Project Area: Smart City

Revision: July 2018

Research Themes and Topics - I

- 5 main research areas:
  - **Mobility**
    - Design of Demand Responsive Transportation (DRT) systems (IAC, IASI, IIT)
    - Mobility models (IAC, ISTI)
    - Optimisation methods for logistic and transportation service. Logistics and fleet management (IAC, IASI)
    - Virtual Traffic Lights (IEIIT)
    - Communication systems for vehicular environments (IEIIT, IIT, ITAE)
    - Intelligent Transportation Systems (IMATI, ITAE, ISTI)
    - Low-emission vehicles (ITAE)
    - Electrical mobility (ITAE, IM, IIT)
  - **Energy**
    - Vehicle-to-Grid (V2G) services (IM, ITAE)
    - Power-to-Gas (P2G) systems (ITAE)
    - Resiliency in SGs (IEIIT)
    - Communication and control of SGs (IEIIT, INM, IASI)

Research Themes and Topics - II

- 5 main research areas:
  - **Building**
    - Building monitoring and control (ITAE, ISTI, ICAR, ITC)
    - NZEB technologies (ITAE)
    - Cognitive buildings (ICAR)
  - **Communities of Citizens**
    - Open Data, Linked Data and semantic technologies (IMATI)
    - Social networking applications (IREA, IIT)
    - Applications for tourism and use of cultural heritage (IAC, ISTI)
    - Applications for a safer and more accessible city (IAC)
    - Water management system (ICAR)
  - **Platforms**
    - Smart IoT Platform (ICAR)
    - Urban monitoring (ICAR, IEIIT, INAMOTER, IMEM, IRC, ISTI)

MOBILITY

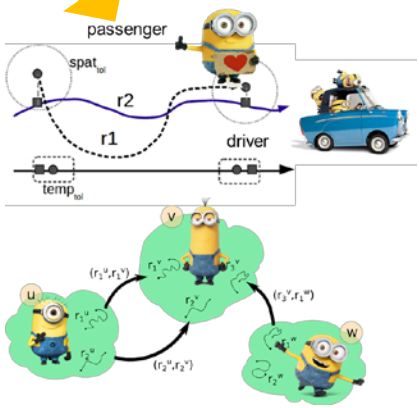
Data-driven car pooling

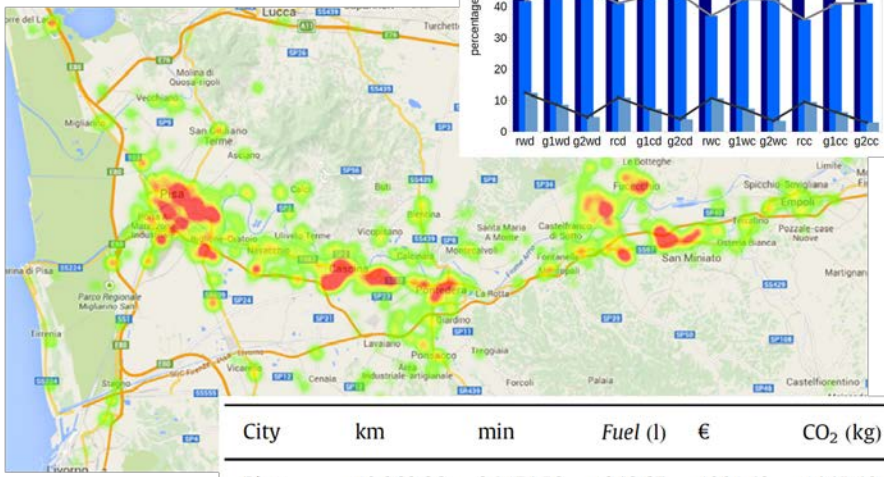
Mobility

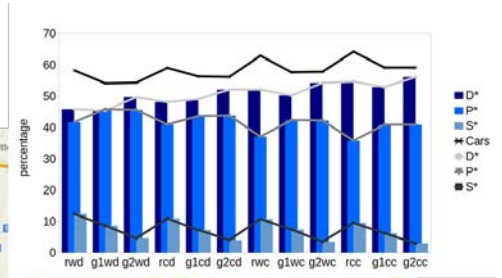
- Studying potential impact of carpooling (case study on Pisa province)
- Based on systematic trips (commuters' car pooling)

GPS data stream

946826,14/06/10 14:08:54,43964259,10216895,0,0,1,0,0
457380,13/06/10 22:05:27,43682201,10408320,0,0,3,0,0
457380,13/06/10 22:06:00,43682488,10408501,10,10,3,1,33
457380,13/06/10 22:07:43,43689779,10412032,50,18,3,1,484
457380,13/06/10 22:08:19,43692906,10413910,32,356,3,1,401
457380,13/06/10 22:08:53,43690801,10415016,60,126,3,1,279
...







< 5% SOV

City	km	min	*Fuel* (l)	€	CO_2 (kg)
Pisa	10,868.36	24,174.58	646.67	1001.49	1445.49
Florence	16,748.99	43,300.28	996.56	1543.37	2227.62

- SOV = Single Occupancy Vehicle (no passengers)

Personalized car pooling services

Mobility

Challenge:

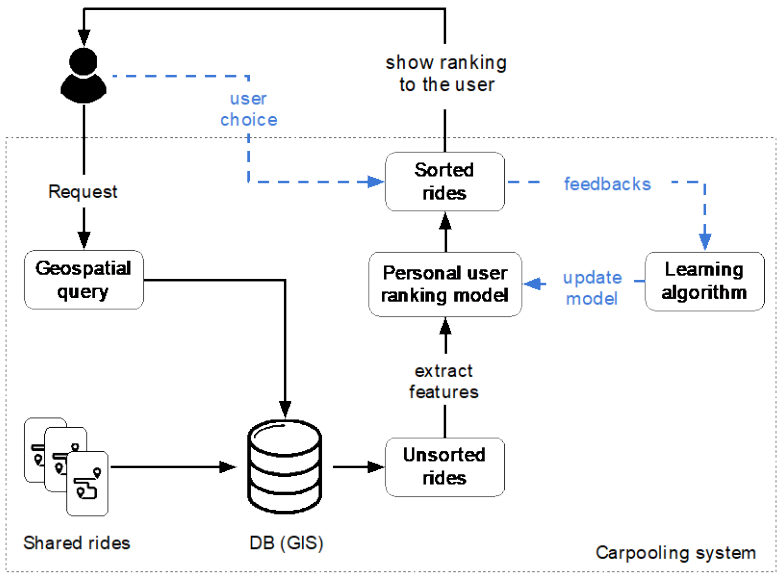
- Many non-monetary aspects and social considerations, besides simple mobility needs, may influence the individual willingness of sharing a ride, which are difficult to predict

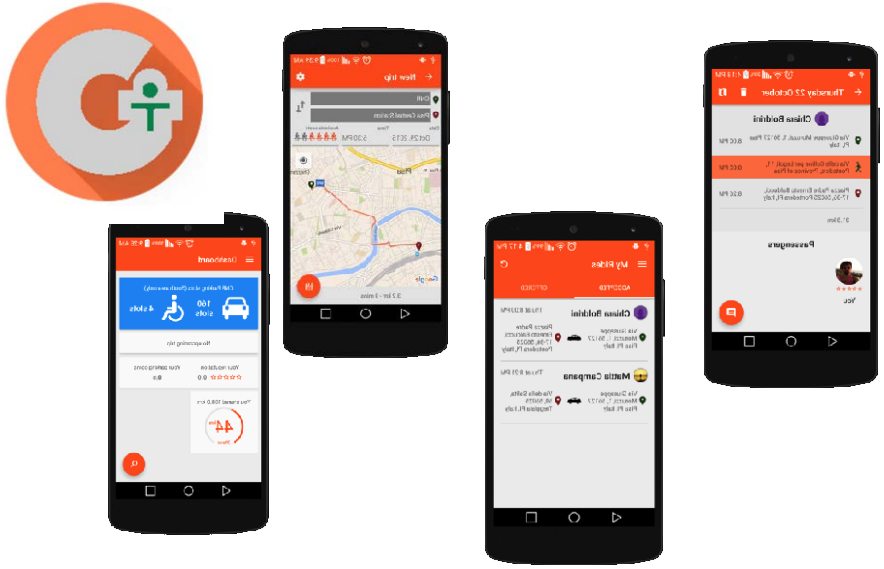
Approach:

- Develop **recommender systems** for car pooling services that leverage on machine learning techniques to automatically derive the **personalised pooling preferences** of each user from the history of his/her choices

Application:

- The GOTOGETHER mobile app implements the recommender system

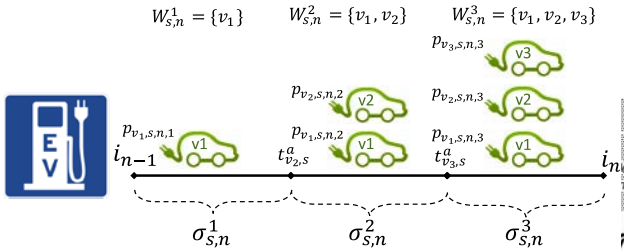


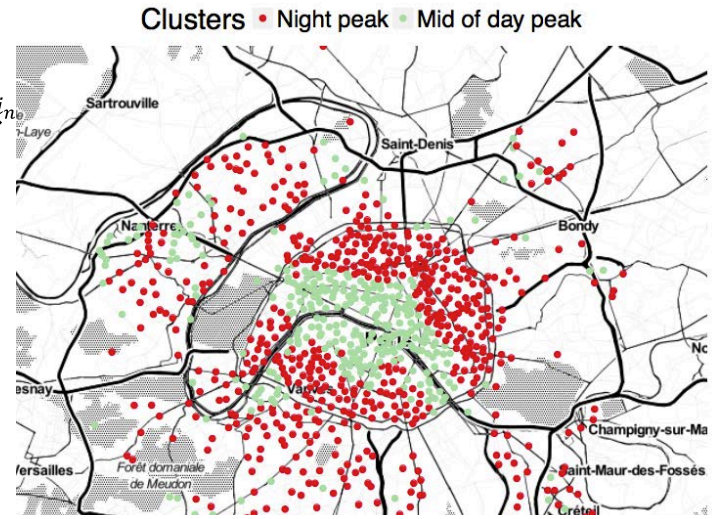


Electrical car sharing

Mobility

- Personal urban mobility is undergoing rapid transformations with the development of new Mobility-on-Demand (MoD) services, such as car-pooling and car-sharing
- Electrification of transport systems is emerging as a trend for more sustainable transports





- **Research topics**:
  - Data mining methods and predictive models of mobility data
  - Agent-based simulation tools of multi-modal transportation systems
  - Decision tools for optimized and robust planning and operation of car sharing systems

- **Research projects**:
  - H2020 ESPRIT Project – Easily Distributed Personal Rapid Transit (2015-2018)
  - MISE Ricerca di Sistema PAR 2013-2014 - Development of innovative solutions for fast charging stations and their integration in the smart grid

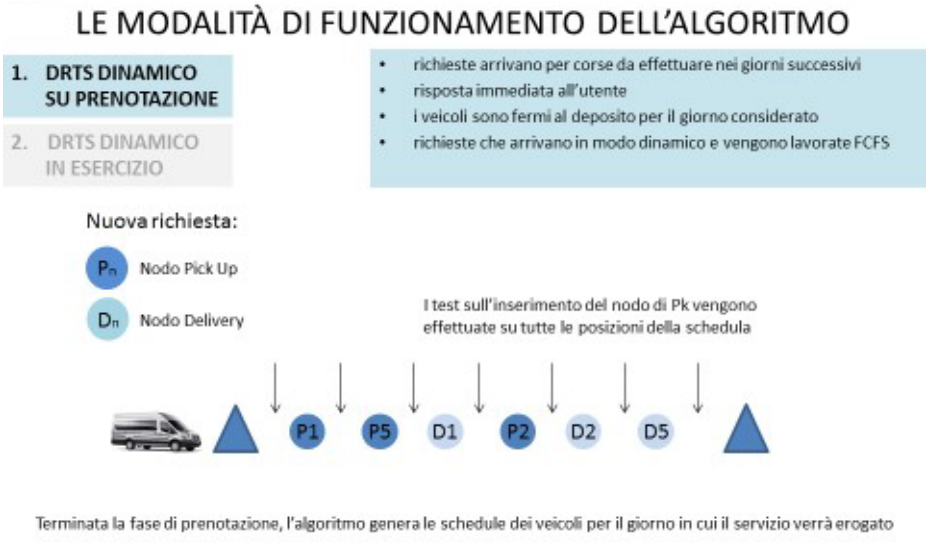
ESPRIT
Connecting Transport

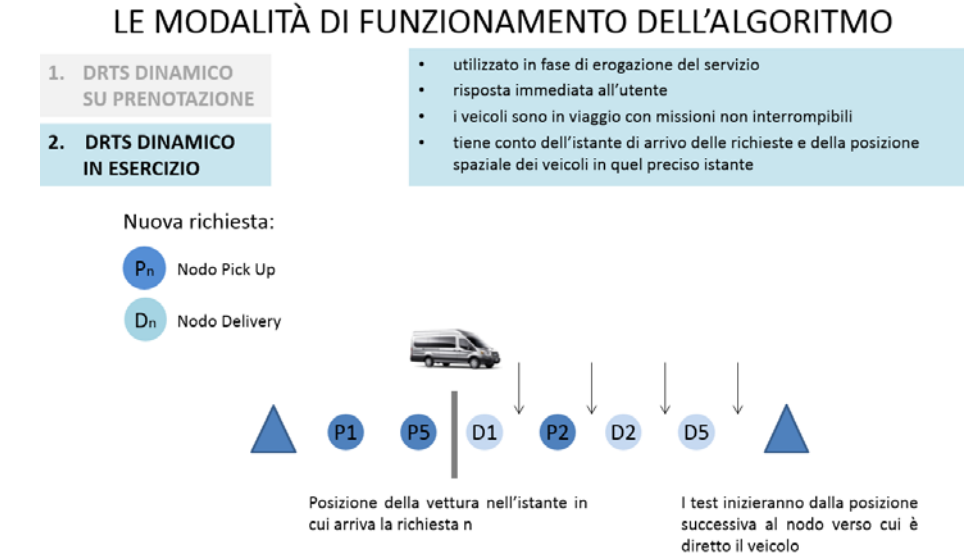
Flexible transport services for the last mile in a coordinated and multimodal transport system

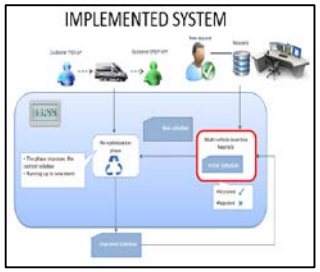
Mobility

Aims: The project activities are aimed at developing new models and tools to promote the integration of flexible transport systems with conventional transport modes, providing an effective tool for both the "last mile" transport system planning phase that for the operating phase of the system. The algorithm implemented is doubly dynamic and can work both in the booking phase of transport requests and during the service phase.

Results: A web-based application has been developed that allows a two-level algorithm to manage, in the first phase, the insertion of user transport requests into one of the schedules of the transport service executive plan, while in the second phase, between arrival of a request and the subsequent re-optimizes the active executive plan.







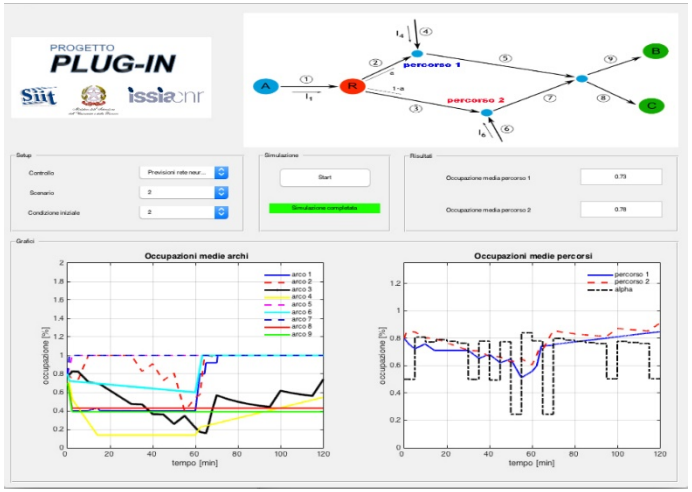
Control and optimization of logistics and transportation systems

Mobility

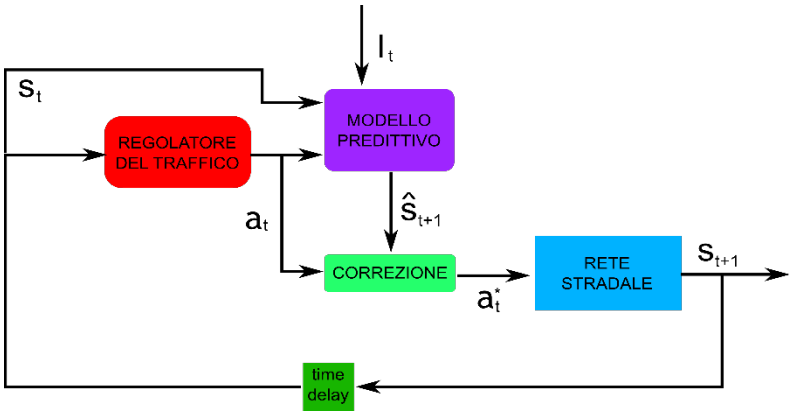
- **Goal**: development of optimization and control techniques that provide **optimal management policies for logistics systems**, aimed at increasing transportation and quality of service or reduce costs and environmental impact. The main goal is to pursue a sustainability paradigm

- **Methods**: optimal control techniques and predictive control based on dynamic models of transfer operations. In general, it is necessary to compute optimal policies in a very reduced amount of time to react to sudden environmental changes, possibly using only partial information

- **Applicative example (Optimal routing)**: use of predictive models to deliver personalized routing advice to the users in real time, pointing at the most suitable main route to follow, depending on the current state of the network



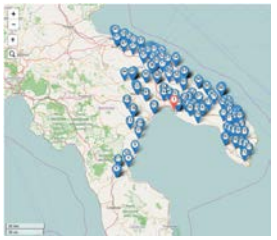
Optimization tool (MIUR PLUG-IN Project)



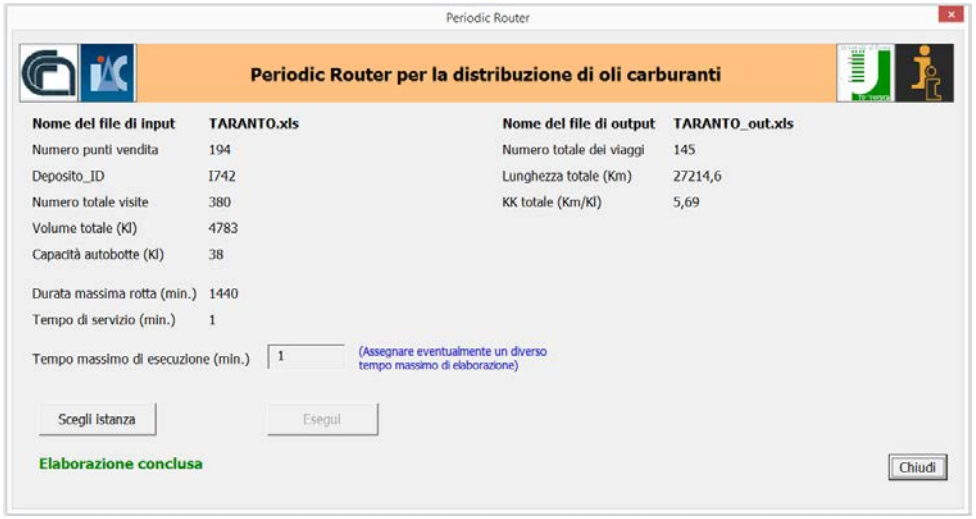
Predictive routing control scheme

Q8 Project - “Study and research program aimed at analysing the feasibility and the subsequent development of an optimization model and the related resolution algorithm for the tactical management of the secondary distribution of fuel oils”.

