PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Alberto Petrillo

XXXI Cycle

Training and Research Activities Report – Second Year

Tutor: Stefania Santini

1. Information
    a. Alberto Petrillo, MS degree in Automation and control Engineering – Università degli studi di Napoli Federico II.
    b. XXXI Cycle- ITEE – Università degli studi di Napoli Federico II.
    c. Fellowship type: “Borsa di Ateneo”.
    d. Tutor: Stefania Santini.

2. Study and Training activities
    a. Courses
        i. “Analisi e prestazione di Internet” (6 CFU),
        Lecturer: Prof. Antonio Pescapè.
        ii. “Big data analytics and business intelligence” (6 CFU),
        Lecturer: Prof. Antonio Picariello.
        iii. “Modelli per la previsione e l’ottimizzazione” (3 CFU),
        Lecturer: Prof. Stefania Santini.

    b. Seminars
        i. “Diritti umani e nuove tecnologie” (0.5 CFU),
        Lecturer: Dott. Daniele Amoroso, 09/11/2016.
        ii. “Security Operations in una Telco, esperienze e riflessioni dal campo” (0.4 CFU),
        Lecturer: Ing. Fabio Zamparelli, 11/11/2016.
        iii. “Identifying the coupling structure in complex systems through the optimal causation principle” (0.4 CFU),
        Lecturer: Prof. Erik M. Bolt, 23/11/2016.
        iv. “Lateral technology for power devices: concepts, state of the art and applications” (0.4 CFU),
        Lecturer: Dott. Gianluca Camuso, 24/12/2016.
        v. “Plasma stability and dynamic events in tokamaks with a resistive wall” (0.4 CFU),
        Lecturer: Dott. Vladimir Dmitrievich Pustovitov, 30/01/2017.
        vi. “1st Workshop on Formal Methods in AI” (2.5 CFU),
        Organizer: Aniello Murano, Università degli studi di Napoli Federico II, 22-23/02/2017.
        vii. “55th IEEE conference on Decision and Control”, Las Vegas, USA (2 CFU),
        12-15 December 2016.

3. Research activity
    a. Title: “Cooperative Synchronization of multi-agent systems in the presence of multiple communication time-varying delays: theory and applications”.

    b. Study: Multi-agent systems, synchronization, time-delay systems, multiple communication time-varying delays, cyber security vulnerabilities, autonomous ground vehicles, smart and autonomous system.

    c. Research description

Many real systems in nature and human society can be modelled as multi-agent system, thus, in the last two decades cooperative systems have received a compelling attention in different research fields such as physics sciences, energy systems, intelligent transportation systems, smart cities and communication networks. The coordinated motion of autonomous vehicles and the time synchronization of wireless networks, gives examples.

The synchronization problem of multi-agent systems deals with the design of distributed control strategies ensuring that all agent track a leader agent which imposes a desired behaviour, e.g. the motion along a command trajectory. To this aim, each agent shares their state information through a communication channel (wired or wireless) and receive the reference signal coming from the leading agent. On the basis of these information, received from agents within the network, each agent computes the control algorithm that is responsible for the safe tracking of the desired behaviour. The communication networks are hence key tools for the deployment of distributed synchronization-based control strategies.

Since in practice, agents exchange information thought non-ideal communication environment, information can be received by each agent with a different (multiple or heterogeneous) time-varying delay, whose current value depends on the network conditions. Therefore, communication impairments, such as delays or packet losses, are unavoidable. This implies that the distributed control input, computed on the basis of the network information, turn out to be affected by delays and packet losses.

In addition, for a correct functioning of synchronization-based application, the cooperation among agent has to be based on a reliable communication structure. However, real communication networks can suffer different cyber security threats. For instance, the sudden appearance of a malicious attack, such as a message falsification one, can mainly compromise the correctness of data traffic flow. In view of the fact that cyber attacks can lead to dangerous implications for the security of the involved application, it is fundamental to consider their effects on the behaviour of the multi-agent systems, and to try to limit them from the control design stage.

In this framework, my research topic focus on the design of control strategies able to ensure the synchronization behaviour of multi-agent systems in presence of communication impairments, i.e. multiple time-varying delays and packet losses, and cyber security vulnerabilities, i.e. message falsification attack.

The solution proposed in my work is a novel collaborative distributed adaptive control strategy able to guarantee the correct leader tracking, securely coping with both malicious attacks, acting on the V2V communication network, and communication delays, assumed to be multiple (heterogeneous) and time-varying. The adaptive approach provides robustness to deal with unmodelled dynamics, uncertain parameters and all disturbances characterizing the real vague environment, while a distributed detection mechanism of malicious information, embedded into the control protocol, is responsible for counteracting, or mitigating, some of the most critical effects due to message falsification attack.

The effectiveness of approach has been analytically proven leveraging a Lyapunov-Krasovskii approach and a comprehensive performance evaluation, that considers the vehicular platooning application, has been carried out for the message falsification attack scenario. Moreover, an explicit analysis of the attack effects has been provided to reveal how secure is the leader-tracking for message falsification attack that is likely to be present in real communication networks. Finally, the resilience of the control protocol has been disclosed for different and typical communication network topologies.

4. Products
    a. Publications
        i. Conference Paper
            - Giovanni Fiengo, Alberto Petrillo, Alessandro Salvi, Stefania Santini and Manuela Tufo, "A control strategy for reducing traffic waves in delayed vehicular networks." *Decision and Control (CDC), 2016 IEEE 55th Conference on*. IEEE, 2016.
            - Alberto Petrillo, Antonio Pescapé and Stefania Santini. "A collaborative control strategy for platoons of autonomous vehicles in the presence of message falsification attacks." *Models and Technologies for Intelligent Transportation Systems (MT-ITS), 2017 5th IEEE International Conference on*. IEEE, 2017.
        ii. Journal Paper
            - Alberto Petrillo, Alessandro Salvi, Stefania Santini, Antonio Saverio Valente, Adaptive synchronization of linear multi-agent systems with time-varying multiple delays, *Journal of the Franklin Institute* (2017), doi: 10.1016/j.jfranklin.2017.10.015.
        iii. List those in preparation
            - Alberto Petrillo, Stefania Santini, “A secure adaptive control for collaborative driving of autonomous connected vehicles with multiple communication delays”.

5. Conferences and Seminars
    a. Details
        i. “*55th IEEE conference on Decision and Control*”, Las Vegas, 12-15 December 2016.
        ii. “*5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS) ”*, Napoli,Italy, 26-28 June 2017.
    b. Presentations made

i. Presentation of the paper "*A control strategy for reducing traffic waves in delayed vehicular networks*" at *55th IEEE conference on Decision and Control*, Las Vegas, 12-15 December 2016.

ii. Presentation of the paper "*A collaborative control strategy for platoons of autonomous vehicles in the presence of message falsification attacks*" at 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS), Napoli, Italy, 26-28 June 2017.

6. First and second year activities and outlook on the third year

Student: Alberto Petrillo alberto.petrillo@unina.it **Tutor: Stefania Santini** stefania.santini@unina.it **Cycle XXXI**

	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	13		6		3	4	4	**17**	13				12	3		**15**	0							**0**	**32**	30-70
Seminars	5		1,7	1,3	2			**5**	5	3,7	2,9					**6,6**	0							**0**	**12**	10-30
Research	42	10	2,3	7,7	7	5	6	**38**	42	6,3	7,1	10	3	4	8	**38**	60							**0**	**76**	80-140
	60	10	10	9	12	9	10	**60**	60	10	10	10	15	7	8	**60**	60	0	0	0	0	0	0	**0**	**120**	180