under the ideal assumption of a homogeneous and constant delay.

- The aim of the research is devising strategies that are robust with respect to communication delays or vulnerabilities (e.g. due to cyber-attacks) that may arise real networks.

- The idea is to tailor the theoretical results also with respect to practical problems or new technological paradigms, *e.g.*, for some innovative ITS applications.

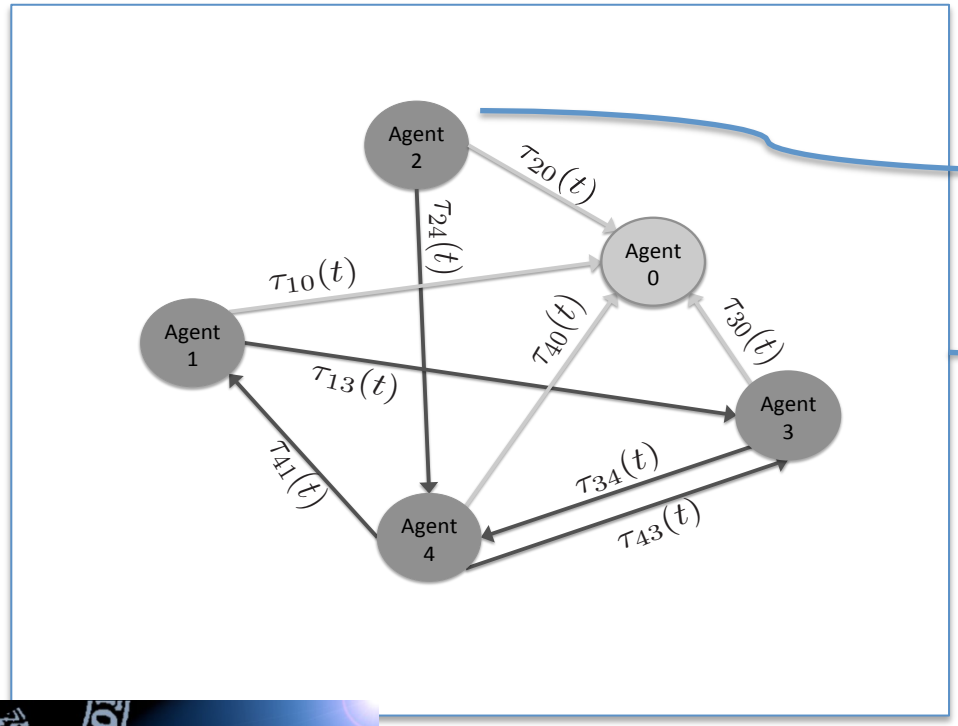
My first Year

- My first year activity focuses on the theoretical design of a collaborative control strategy (based on synchronization tools) in the presence of communication delays.

- My contribution consists in:
  - overcoming the simplifying hypothesis made on constant or homogeneous time-delay;
  - providing theoretical results on the stability of delayed networks;
  - applying the theoretical framework to vehicular networks in urban and extra-urban scenario and power-frequency networks oscillators.

The multi agent system

- The design of the cooperative control leverages on a model of the networked system that is based on a multi-agent representation embedded in the communication structure.



$$\dot{x}_i(t) = Ax_i(t) + Bu_i(t, \tau_{ij})$$

$$x(t) \in \mathbb{R}^n$$

$\tau_{ij}(t)$

Delayed Communication structure

The proposed Solution

- The proposed solution exploits the adaptive control theory to provide robustness with respect to multiple time-delays.

$$u_i = -\sum_{j=0}^{N} \alpha_{ij} \kappa_{ij}^{\top}(t) \left(x_i(t - \tau_{ij}(t)) - x_j(t - \tau_{ij}(t)) \right) \quad \forall i = 1, \ldots, N$$

$$k_{ij}(t) = \left[\; k_{ij,1}^{\top}(t) \; k_{ij,2}^{\top}(t) \; \cdots \; k_{ij,n}^{\top}(t) \; \right]^{\top}$$

$$\dot{\kappa}_{ij,k}(t) = \zeta_{ij,k} \left| x_{i,k}(t) - x_{j,k}(t) \right|^2$$

- The stability of closed-loop system has been analitically proved.