Mobility



Aims: The research project, carried out in collaboration with the University of Rome Tor Vergata, was directed to the design and implementation of a software for the **planning of the secondary distribution of fuel oils** at a tactical level, with a pre-established programming horizon and a set of supply pattern assigned.



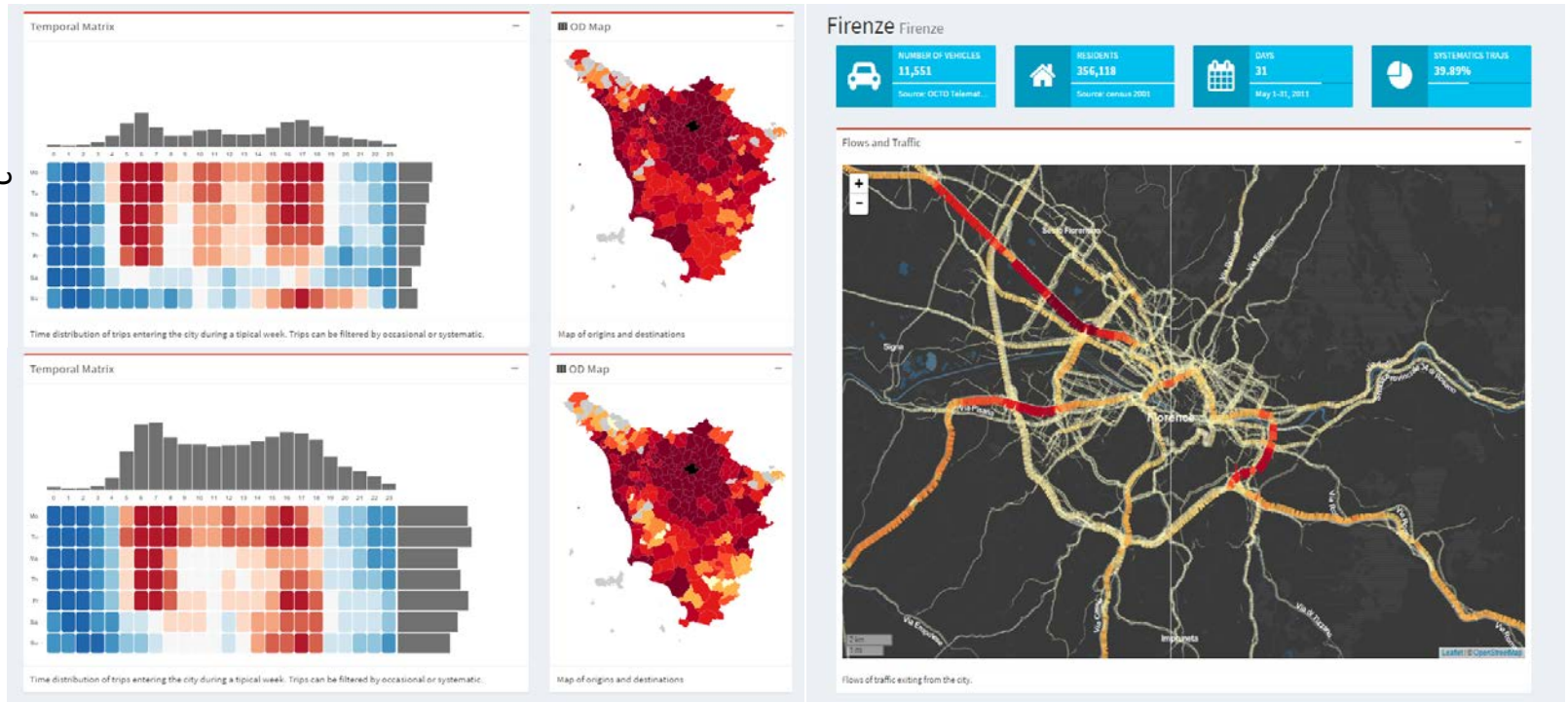
Results: We have designed and developed an optimization model and the relative resolution algorithm for a particular problem of periodic vehicle routing based on a hybrid genetic algorithm that realizes the evaluation and optimization of tactical activities of secondary distribution of fuel oils while minimizing operating costs. (€ per km) and balancing (if required) the fuel transported between the vehicles of the fleet used. Subsequently, some heuristics were made to solve the same problem and to compare it with the genetic algorithm.

Urban Mobility Atlas

Mobility

- Inferring concise summaries of mobility over large territories
- Based on GPS data streams from vehicles

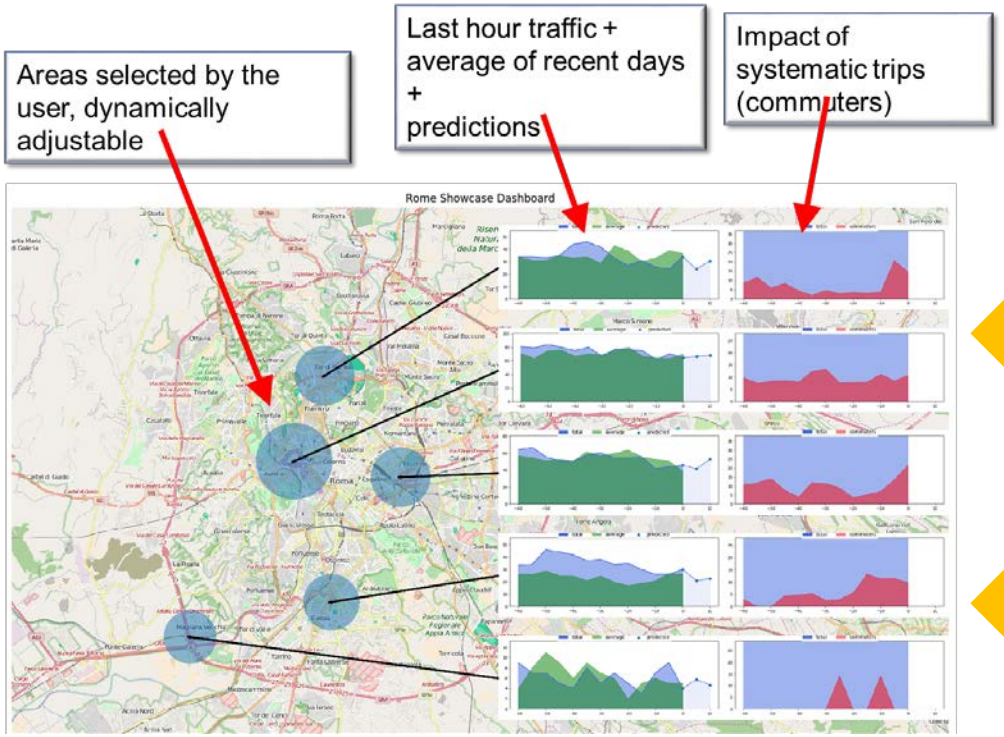
Online, interactive version: **http://kdd.isti.cnr.it/uma2/**



Traffic monitoring with data-driven mobility models

Mobility

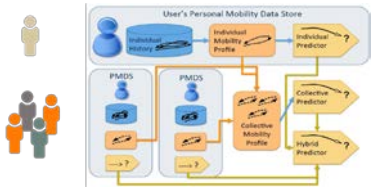
- Real time monitoring & prediction of traffic (case study on Rome)



GPS data stream

946826,14/06/10 14:08:54,43964259,10216895,0,0,1,0,0
457380,13/06/10 22:05:27,43682201,10408320,0,0,3,0,0
457380,13/06/10 22:06:00,43682488,10408501,10,3,1,33
457380,13/06/10 22:06:46,14,24,3,1,115
457380,13/06/10 22:07:43,43689779,10412032,50,18,3,1,241
457380,13/06/10 22:07:43,43689779,10412032,50,18,3,1,484
457380,13/06/10 22:08:19,43692906,10413910,32,356,3,1,401
457380,13/06/10 22:08:53,43690801,10415016,60,126,3,1,279
...

Mobility Prediction model

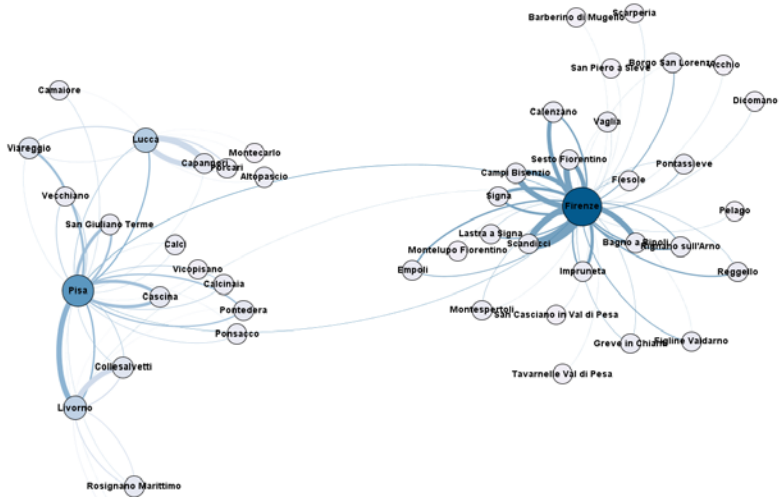


Mobility demand estimation from Big Data

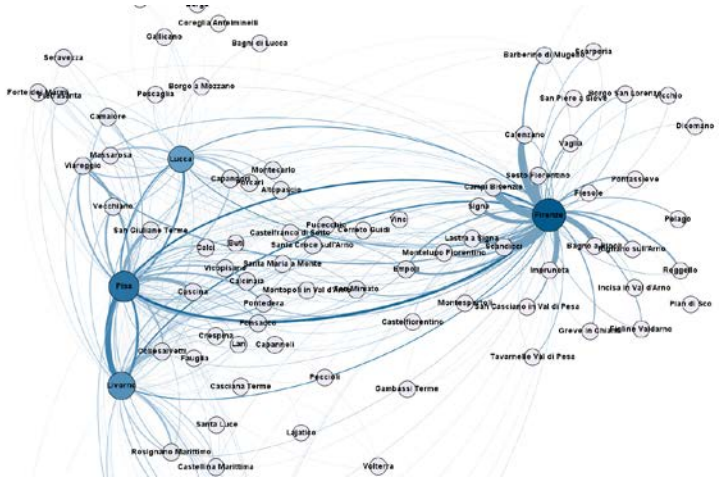
Mobility

- Tool: City users recognition through mobile phone CDR data analysis
- Reconstruction of traffic / mobility exchanges among municipalities

Systematic mobility exchanges

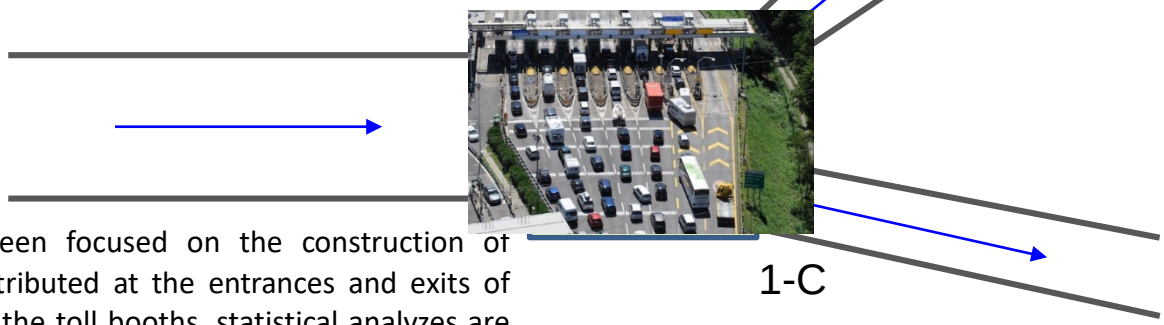


Occasional mobility exchanges



SPaRTA - Realtime Forecasting System of Motorway Traffic

Mobility



Aims: The project activities are finalized to the comparison of multiclass models with real macroscopic traffic data.

Advances: Currently the activities have been focused on the construction of statistics that reports how the vehicles are distributed at the entrances and exits of motorway tollbooths. Observing the crossing of the toll booths, statistical analyzes are performed on historical data to obtain information on the distribution of traffic (also by vehicle type) in the opposite directions by time slots and period.

Input parameters for the model

Model parameters 1 population	Model parameters 2 populations	Network model parameters
ϱmax: maximum vehicle density (fixed or to be calibrated)	ϱAmax: maximum car density	D: distribution parameter at the diversions
vmax: maximum vehicle speed (to be calibrated on the data)	ϱBmax: maximum density of slow vehicles	P: parameter of precedence at the junctions
fmax: maximum vehicle flow (to be calibrated on the data)	vAmax, fAmax: maximum speed and maximum car flow	C: distribution parameter at the toll booths
	vBmax, fBmax: maximum speed and maximum flow slow vehicles	

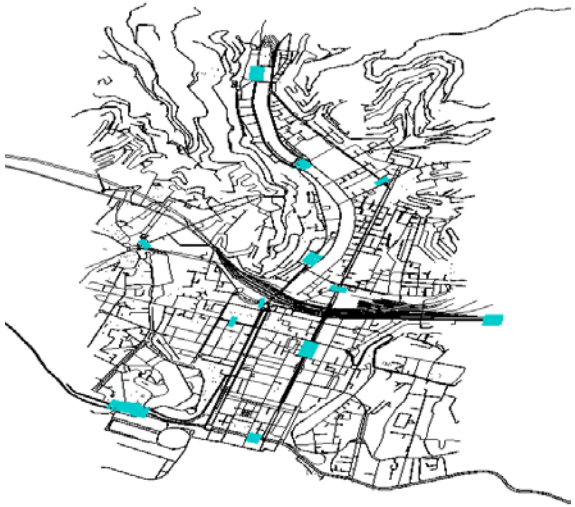
Data-driven learning and optimization models to support transportation and mobility

Mobility

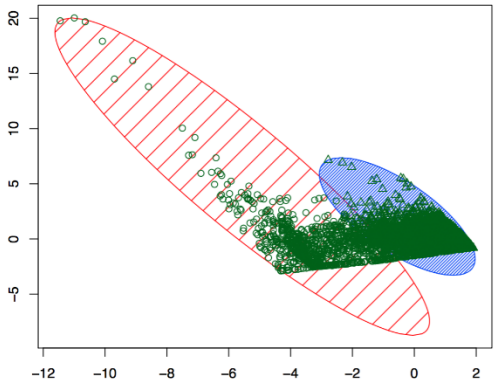
- **Goal**: Development of efficient predictive algorithms for traffic and logistics flows, based on data-driven models (e.g., neural networks, decision trees, etc.) suitably trained exploiting the available data

- **Methods**: Integration of machine learning and data analytics methods with dynamic optimization methodologies for the solution of problems such as:
  - state forecasting and identification of critical situations
  - dynamic management of flows
  - generation of rules to support mobility and logistics

- **Applicative example (Anomaly detection)**: use of predictive models to monitor traffic and forecast critical conditions (e.g., congestions)



Urban network monitoring (PAR-FAS SMILE Project)



Clustering traffic data features

Virtual Traffic Light

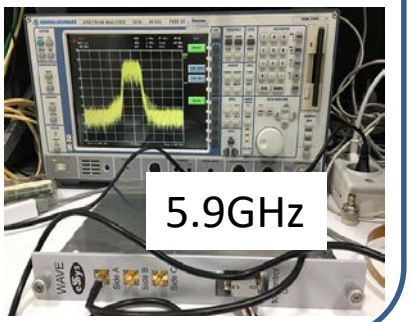
Mobility

Connected vehicles for safety (up to 80% of accidents avoided) and efficiency (up to 40% saved time)

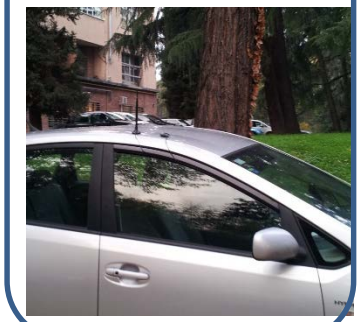
VTL: what it is

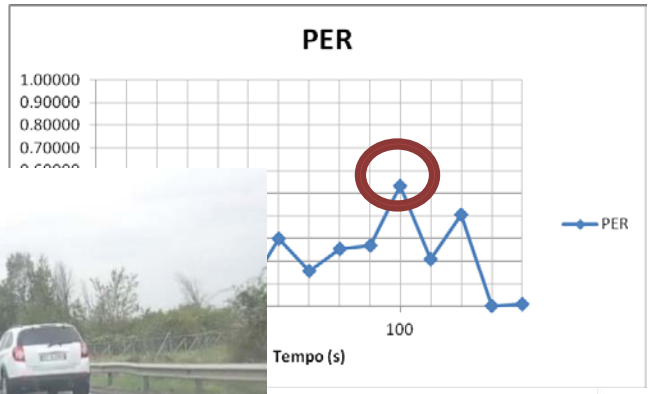
Vehicles can manage the traffic flow by themselves via vehicle-to-vehicle (V2V) communications

