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XXXIII Cycle

Connected Vehicles for Autonomous Driving

Marco Malinverno

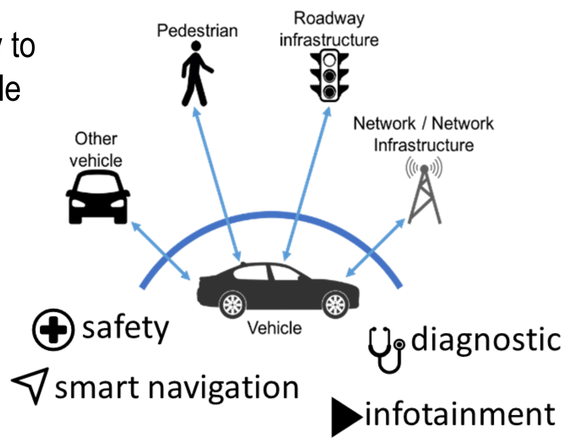
Supervisors: Prof. Claudio Ettore Casetti
Prof. Nicola Amati

Research context and motivation

- The concept of **Connected Vehicles** comes from the need of **an enhanced driving experience** that leverages the modern communication technologies and enable a new set of services. These technologies are advancing rapidly, with large investments in the private sectors and accelerating competition in the marketplace.

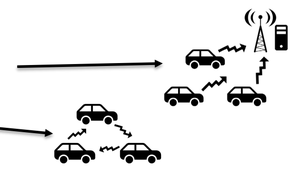
- Connected vehicles are vehicles that use different communication technologies (GPS, LTE, Wi-Fi, Bluetooth etc.) to communicate with the driver, other cars on the road (vehicle-to-vehicle, **V2V**), roadside infrastructure (vehicle-to-infrastructure, **V2I**), network infrastructure (vehicle-to-network, **V2N**) etc.
  These technologies, often referred to as **V2X (Vehicle to Everything)**, can be used not only to make vehicles safer, but also to improve vehicle efficiency and commute times.

- This paradigm is part of a bigger vision fostered by the most important ITS (Intelligent Transportation System) players and that will bring, within the next few years, the **first commercial autonomous vehicles** in our streets.

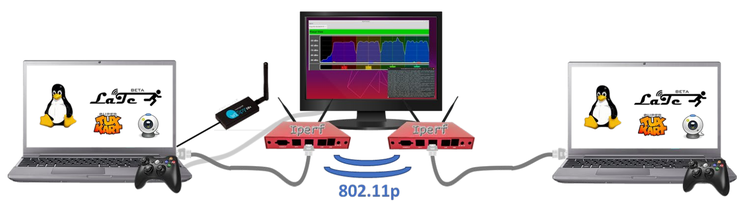


Novel contributions

- Development of a **Collision Detection service** able to detect collisions between vehicles and other road users. Two different versions:
  - Centralized (Vehicle-to-Infrastructure communication)
  - Distributed (Vehicle-to-Vehicle communication)



- Creation of a **real implementation of a V2I/V2V communication** using embedded boards. Using this setup, which combines the Linux-based operating system OpenWRT with off-the-shelf-available hardware, it has been possible to create a completely working IEEE 802.11p testbed which we evaluated extensively.



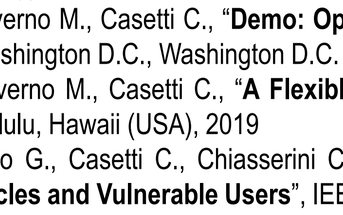
- Creation of an **application-layer protocol called LaMP** (Latency Measurement Protocol). The protocol has been designed to allow micro-second precise latency measurements. Moreover, **the first application using LaMP** has been proposed: **LaTe** is a completely open-source software written in C, that allows precise latency measurements between Linux-based devices.

Addressed research questions/problems

- Two are the candidate protocols for vehicular communication:
  - C-V2X, proposed by 3GPP
  - 802.11p, proposed by IEEE

Which one is the best for the vehicular environment?
This question can be addressed by considering several metrics of interest like **latency**, **throughput**, **network availability**, etc. A way to compare them is **to build custom simulation scenarios**, by leveraging the existing simulation frameworks.

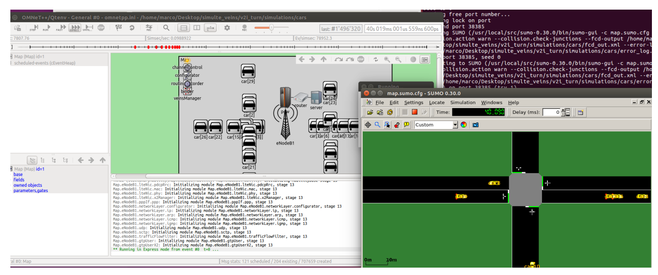
- **The absence of off-the-shelf dedicated products** highlights the need of the creation of open-source solutions using Linux-based embedded devices, so as to test the protocols in real scenarios with real hardware.