Obtained results

- To validate the theoretical results, two different cases of study have been analyzed:
  - Automated driving for autonomous ground vehicles moving as a platoon (in Fig.1);
  - Frequency control for a power-oscillators network (in Fig.2).

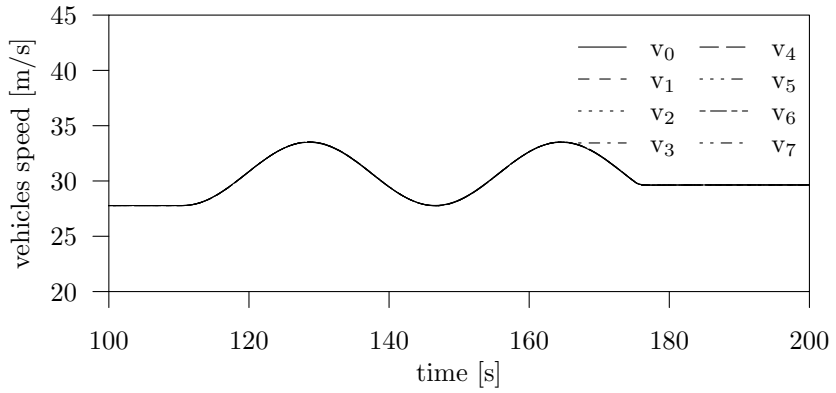


Fig. 1

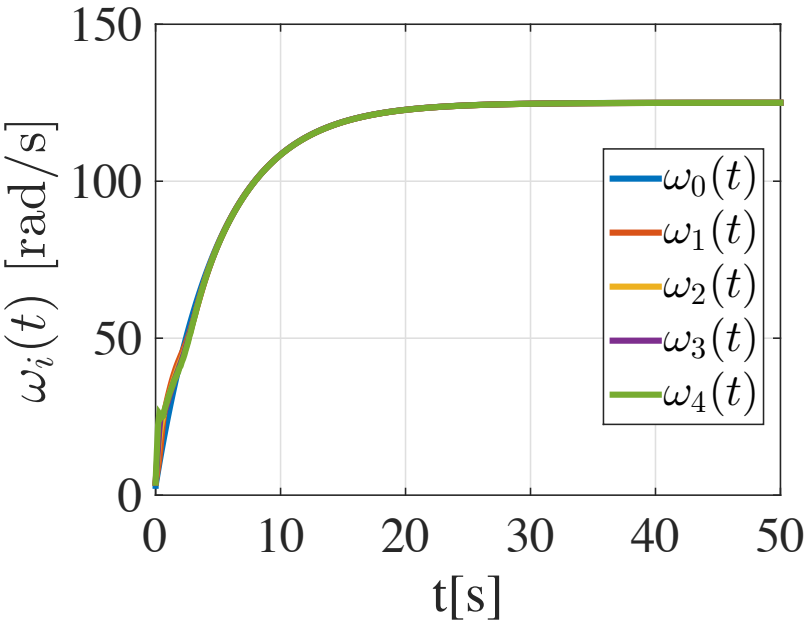


Fig. 2

My products

- To be published: Alberto Petrillo, Giovanni Fiengo, Alessandro Salvi, Stefania Santini, and Manuela Tufo, “A control strategy for reducing traffic waves in delayed vehicular networks”, in *IEEE 55rd Annual Conference on Decision and Control (CDC)*, December 2016.

- In preparation: “Adaptive Cooperative Tracking with time-varying multiple delays in the presence of cyber-attacks on communication channel”.

Next year

- My aim is to extend the cooperative approach developed during the first year of my Ph.D. so to provide robustness in the presence of cyber-attacks.

- The idea is to exploit the control theory for their rejection or mitigation.

- The first year activities and the outlook on the second year can be summarized as:

	Credits year 1							Credits year 2
	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated
Modules		6		3	4	4	**17**	**13**
Seminars		1,7	1,3	2			**5**	**5**
Research	10	2,3	7,7	7	5	6	**38**	**42**
	10	10	9	12	9	10	**60**	**60**