Internal Equipments



Antenna





Four vehicles approaching the junction

Communication systems for vehicular environments

Mobility

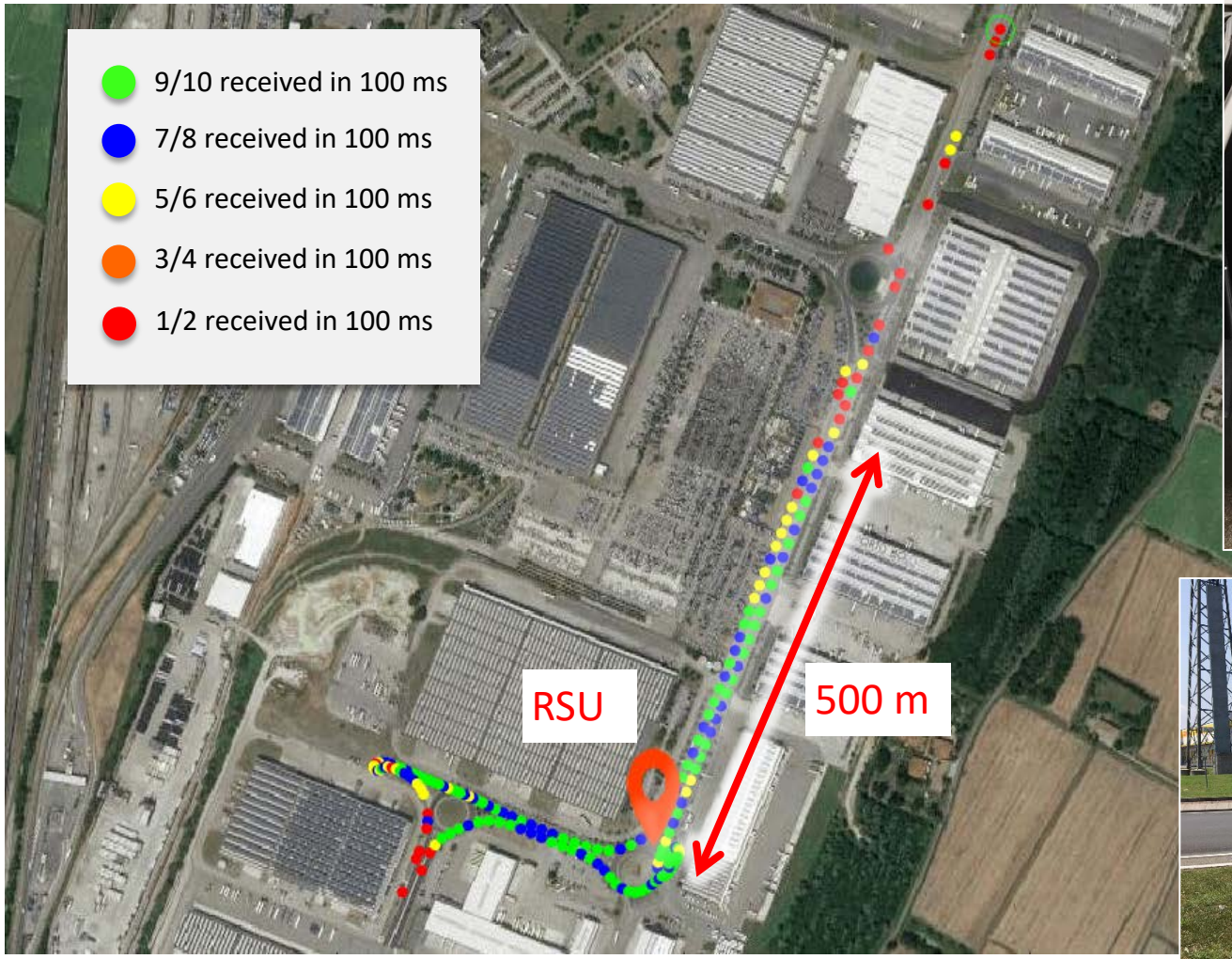
We investigate

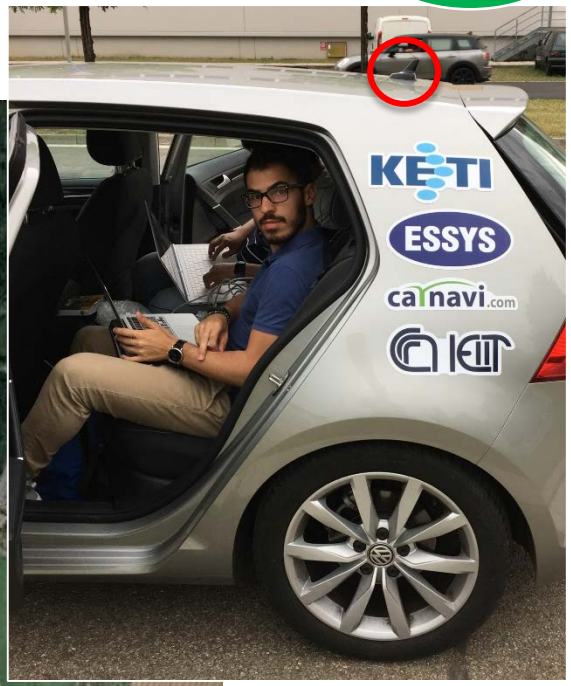
- hybrid cooperation of different wireless access technologies for ultra-reliable and low-latency communications (LTEV2VSim simulator for LTE-V2X is available at http://www.wcsg.ieiit.cnr.it/products/LTEV2Vsim.html)

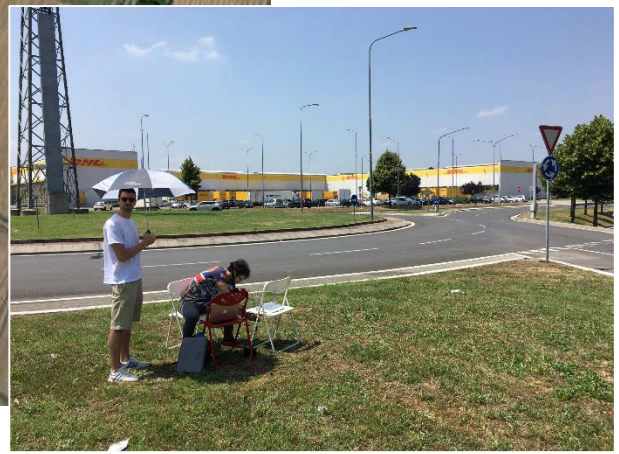
- models and algorithms of D2D-based offloading in vehicular environments
- Impact of number and position of road side units (RSUs) on V2X communications
- Visible Light Communication as a complementary technology for the Internet of vehicles
- Full Duplex communication technologies in vehicular networks

Coverage with a single road side unit (RSU) measurements on field trial

Mobility







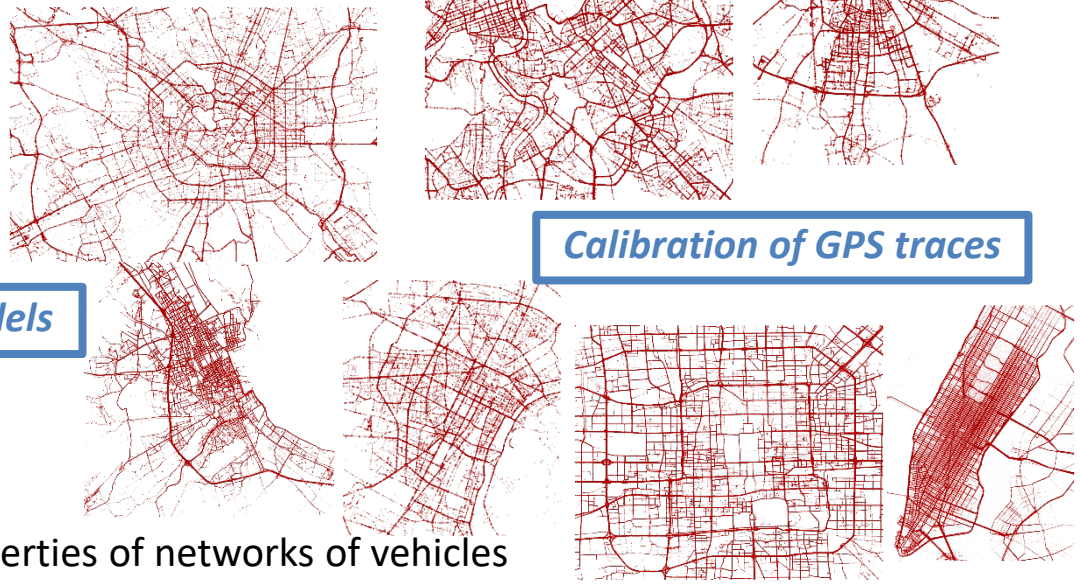
Characterizing vehicular communications

Mobility

1. Large-scale road traffic scenario generation

– Realistic citywide vehicular mobility for network simulations

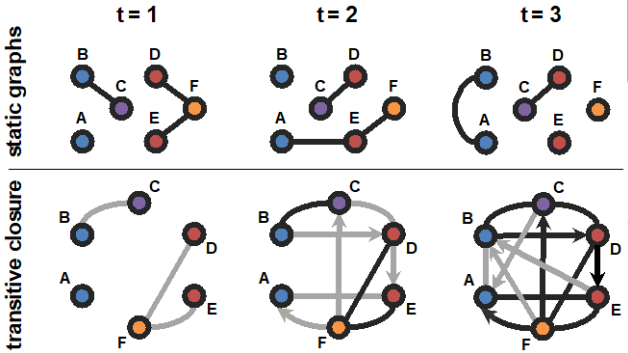
Synthetic models



Calibration of GPS traces

2. Network analyses

– Understanding the fundamental properties of networks of vehicles



Temporal connectivity graph

Instantaneous connectivity graph

https://youtu.be/BiuxgWntcRY

Smart Mobility and Resilient Territories

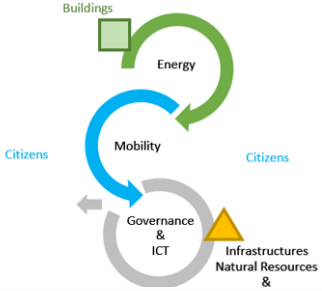
Mobility

To develop an integrated technological solution able to transform Sicilian urban communities in "smart" organizations", where the investments in human capital and as well as in the infrastructures for mobility and communication, are the driving forces of a development addressed to the quality of life and the exploitation of natural resources.

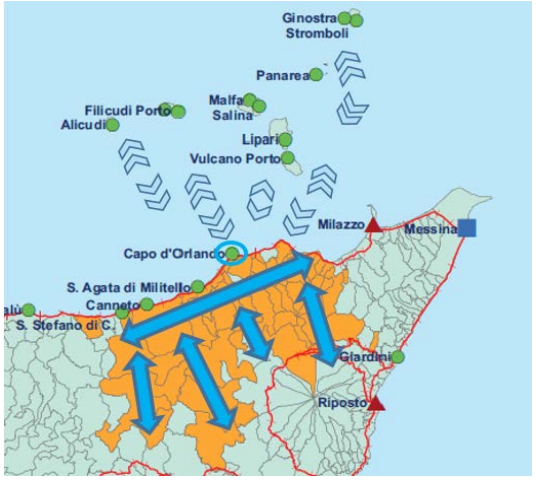
Micro and nano electronics fully represents the enabling technology for the full realization of a pervasive system of implementation and sensing devices always connected through the Internet.

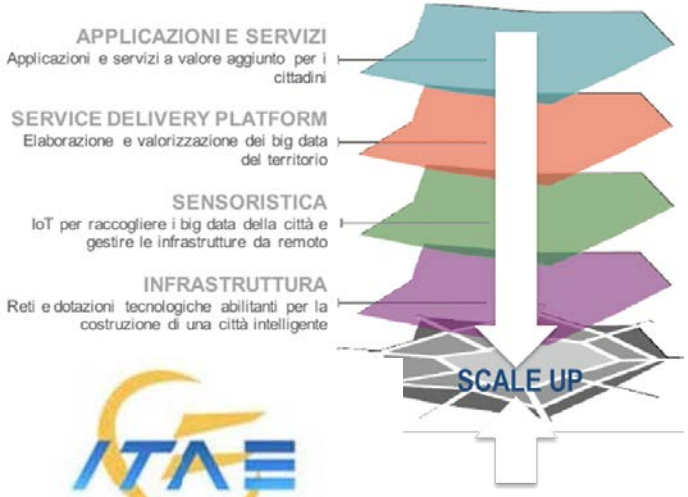
The activity also makes use of "photonics" and "nanotechnology" enabling technologies. These KET contribute to the pursuit of the project objectives thanks to innovative solutions in the field of sensors used for assisted / autonomous driving of cars and drones and for land monitoring.

Smart City Approach in a Large area for small village rE-Urbanization and Promotion



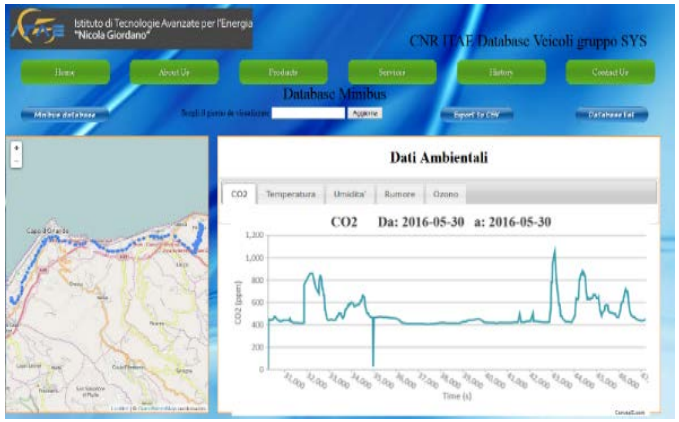
The activities aims to support innovation in the Smart Communities Area through the development of functional technologies and systems to promote, develop and integrate both low-impact interurban mobility and the integrated production and management of the various renewable energy sources. The approach takes into account the needs to enhance relations between small municipalities and defining shared development strategies with a view to overall strengthening a vast area.



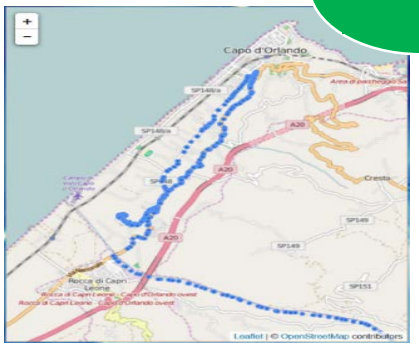


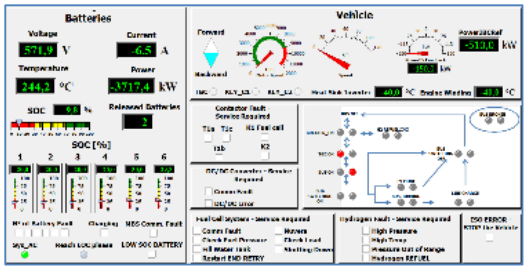
ITS systems development

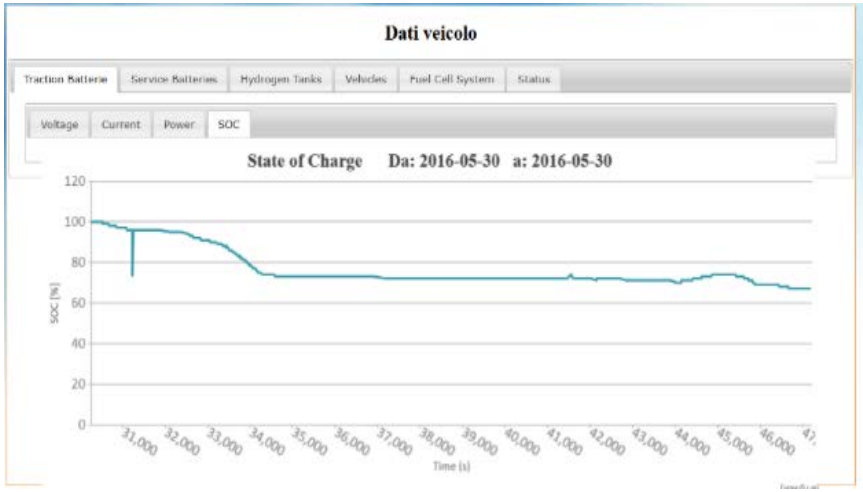
Mobility

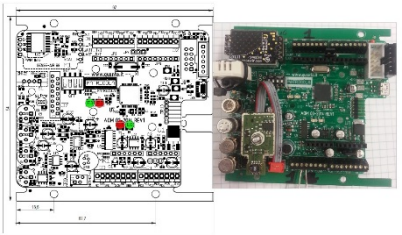


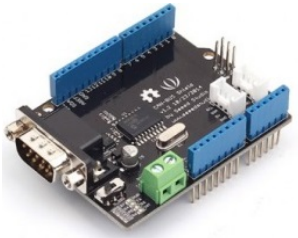
Objective: Development of diagnostic systems, telemetry and environmental monitoring based on open source hardware







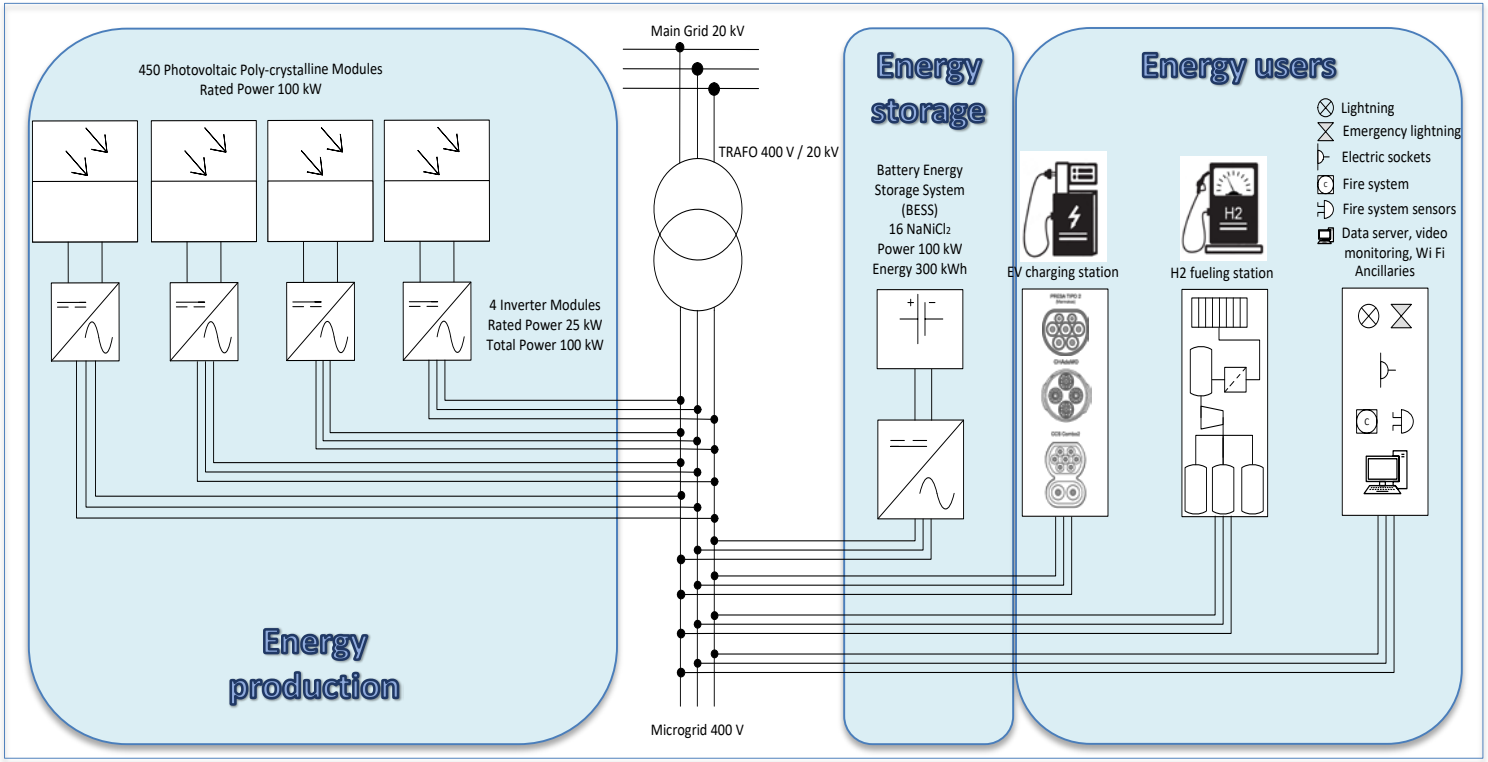




Hydrogen and mobility – I-NEXT project: Plant Layout

Mobility

The activities started from the I-Next project, funded by the MIUR in the framework of "Smart cities and Communities" call and it is coordinated by CNR ITAE.