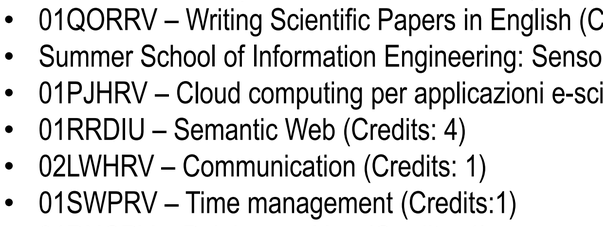
- The development **of protocols, tools, and open-source platforms** is very important to speed up the creation of new and ground-breaking services for the vehicular world.

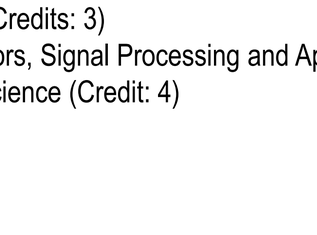
Adopted methodologies

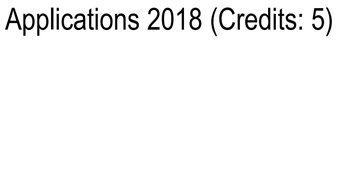
- The Collision Detection service has been evaluated by means of **simulation campaigns**, aimed at testing the service under various situations. The simulations were run both adopting the centralized architecture (V2I) and the distributed one (V2V). The simulation software used are Omnet++, with the SimuLTE framework and ns3, with the LENA framework.



- The IEEE 802.11p testbed has been validated through **spectrum analysis** and through several **measurement sessions** aimed at finding the achievable throughput, the maximum distance range, and the latency experienced at application layer.







- The **LaMP specification** and the **LaTe software** have been made available on **GitHub** and have been used to validate and characterize the performances of the vehicular testbed.

Future work

- Improvements in the Collision Detection service
- Deployment of a testbed with real vehicles connected through our devices
- Performance evaluation of the Collision Detection service in a real scenario with real vehicle running instances of the service
- Improvement of the LaMP protocol and LaTe software

Submitted and published works

- Avino G., Malinverno M., Malandrino F., Casetti C. E., Chiasserini C. F., "**Characterizing Docker Overhead in Mobile Edge Computing Scenarios**", HotConNet'17 @ ACM SIGCOMM, Los Angeles, California (USA), 2017
- Avino G., Malinverno M., Malandrino F., Casetti C. E., Chiasserini C. F., Nardini G., Scarpina S., "**A Simulation-based Testbed for Vehicular Collision Detection**", IEEE VNC, Turin (Italy), 2017
- Malinverno M., Avino G., Casetti C., Chiasserini C. F., Malandrino F., Scarpina S., "**Performance Analysis of C-V2I-based Automotive Collision Avoidance**", IEEE WoWMoM, Chania (Greece), 2018
- Avino G., Malinverno M., Casetti C., Chiasserini C. F., Malandrino F., Rapelli M., Zennaro G., "**Support of Safety Services through Vehicular Communications: The Intersection Collision Avoidance Use Case**", AEIT Automotive, Milan (Italy), 2018
- Malandrino F., Chiasserini C. F., Avino G., Malinverno M., Kirkpatrick S., "**From Megabits to CPU Ticks: Enriching a Demand Trace in the Age of MEC**", IEEE Transactions On Big Data, 2018
- Raviglione F., Malinverno M., Casetti C., "**Characterization and performance evaluation of 802.11p NICs**", TOP-Cars @ ACM MobiHoc, Catania (Italy), 2019
- Raviglione F., Malinverno M., Casetti C., "**Demo: Open source testbed for vehicular communication**", ACM MobiHoc, Catania (Italy), 2019
- Raviglione F., Malinverno M., Casetti C., "**Demo: Open source platform for IEEE 802.11p NICs evaluation**", IEEE WoWMoM, Washington D.C., Washington D.C. (USA), 2019
- Raviglione F., Malinverno M., Casetti C., "**A Flexible, Protocol-agnostic Latency Measurement Platform**", IEEE VTC-fall, Honolulu, Hawaii (USA), 2019
- Malinverno M., Avino G., Casetti C., Chiasserini C. F., Malandrino F., Scarpina S., "**MEC-based Collision Avoidance for Vehicles and Vulnerable Users**", IEEE Vehicular Technology Magazine *[submitted]*

List of attended classes

- 01SHBRP – Examples of graph optimisation models in management science (Credits: 4)
- 01QTEIU – Data mining concepts and algorithms (Credits: 4)
- 01SHCRV – Unsupervised neural networks (Credits: 6)
- 01QORRV – Writing Scientific Papers in English (Credits: 3)
- Summer School of Information Engineering: Sensors, Signal Processing and Applications 2018 (Credits: 5)
- 01PJHRV – Cloud computing per applicazioni e-science (Credit: 4)
- 01RRDIU – Semantic Web (Credits: 4)
- 02LWHRV – Communication (Credits: 1)
- 01SWPRV – Time management (Credits:1)
- 01RNCRV – Public speaking (Credits: 1)

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