The developed microgrid integrates the three key topics of the project: 1) Smart mobility and urban transport, 2) Infrastructures and Renewable Energy Source, 3) Logistics and interaction with Local Public Administration.

Urban mobility and transport: a hybrid battery and FC electric minibus, two pedal-assisted bicycles and an electric delivery van for the distribution of goods within the last mile were developed.

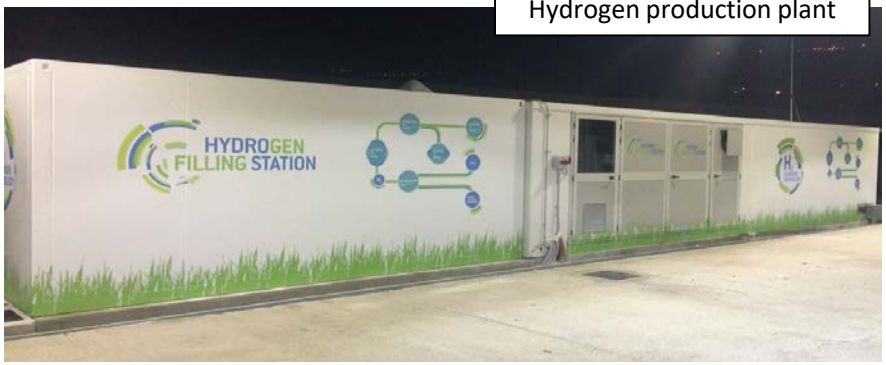
Energy infrastructures: a hydrogen production plant by electrolysis with a refueling station, a PV plant and an electrical storage system have been built. The goal of the microgrid is the minimization of the electricity coming from the grid and the energy independency .

Logistics: a demonstration station of smart parking has been created that can be booked for goods loading / unloading operations.

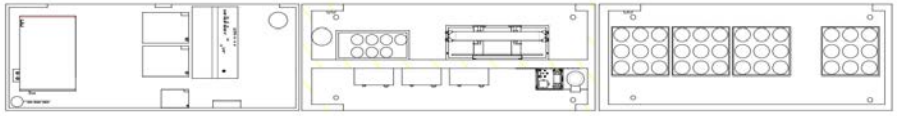
Hydrogen and mobility – I-NEXT project: Energetic Infrastructure

Mobility

Hydrogen production plant



H_2 compression section

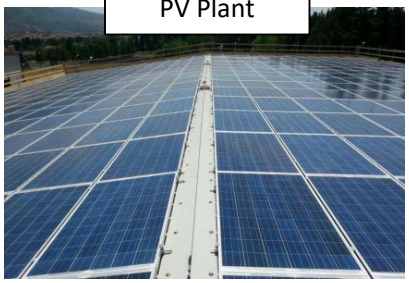


H_2 Production Section | Control Unit | H_2 Back up and Storage

H_2 Refueling

Hydrogen Plant Technical Characteristics	
H_2 production	6,6 Nm^3/h @ 9 bar
H_2 purity	99,995% with ppm O_2 < 5 ppm
H_2 compression	360 Bar
H_2 max pressure	350 Bar
H_2 Storage capacity	126 Nm^3
Refill time	30min [300l @350Bar]
System Power Consumption	Production: 30,5 kW Compression: 6,5 kW Auxiliaries: 3 kW

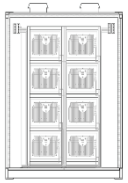
PV Plant



Photovoltaic plant Technical Characteristics	
Inverter	4 x 25 kW
String for each inverter	5 (22 modules)
Exposition	East - West
Power	100 kWp
Production Estimation	150 MWh/year

Batteries Energy Storage System Technical Characteristics	
Batteries type	Fiamm SoNickST523 ($NaNiCl_2$)
Batteries number	16
Power	100 kW
Energy (80% DOD)	300 kWh

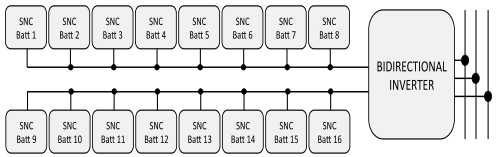
FIAMM SoNick ST523



Layout Stringhe batterie

BESS

Battery Energy Storage System (BESS)



Vehicles development

Mobility

Objective: *Development of a zero emission vehicle based on a hybrid electric powertrain (FCHEV - Batteries / Fuel Cell) with long range autonomy for urban and suburban applications*

Fuel Cell Hybrid Electric Minibus	
Seating Capacity	16 + 1
Engine Power	Nominal: 40 kW Peak: 80 kW
Battery Power	Nominal: 30 kW Peak: 120 kW
Battery Energy	65 kWh
Fuel Cell System Power	20 kW
H_2 Storage	300 l, 350 bar
Range	HEV: > 220 Km (80% DOD) EV: > 90 Km (80% DOD)
FC/Battery Power Ratio	1/2
Consumption (average)	0,6 kWh/Km

Objective: Development of a pedal assist[illegible]ic motor powered entirely by fuel cells (FCEV) for bike sharing services

BHyke	
Max. Power output	250 W
Max. torque	15 Nm@66 rpm
Motor Voltage range	24 V regulated DC
Hydrogen storage	Solid state (Idruri metallic)
Hydrogen capacity	900 Sl@12 bar
Max. range	100 km
Total weight	26 Kg

Objective: Development of a highly modular battery-powered vehicle (EV) and load capacity for freight transport in last-mile applications

Electric Urban Delivery Van	
Design	New concept
Load Capacity	> 800 Kg. Payload: 2 euro pallets
Engine Power	Nominal: 45 kW Peak: 70 kW
BESS Power	Nominal: 70 kW Peak: 140 kW
BESS Energy	30 kWh
Max. range	> 120 Km
Gradeability	18 %

Progetto H-BUS

Objective: Development of a zero emissions vehicle, based on a hybrid electric powertrain (FCHEV - Batteries / Fuel Cell) capable of increasing the autonomy of 30% compared to the EV electrical one.

Fuel Cell Hybrid Electric Bus	
Seating Capacity	44 + 1
Engine Power	Nominal: 80 kW Peak: 150 kW
Battery Power	180 kW
Battery Energy	127 kWh
Fuel Cell System Power	5 kW
H_2 Storage	300 l, 350 bar
Max. range	HEV: > 170 Km (80% DOD) EV: > 120 Km (80% DOD)
FC/Battery Power Ratio	1/16
Consumption	0,9 kWh/Km

ENERGY

Characterization and development of storage systems

Energy

Characterization, stress tests, typical profiles of network services

Battery cyclers

Climatic chamber

Protocolli e standard di riferimento

- EUCAR Traction Battery Working Group “Specification of test procedures for Hybrid Electric Vehicle Traction Batteries”;
- IEC 62660-1 International Standard “Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 1: Performance testing”;
- IEC 62660-2 International Standard “Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 2: Reliability and abuse testing”;
- IEC 62485-2 International Standard “Safety requirements for secondary batteries and battery installations – Part 1: Stationary batteries”;
- IEC 62485-2 International Standard “Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries”;
- IEC 61427-2 International standard: “Secondary cells and batteries for renewable energy storage- General requirements and methods of test - Part 2: on-grid applications”;

Performance and degradation evaluations

Cabinet 24.3 kW

Activated Contracts

National Research Council of Italy

Ministero dello Sviluppo Economico

CECOMP

ITAE

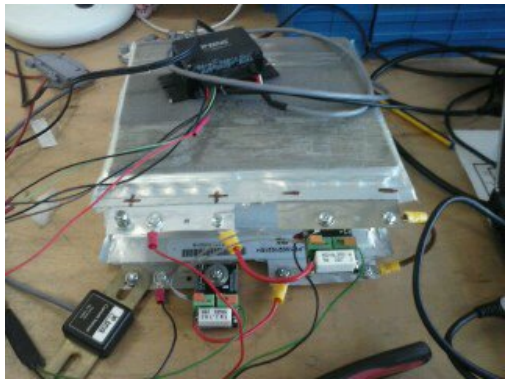
FIAMM

Terna

Characterization and development of storage systems

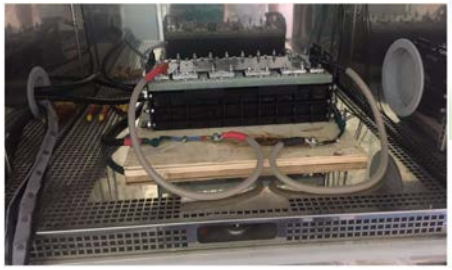
Energy

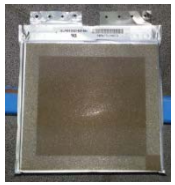
Litio-Ferro-Fosfato



Litio-Polimeri

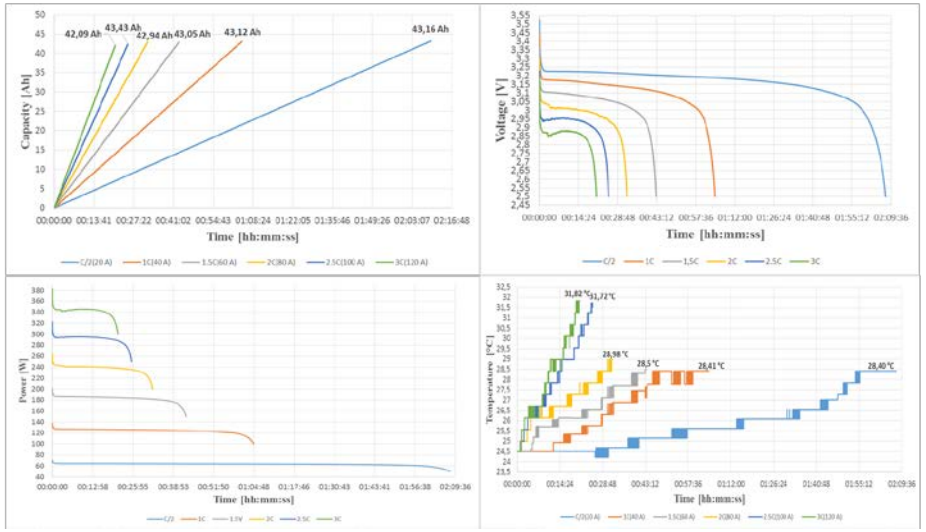
Litio: Nichel-Cobalto-Manganese





Discharging test: LiFePO4

- Initial Voltage drop: 0,15 V;
- Flat voltage trend during discharging (Voltage variation: 0,2 V)
- Capacity reduction (C/2-3C): 2,5 %
- Max temperature: 31,82 °C at 3C



Main technologies tested thanks to funded projects

Panasonic

SAMSUNG SDI

FZSoNick

SODIUM NICKEL TECHNOLOGY

A123 SYSTEMS

FIAMM

SONY

HITACHI

saft

Maxwell TECHNOLOGIES

Enabling Energy's Future™

LipoTech s.a.

Kokam

Great Power for Everyone

TOSHIBA

Leading Innovation

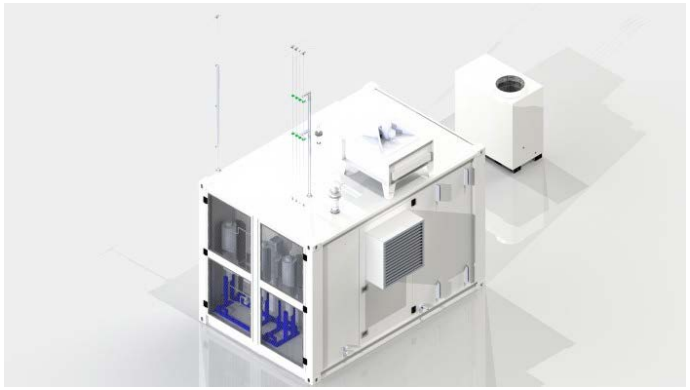
Development of power to gas systems based on electrolyte cells

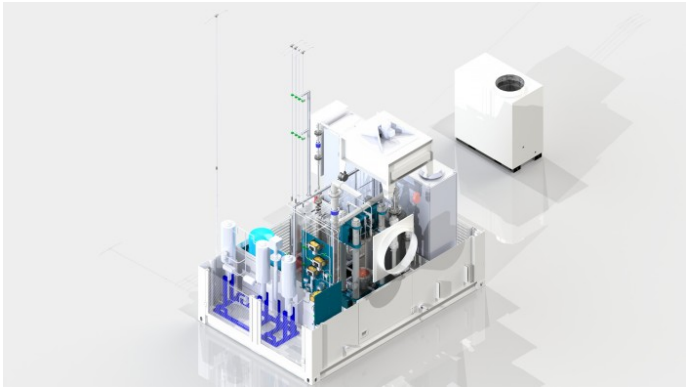
Energy

HPEM2GAS

HPEM2GAS project: High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications

HPEM2GAS refers to the systems development able to manage the energy surplus from renewable sources, trasforming it in gas (hydrogen) to input in gas network. The HPEM2GAS project will develop a low cost PEM electrolyser optimised for grid management through both stack and balance of plant innovations, culminating in a six month field test of an advanced 180 – 300 kW PEM electrolyser. The electrolyser developed will implement an advanced BoP and improved stack design and components. Several strategies are applied to lower the overall cost, thus enabling widespread utilization of the technology. These primarily concern an three-fold increase in current density (resulting in the proportional decrease in capital costs) whilst maintaining cutting edge efficiency, a material use minimisation approach in terms of reduced membrane thickness whilst keeping the gas cross-over low, and reducing the precious metal loading.





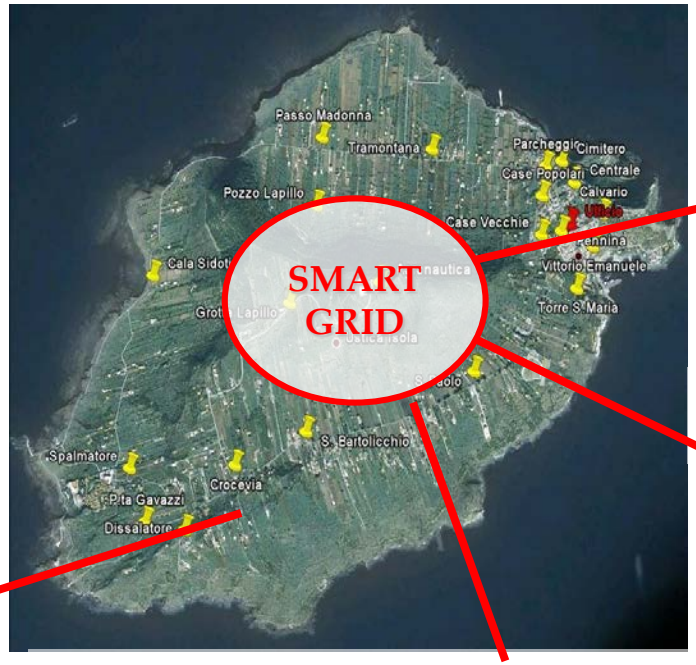
ITAE

Field demonstrator of Smart grid in Ustica and Favignana Islands

Energy

Main advantages:

- **Increase of distributed generation from renewable energy sources**
- **Integration of storage system, including those of electrical vehicles**
- **Reduction of pollution due to the use and the sea transportation of fossil fuels**



Passive users interaction

Distributed generation integration

REIPERSEI Project: funded by *Operative Regional Program PO-FESR Sicilia 2007-2013* Action 4.1.1.1: Smart grids for the exploitation of renewable energy sources in the little islands of Mediterranean sea. Project total grant: € 1.200.000

Fossil fuels reduction

Storage systems integration

INM *INstitute for Marine engineering*

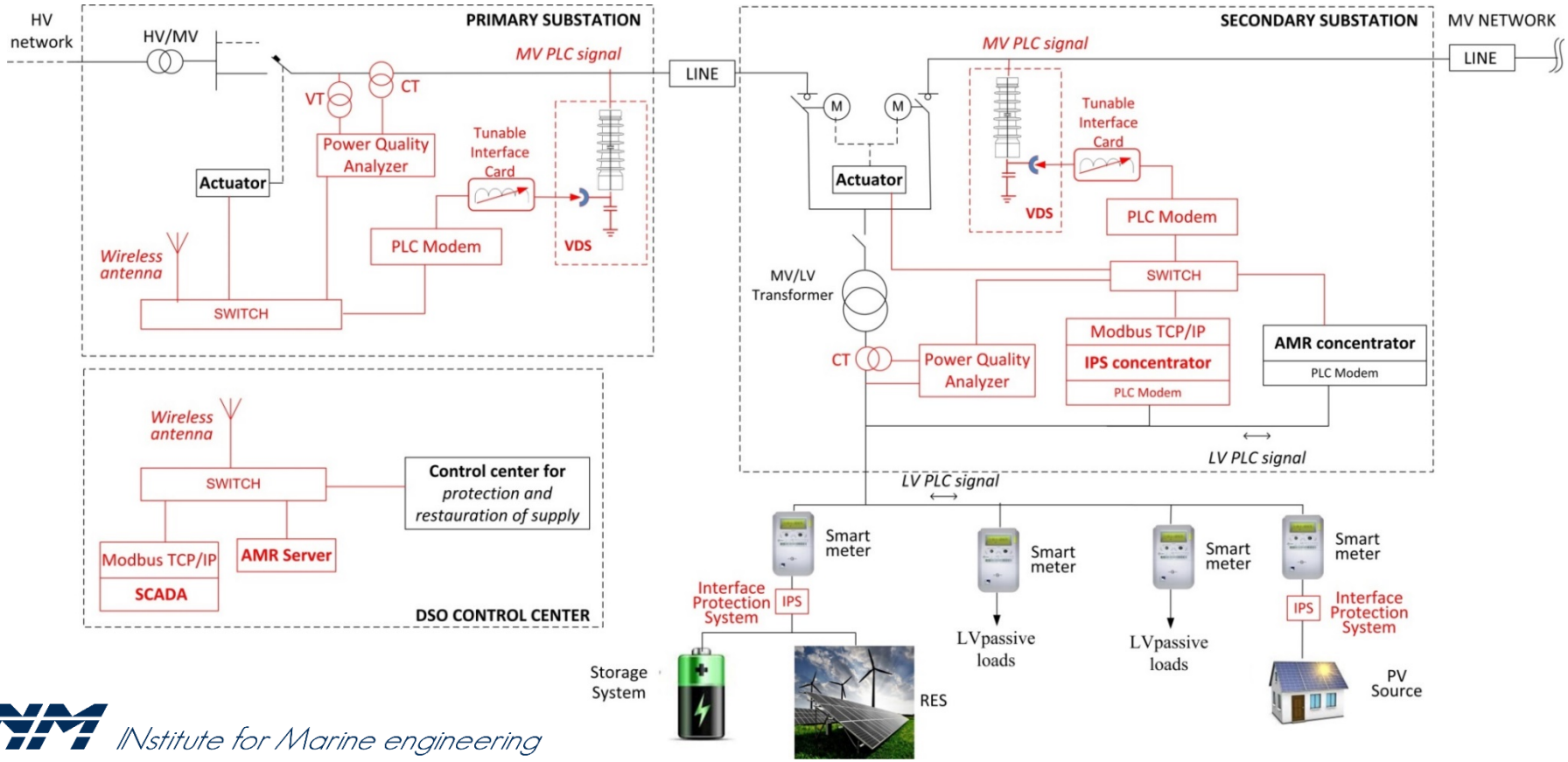
The **present research activities** are focused to **novel contributions** in the medium (MV) and low voltage (LV) smart grids, **experimentally proven**, and based on **low cost and industrial hardware solutions**:

1. Innovative **Intelligent Electronic Devices (IED)** for distributed generation and storage systems remote monitoring, protection and control;
2. Measurement architectures and software for MV and LV distribution network real time **state estimation and energy management;**
3. Innovative **low cost communication architectures**, with a special focus on power line communications.

Proposed solutions for monitoring and control of smart grids

Energy

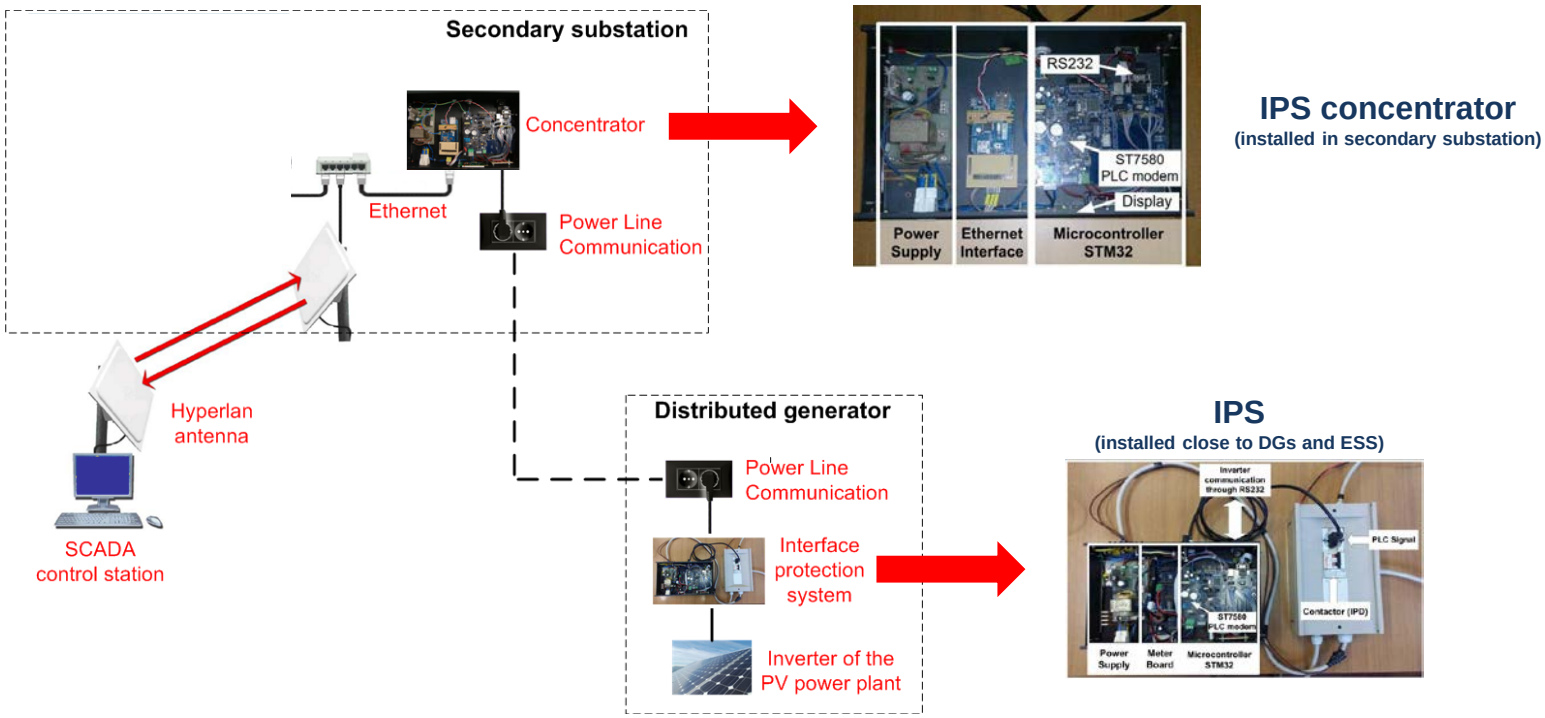
- Contributions include:
  - innovative devices for DG and ESS protection and control,
  - new state estimation algorithm,
  - low cost measurement and communication architectures



INM INstitute for Marine engineering

DG and ESS remote monitoring and control system architecture

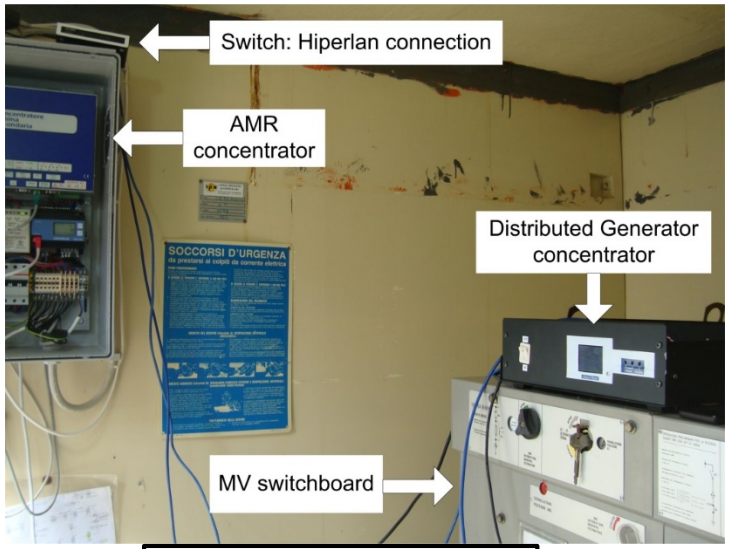
Energy



- Two intelligent electronic devices have been developed: an innovative **interface protection system** (IPS) and a **IPS concentrator** with the following features:
  - Implementation of all the protection functions of standard CEI 0-21, with additional feature variable protection thresholds remotely controlled by Utility;
  - remote control of DG inverter to change its operation mode, thus contributing to the voltage and frequency regulation

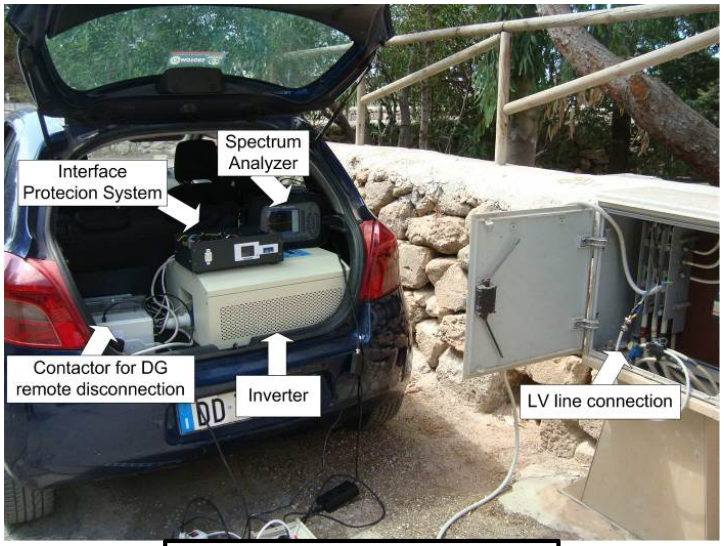
On field tests in Favignana and Ustica distribution network

Energy



Secondary substation

PLC on LV



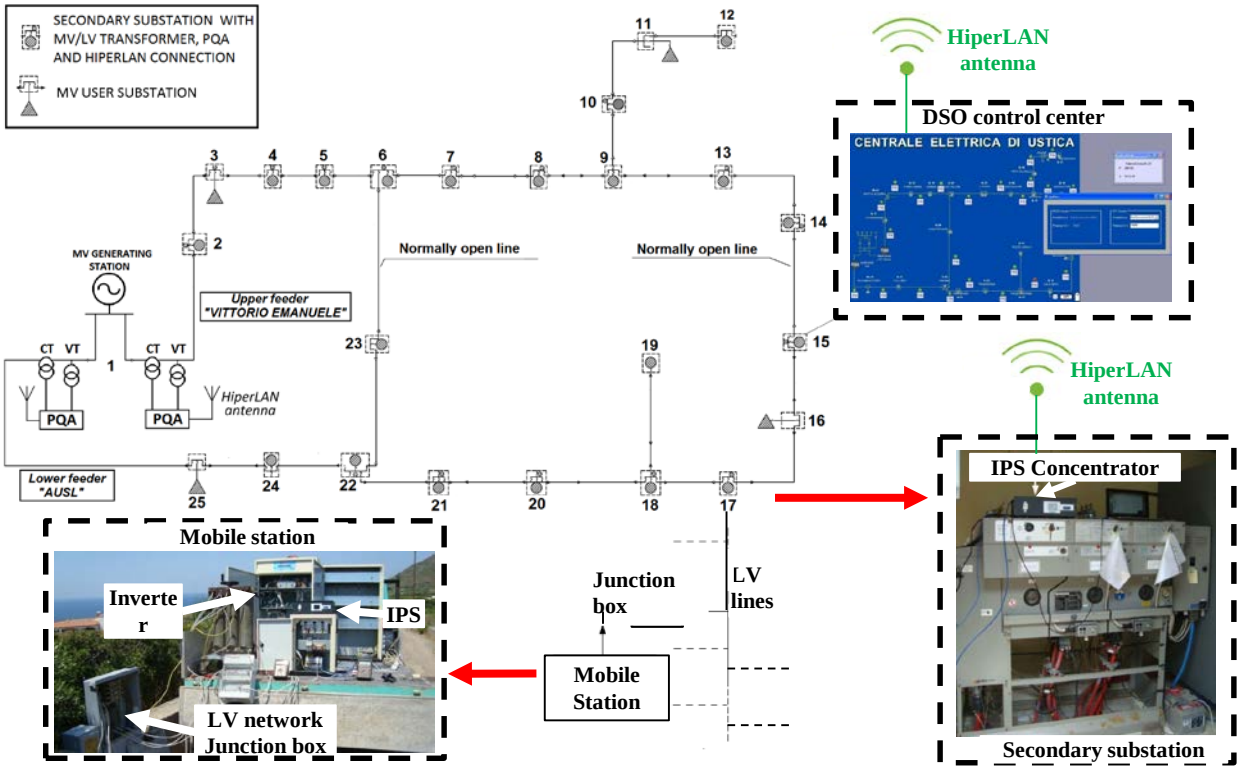
Mobile station on field

Measurement architectures and software for distribution network real time state estimation and energy management

Energy

- Problem: Current state estimation approaches are based on few measurements, made by phasor measurements units (PMU), that require expensive voltage measurement transducers and high computation and complex algorithms
- Solution: novel state estimation algorithm based on active and reactive power measurement by power quality analyser installed on low voltage side, where no voltage measurement transducers are required

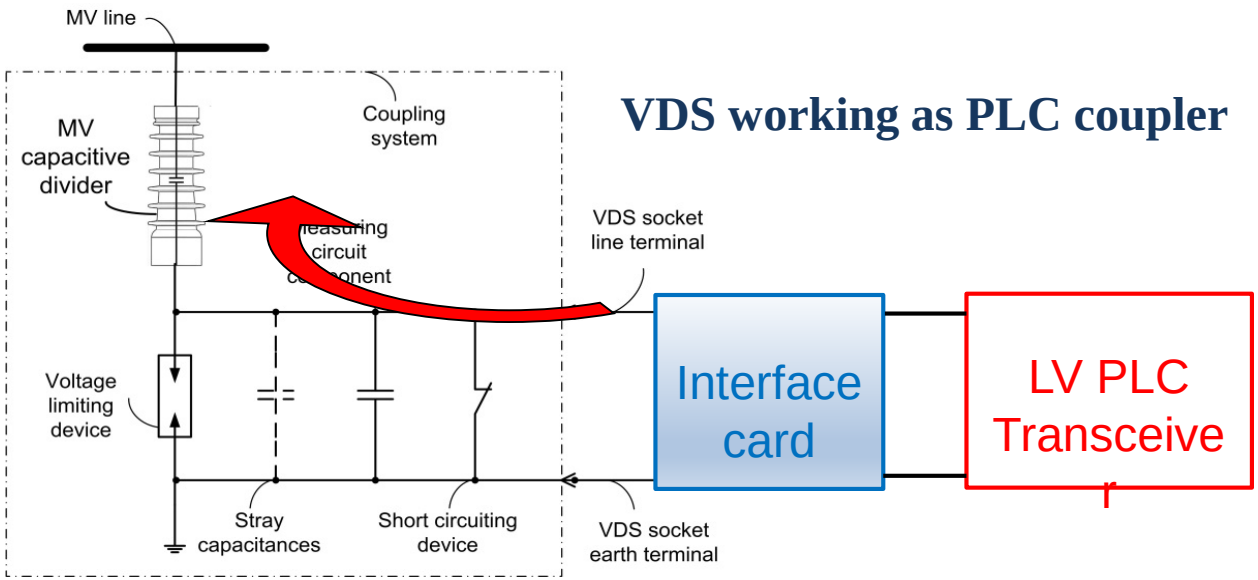
ON FIELD TESTS IN USTICA MV DISTRIBUTION NETWORK



Low cost PLC-based communication architectures

Energy

- Problem: **present PLC MV commercial coupler** has high intrinsic cost, for the large amount of secondary substations in MV distribution network, expensive installation cost for the modification of the MV switchboard and for the service interruption for its installation
- Solution: to couple the PLC signal to the MV network, based on electrical elements already installed in MV substations. The **idea** is to substitute the **voltage indicator** of the VDS, present in the MV switchgear, with a plug of the same dimension through which the PLC signal can be injected or received. In this way, **no modifications** of the MV switchgear are required.



VDS working as PLC coupler

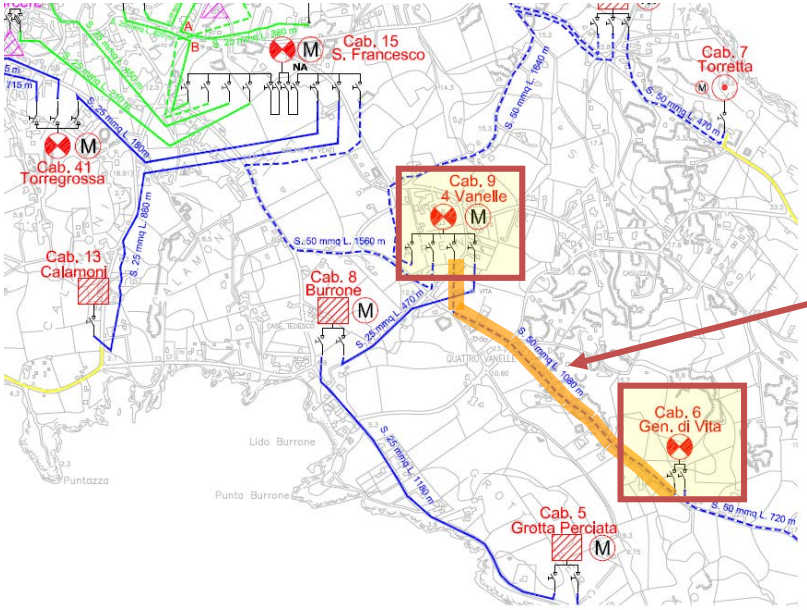
US PATENT

R. Fiorelli, A. Cataliotti, D. Di Cara, G. Tinè, "Coupling circuit for power line communications" Assignee: STMicroelectronics s.r.l., Grant Number US08896393 B2, Grant Date: 25/11/2014. Priority date: 22/12/2010 https://www.google.it/patents/US8896393

Field tests in Ustica and Favignana MV distribution network

Energy

Field tests in Ustica and Favignana MV distribution network

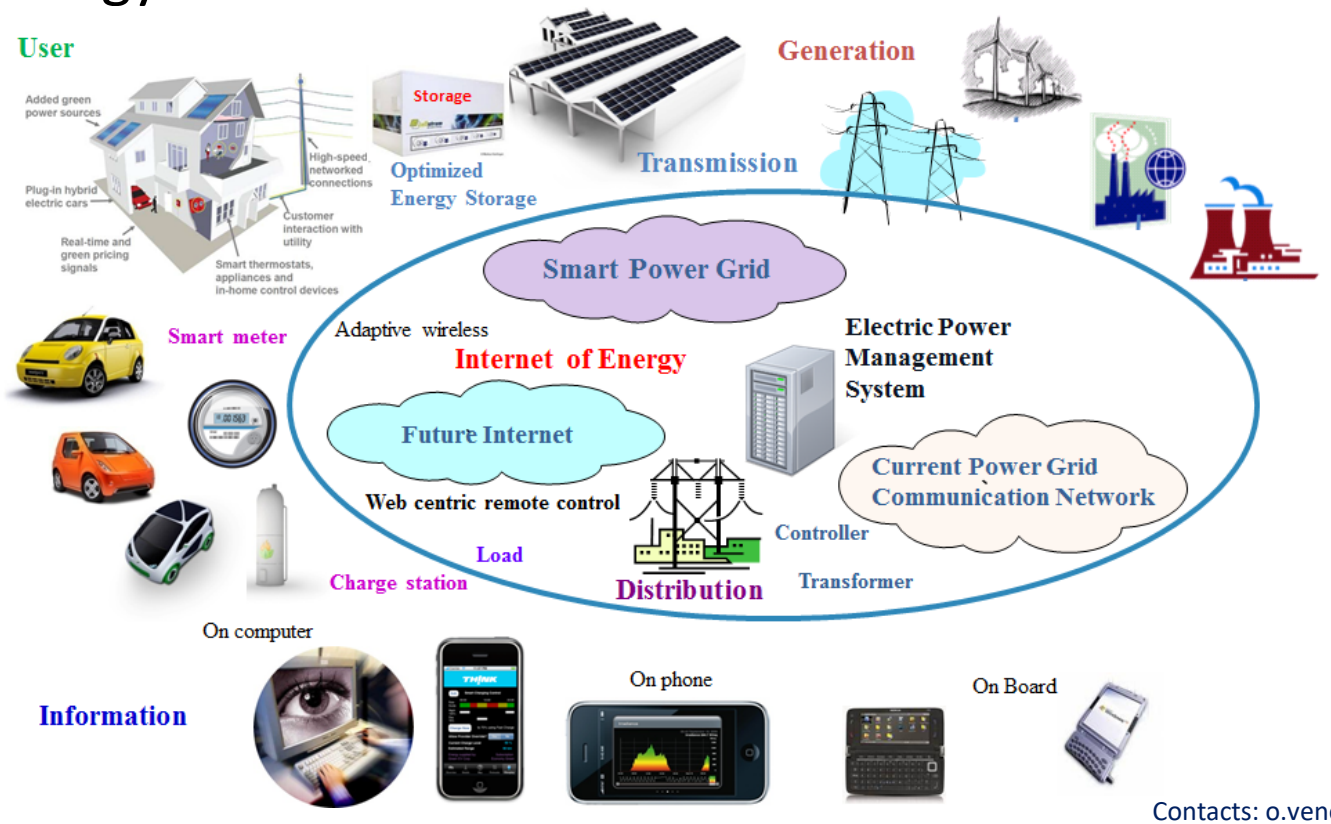


- Substation #6: Gen. Di Vita
- Substation #9: 4 Vanelle
- Substation #6: by pass connection
- Substation #9: nodal connection
- 1.1 km 50 mm^2 MV cable line
- 160 and 250 kVA MV transformers
- Presence of MV voltage

2 VDS couplers with the developed interface board (ST-UniPA-ISSIA)

Integration of electric mobility and distributed generation/storage systems in a smart internet of energy context

Energy



Research Topics:

- Electric mobility and charging infrastructures
- Smart Districts
- Vehicle to grid management
- Smart integration and use of unpredictable renewable energy sources

Contacts: o.veneri@im.cnr.it

Replicate Project: Renaissance of Places with Innovative Citizenship and Technology – European Union's Horizon 2020 Research Project

Internet of Energy - Education and Qualification. Funded by the Erasmus+ Program of the European Union

Projects Involving CNR – Istituto Motori

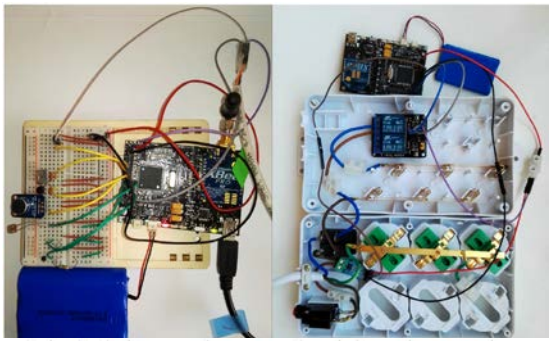
ISTITUTO MOTORI
Consiglio Nazionale delle Ricerche

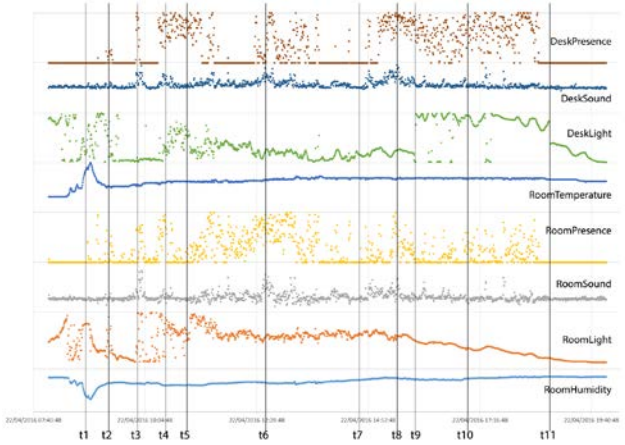
BUILDING

Building monitoring and control

Building

- Digital services that make the building intelligent by acting on parameters such as lighting, thermal comfort, air quality, physical safety, etc.





Device-free systems and passive indoor localisation

Building

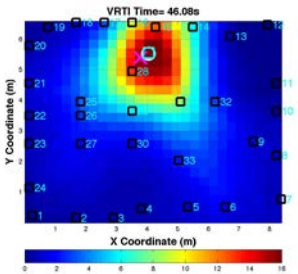
Indoor localisation systems do for indoor areas what GPS does for outdoor

- They can identify the position of a target on a map
- Such systems are still in their infancy, and no generally accepted standards or methods exist which are accurate, cheap, easy to install and interoperable using an official standard.
- Rather, existing systems are built on a case-by-case basis and tailored to a specific application.
- Here, two specific cases are briefly described:

Indoor radio is ubiquitous

A. Device-free systems with low number of anchors

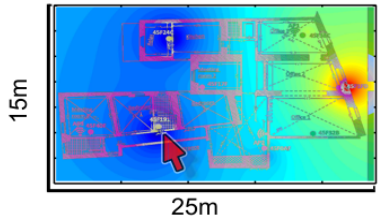
These systems are able to show on a map the position of one target with an accuracy depending on the number of deployed *anchors*, that is, small transceivers which continuously transmit packets each other and are able to detect disturbances in the radio transmission due to the presence of one person. Possible applications are intrusion detection, presence detection, home activity recognition.



A. Device-free estimate of target position

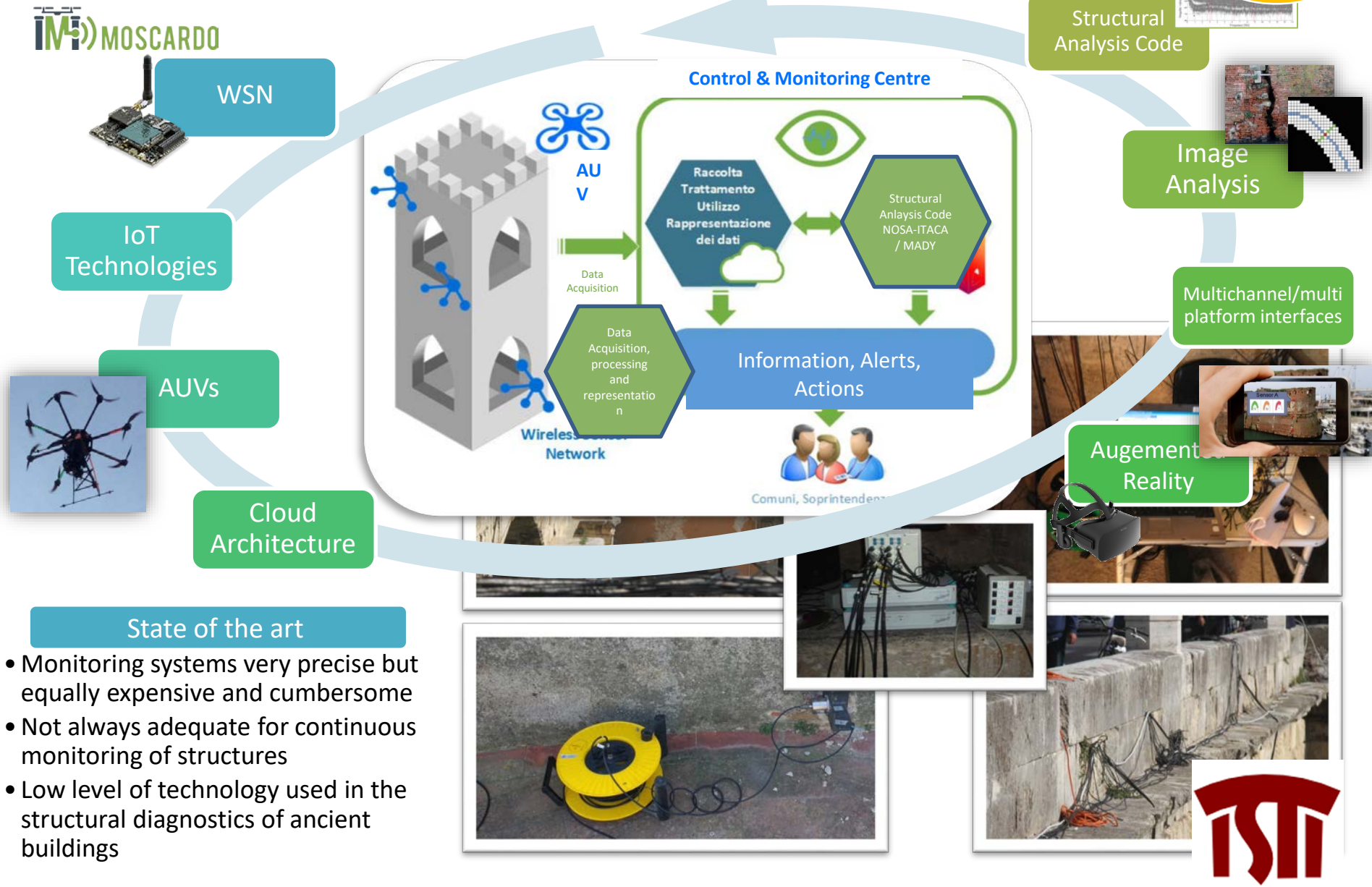
B. Crowd localisation using Wi-Fi probes

Smartphones routinely send out *Wi-Fi probes*, packets that are used to detect the presence of nearby access points. Listening to these probes is a way to identify a crowded area. Possible applications are customer flow measurements in malls and more generally planning in big public areas such as hospitals, stations, airports.



B. Experiment with locating Wi-Fi probe emitters

Monitoring of historical buildings



State of the art

- Monitoring systems very precise but equally expensive and cumbersome
- Not always adequate for continuous monitoring of structures
- Low level of technology used in the structural diagnostics of ancient buildings

GLIMPSE: A monitoring infrastructure for enhanced quality, safety and security

Building

Energy - Maintainance

Automatic switch off
of equipment not in use, detection and notification of faults.

Security

Verification of access to laboratories or restricted areas, management of access policies.

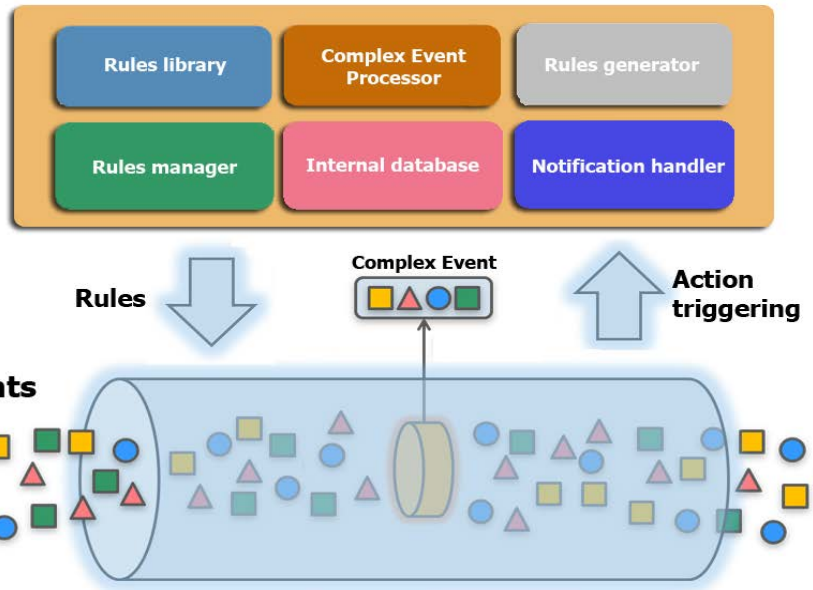
Well-being

Temperature and humidity monitoring with active suggestions or corrective actions to improve working condition.

Intrusions

Connection with smart cameras and intrusion detection with real-time notification.

Drools



ActiveMQ

Java Message Service

RES, storage and domotics for Smart Building

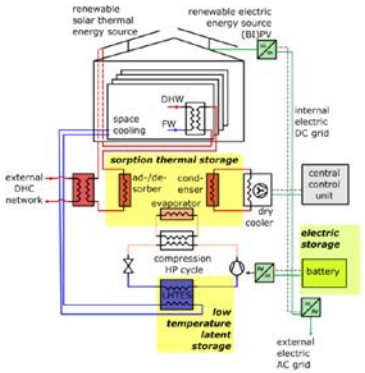
Building

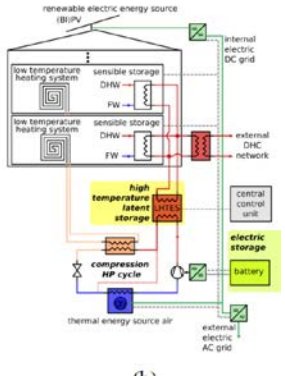
ONSITE FP7

ON-SITE is an European project funded in FP7 programme that has allowed the development of a hybrid generation and storage system based on SOFC-type fuel cell systems and NaNiCl2 salt batteries. The prototype hybrid generator is currently being tested, feeding the telecom loads of a TIM station at the Acqua dei Corsari site in Palermo.

HYBUILD H2020

Hybrid Energy Storage for Buildings





HYBUILD is a project funded by the EU Horizon 2020, led by COMSA Corporación, which aims to develop a hybrid electric / thermal storage system for residential applications.
The overall system will make use of electric and thermal generation from renewable sources (photovoltaic and solar thermal) and the appropriate use of electric heat pumps.

Development and advanced prefabrication of innovative, multifunctional building

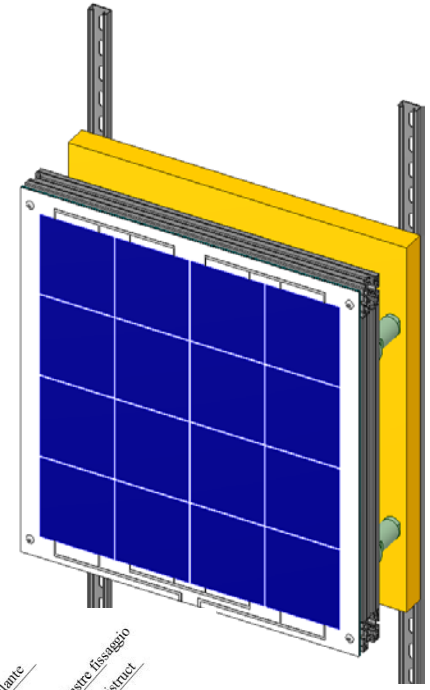
- LOW COST
- EASY TO INSTALL
- ENVIRONMENTAL FOOTPRINT
- NZEB
- MICRO GRID FOR RURAL AREAS
- SMART GRID FOR URBAN AREAS

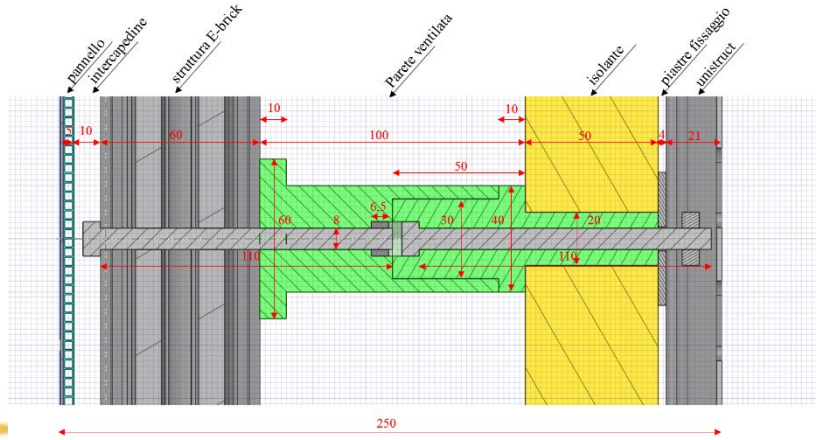
Innovative, multifunctional buildings and Advanced prefabrication systems
Expected outcomes: energy efficient buildings integrating RES, storage and domotics
Results: prototypes of innovative smart buildings developed with SMEs

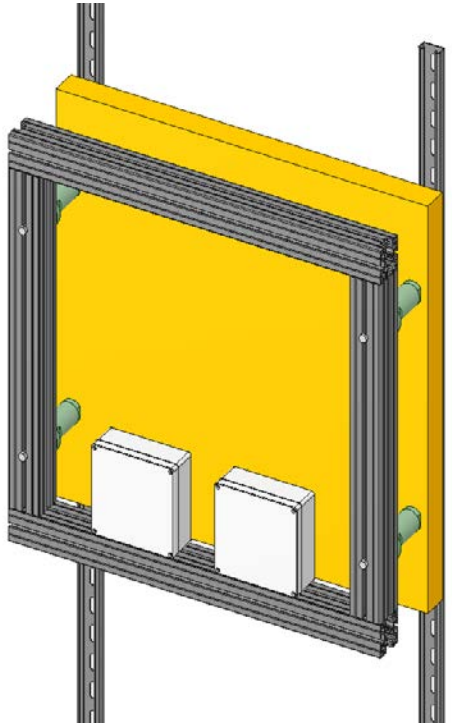
E-Brick project

Building

E-Brick is an Italian project funded in PONMISE Horizon 2020 call. It is related to the development of a active building component for ventilated façades, integrating photovoltaics, batteries and insulated materials.
CNR-ITAE is consultant for the test and design of both photovoltaics and batteries systems. ITAE is the concept developer of the entire project.



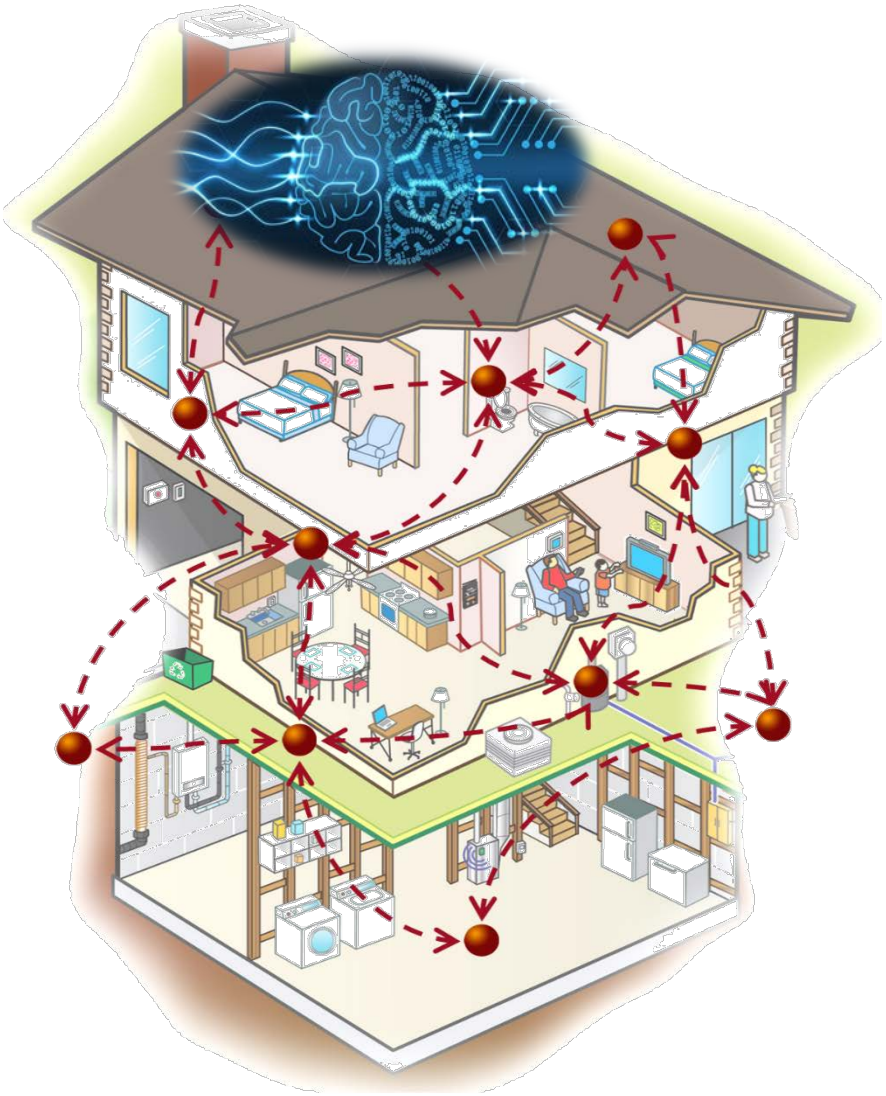




Cognitive buildings

Building

- The goal of the research is to combine all together IoT technology, cognitive computing, big data, machine learning and reasoning to help people live and work better in buildings, as well as maintain and manage the building itself by providing it with the capabilities **to learn** over time how to improve building management.



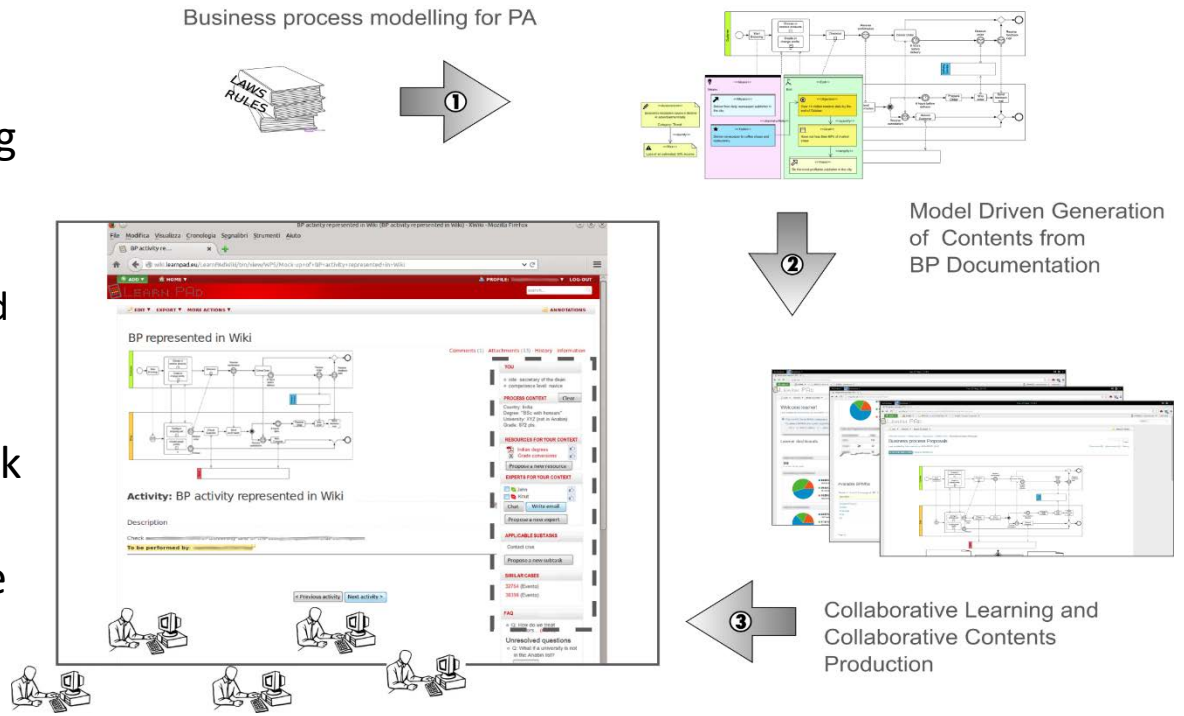
COMMUNITIES OF CITIZENS

Smart Government and eLearning

Citizens

- Civil Servants are challenged in continuous-training in order to comply with the adoption of the European Interoperability Framework
- Research initiatives about **methodologies**, **policies**, and **software eco-systems** enabling both e-government in PAs and training of their civil servants
- ICT solution for (semi-formal) **modelling** and **management** of both operative procedures and organizational structure in place in PAs

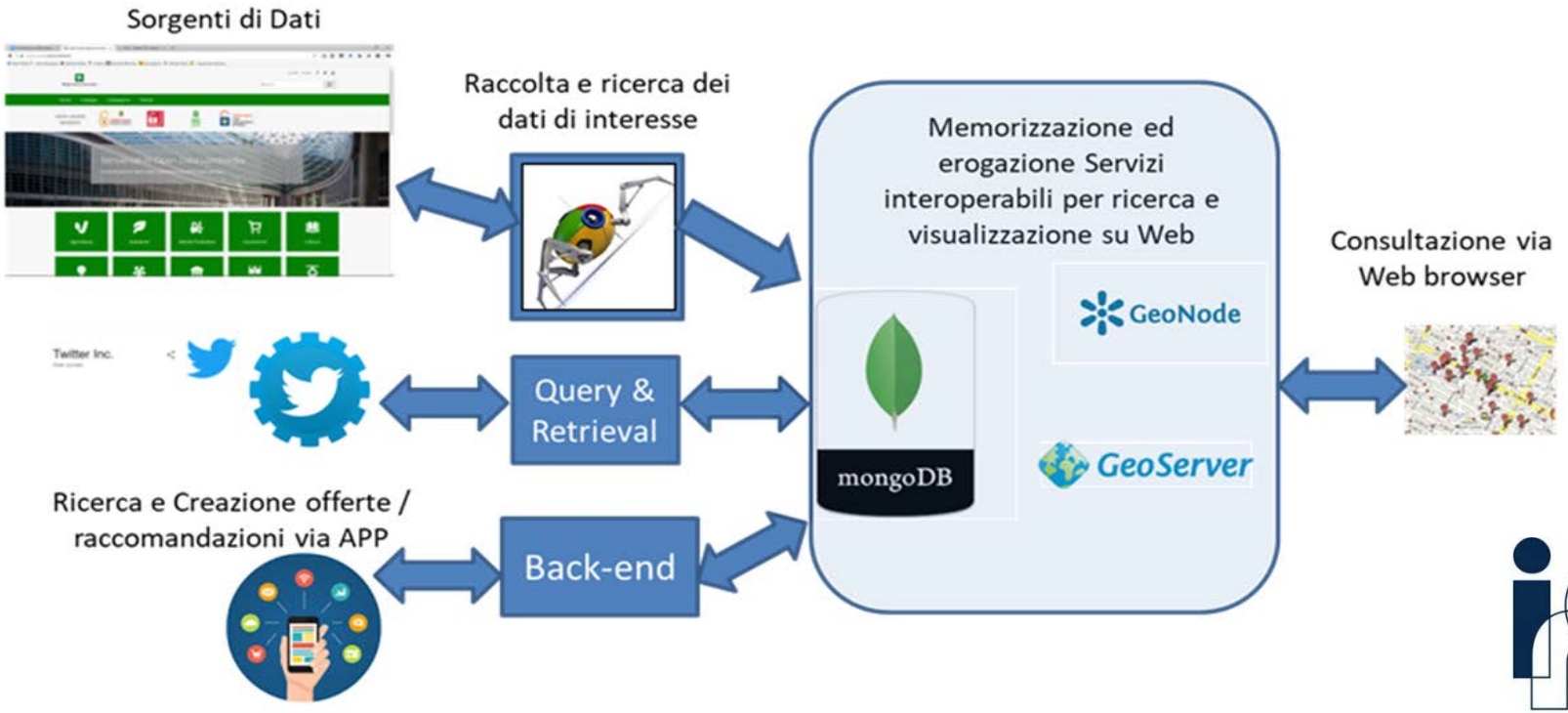
- ICT frameworks and methods for e-learning
- approaches and tools enabling to collect, to explore, and to analyse
  - organizational structures and procedures in PAs
  - training of the PA personnel
- methodologies and framework fostering collaboration and a shared understanding of the PA organizational goals



Tools for connecting citizens with the social context and local resources

Citizens

FHfFC project : Crawling, georeferencing, interoperable Web sharing, querying and retrieval of Open Data, related Social network messages, and Volunteered Geographic Information to enable the connection of citizens with their social neighborhood



Tools for citizen engagement

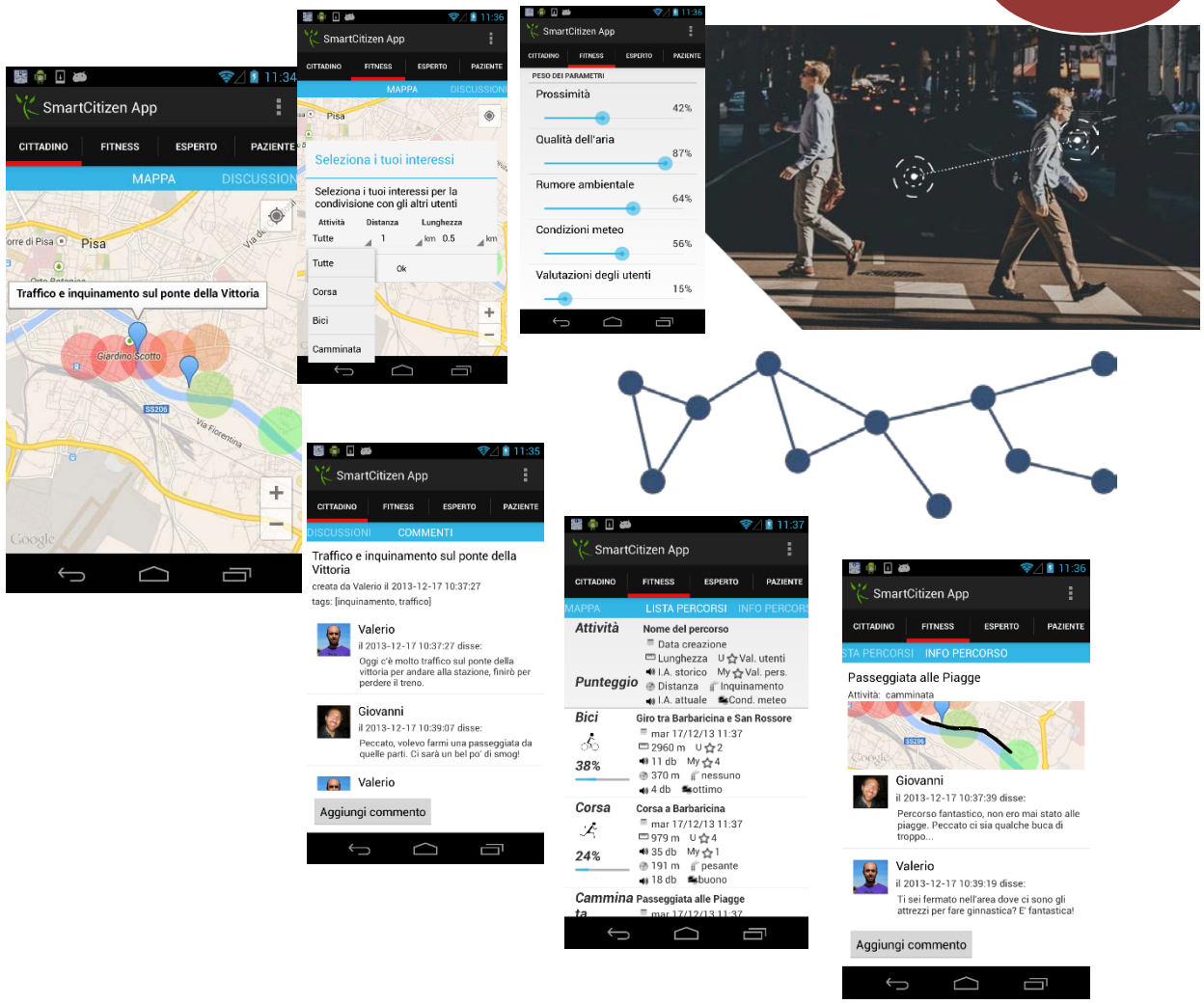
Citizens

Mobile Social Networks applications:

- mobile solutions aimed at **stimulating citizens' participation** through the generation and sharing of contents and experiences based on D2D communications
- They can be applied to several application domains in Smart Cities: e.g., environmental and traffic monitoring, smart mobility, health and well-being apps

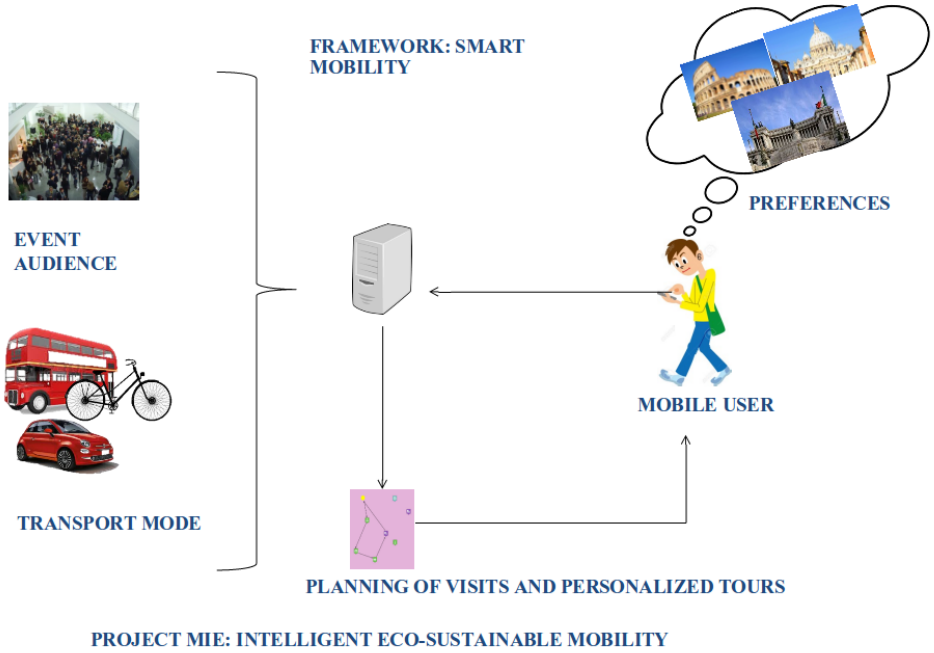
IMPACT/CHALLENGES:

- Definition of **new mobile solutions for smart citizenship**
- Collection of big amount of heterogenous data
- Data analysis and AI techniques to define personalised services and persuasive feedbacks to encourage healthier behaviour.



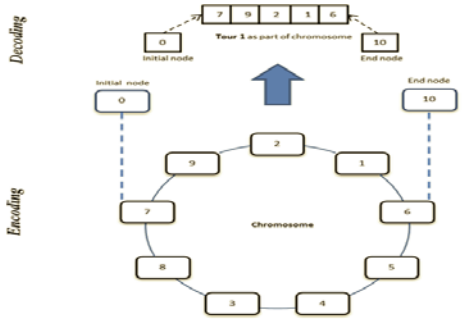
Applications for tourism and use of cultural heritage

Citizens



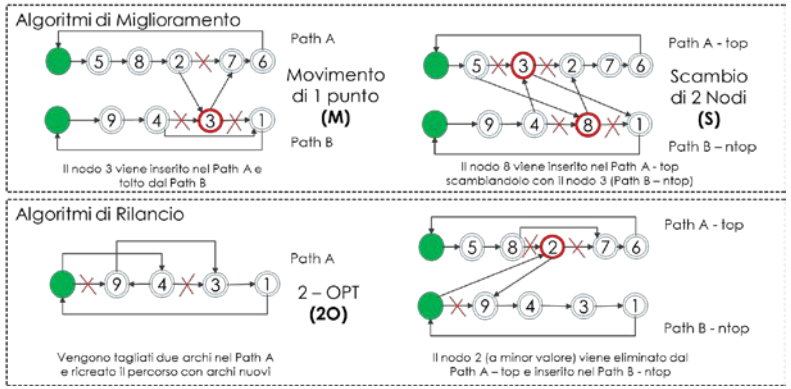
- Development of matheuristics based optimization algorithms for **planning of routes**
- User can plan his (business or tourist) tour by entering his preferences.
- The algorithm will **maximise user preferences** by taking into account user constraints and network parameters (estimated service time, travelling time, time windows).

ACTIVITI Project - Cultural Attractors and Informatics Technologies for Interactive Enhancement and Innovative Tourism.



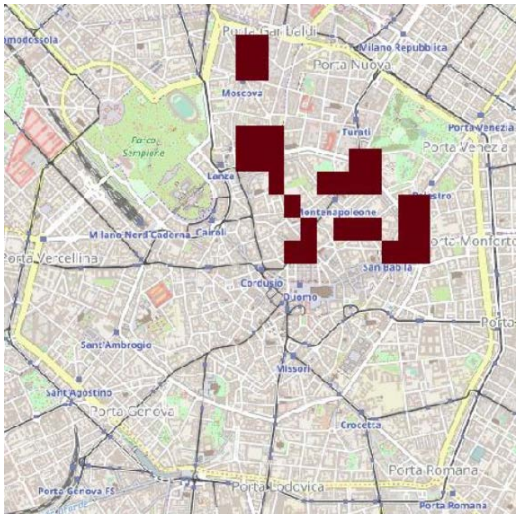
Aims: This interdisciplinary project is focused on the use of new enabling technologies for the promotion and protection of cultural heritage and their valorization in tourism. In particular, activity 3.2 aims at implementing a decision support methodology, useful for tourists and tourism services managers, for organizing routes based on data and preferences expressed by the user. The methodology has also enabled the creation of a **web-based algorithm to provide tourist itineraries in pedestrian or bike-sharing mode**.

Results: Several European cities have developed Bike Sharing Touring (BST) services to reduce CO2 emissions and improve sustainability in urban areas. The activities carried out as part of the Activiti project have allowed the creation of some heuristics and metaheuristics (genetic algorithms) to support web based applications aimed at the construction and optimization of tourist routes in cities of art. Based on a mathematical model known in operational research as a Orienteering Problem (OP), a decision support tool has been developed to help the tourist to organize a visit based on their preferences, respecting the time available and logistic constraints related to the area of interest.



Understanding human mobility flows

Citizens



- Development of data mining and machine learning methods for the **estimation of people aggregation** based on historical data.
- We can evaluate the flow of commuters or the impact of large events on the flows
- Use of **presence data** gathered from mobile phone network

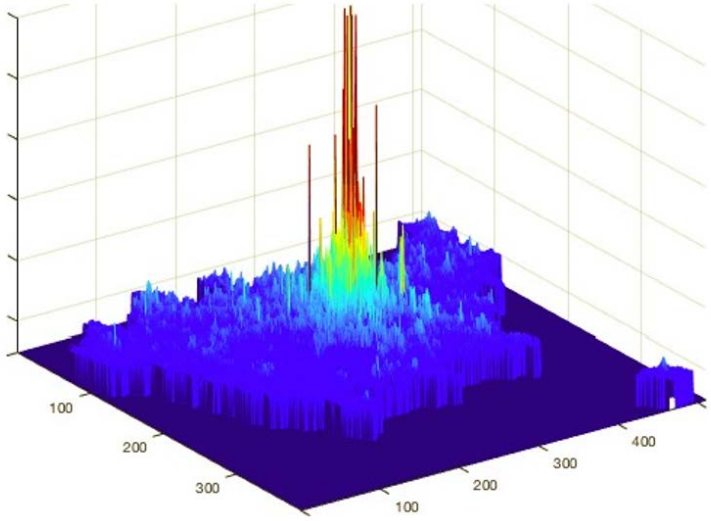


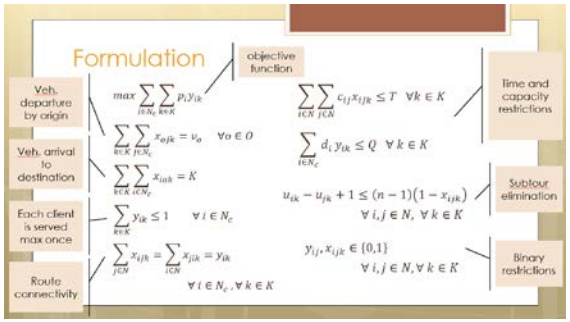
Figure: 3D-plot of the number of TIM users in each cells of Milan's province on Aprl 18, 2017 at 10:00 a.m.

- Development of mathematical models for the reconstruction, forecasting and optimization of traffic flows.
  - Applying a modified version of the Monge-Kantorovich Problem

DIEM-SSP: Disasters and emergencies management for safety and security in industrial plants.

Citizens

Aims: To develop decision support systems (DSS) for the Improvement of safety in industrial plants. Problems considered were: i) assignment and routing of emergency vehicles in case of industrial catastrophe; and ii) to evacuate the greatest number of people with reduced motor capacity using an assigned fleet of vehicles with finite capacity in an assigned time.

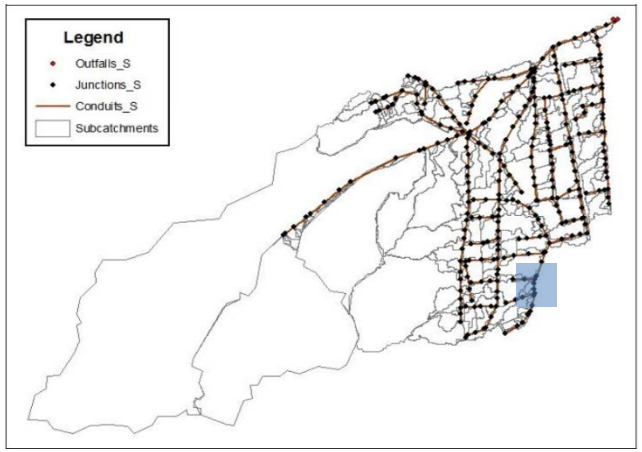


Results: A web-based application that feeds a decision support model for the allocation of ambulances according to different decision-making constraints related to patient status and hospital availability. Furthermore, a routing policy has been formulated to determine the intervention plan from the stopping points (origins) of the rescue vehicles to the accident site and from this to the collection site

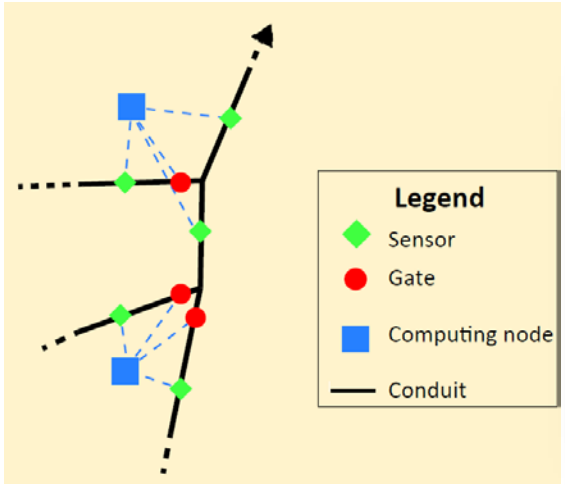
Water management system

Citizens

- We have developed a **decentralized smart system** for real-time control of urban drainage networks, which aims at **avoiding local flooding phenomena and overloading of the sewage treatment plants**, through balancing and regulating the water flow in the conduits.



Urban drainage network of Cosenza, Italy

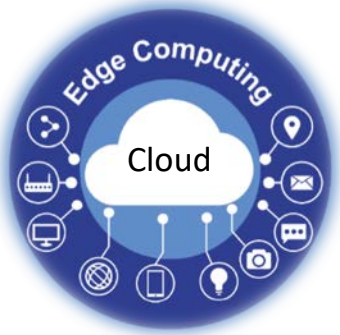


PLATFORMS

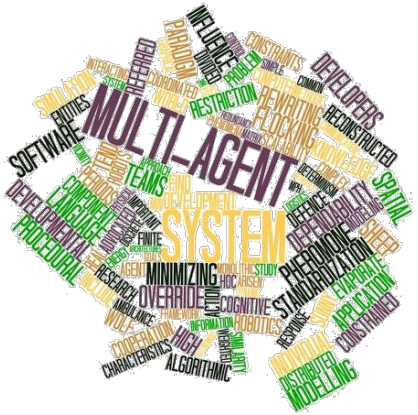
Smart City IoT Platform

Platforms

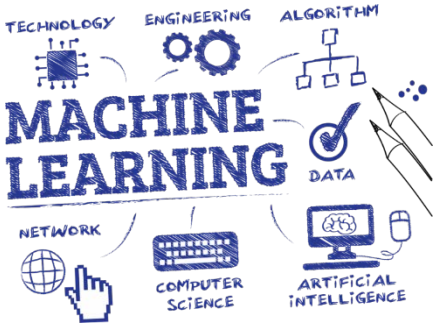
- The platform relies on:
  - Swarm Intelligence (SI) techniques
  - Distributed multi-agent artificial intelligence
  - Collective machine learning
  - Social Internet of Things
  - Edge/Fog and Cloud Computing



- The platform permits:
  - Dynamic addition of devices without interrupting the running services (scalability and extensibility)
  - Development of protocol-agnostic systems (Interoperability)
  - Implementation of learning behaviors and Real-time IoT Analytics services
  - Dynamic data sharing
  - AI-based decentralized self-forming intelligence

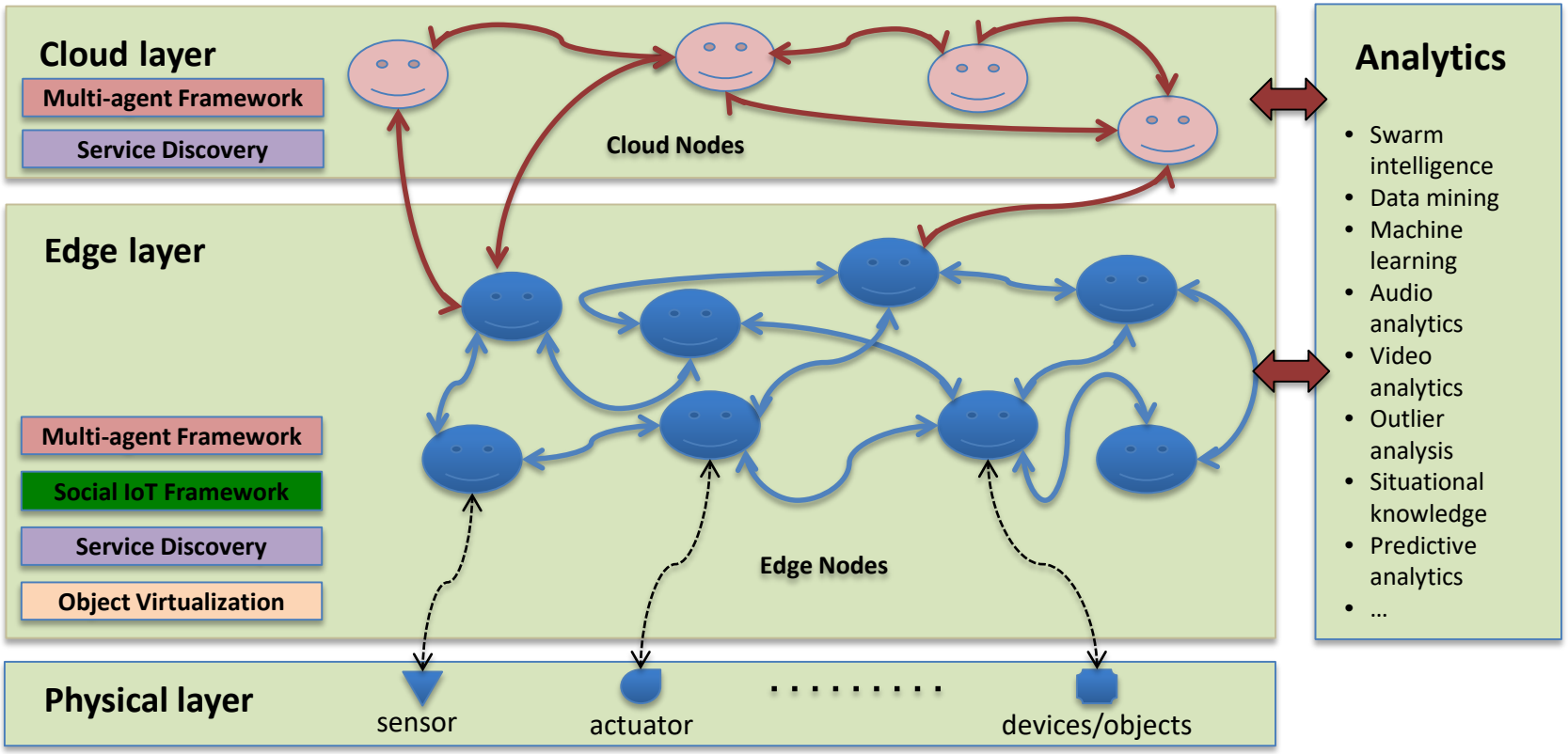


Real-time IoT Analytics



Smart City IoT Platform: Architecture

Platforms



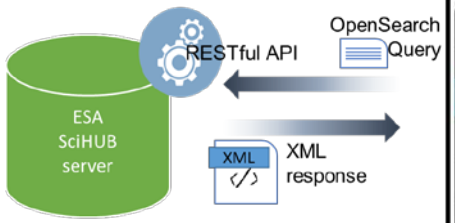
Spatio-temporal monitoring of urban areas

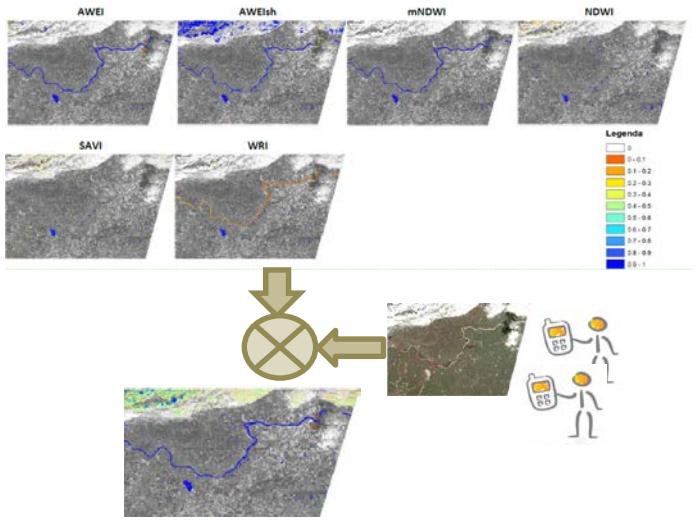
Platforms

Regione Lombardia

Simulator-ADS

Enabling not experts to deploy periodic Downstream services from ESA SciHUB





Flexible Synthesis of multiple remote sensing images by fuzzy aggregation & machine learning optimization based on in situ observations (VGI) to map flooded areas

Fondazione CARIPLO

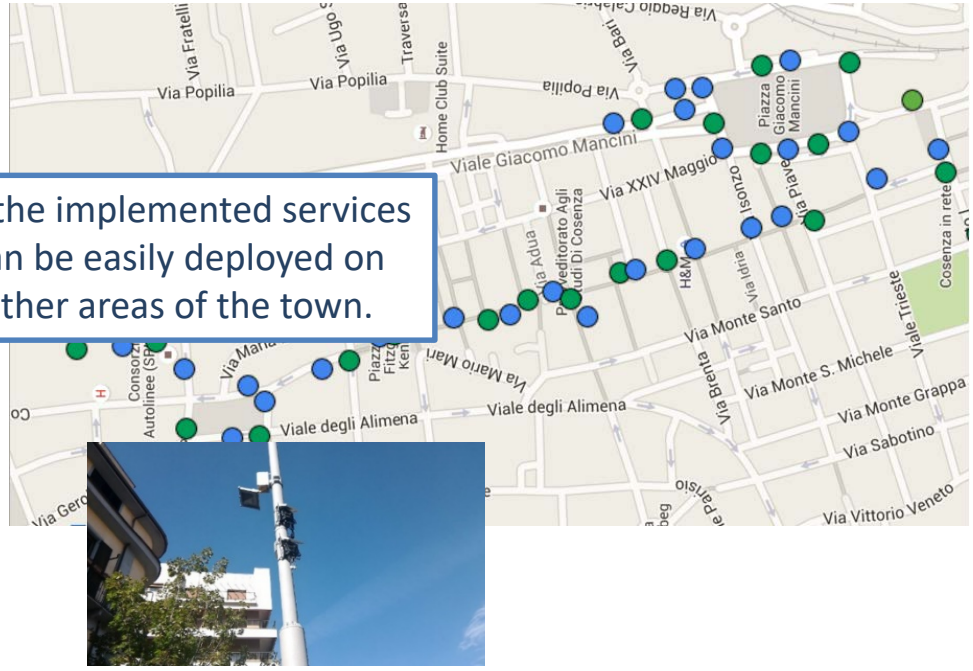
STRESS
Resilient Smart Societies

Monitoring urban phenomena

Platforms

- This research activity concerns with the development of sensing technologies, tools, and models for monitoring urban phenomena and knowledge discovery from urban data collected locally.

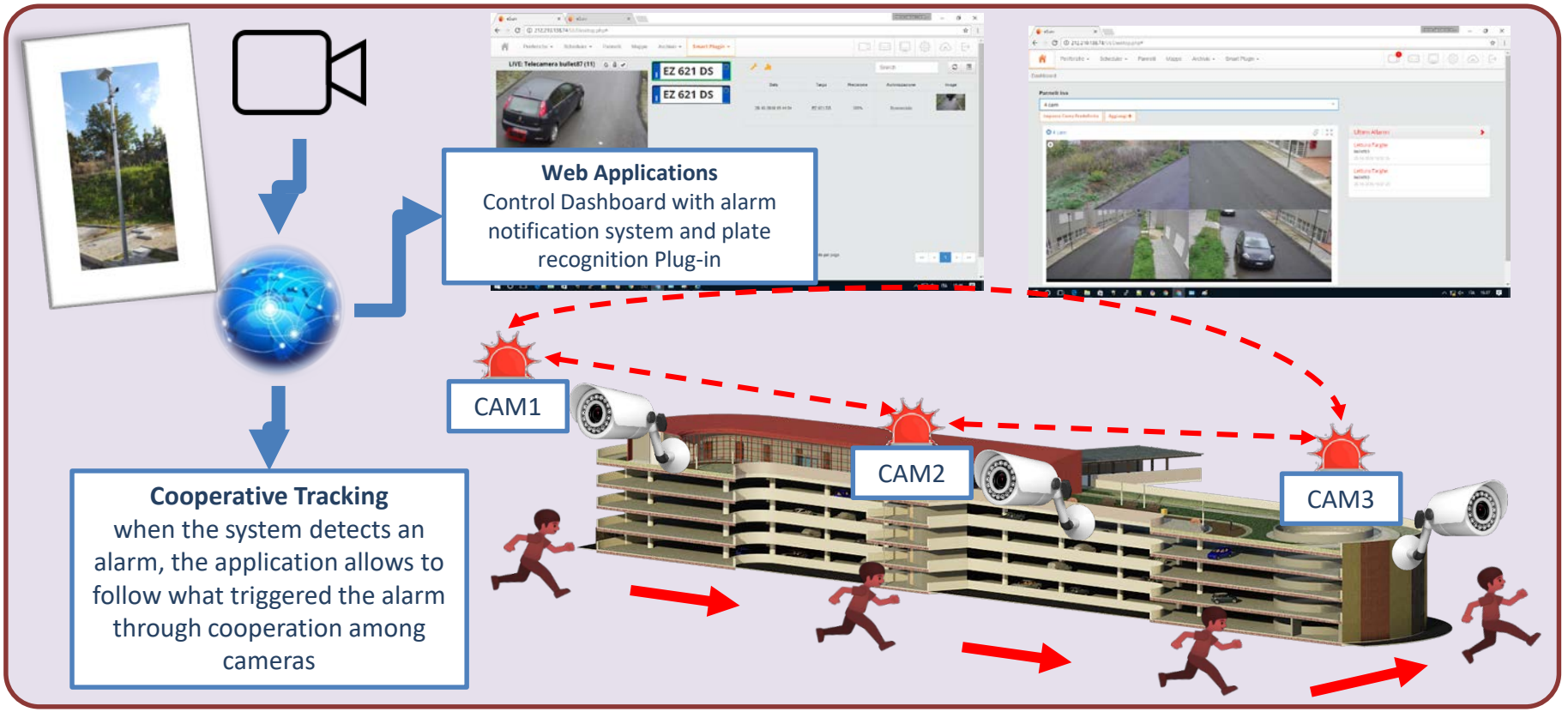
All the implemented services can be easily deployed on other areas of the town.



Smart Cameras - I

Platforms

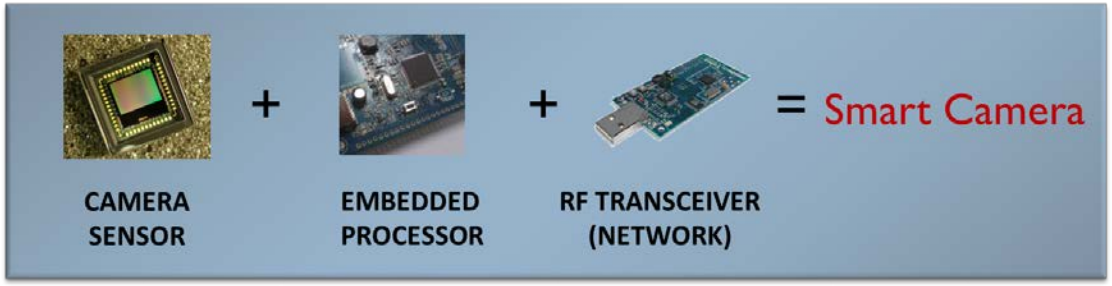
- Development of intelligent cameras for objects and people identification with the use of artificial intelligence technologies



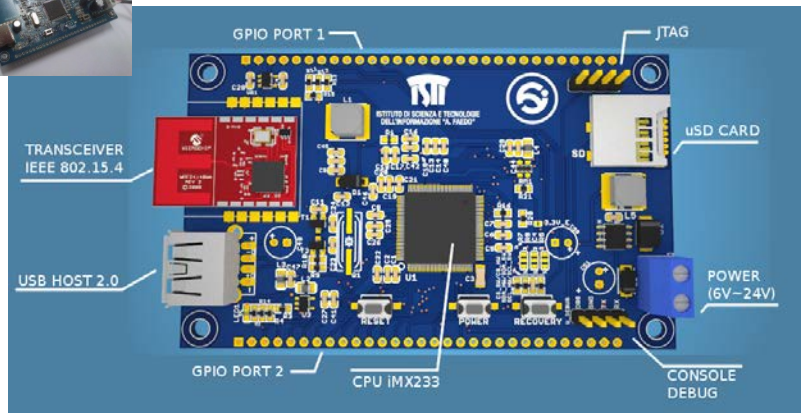
Smart Cameras - II

Platforms

- Embedded processor equipped with application-specific computer vision logics
  - for on board image analysis and understanding
    - Object detection and recognition
    - Event Detection and recognition
  - Integration of Deep Learning methods



PROPRIETARY PROTOTYPE

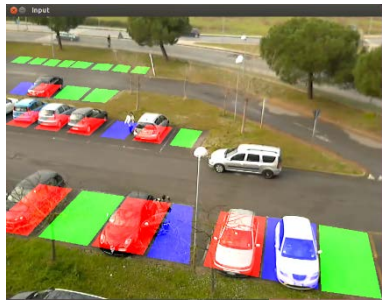


- Advantages:
  - Distributed visual intelligence
  - Pervasive approach
  - Robustness & fault tolerance
  - Autonomy
  - Coverage of very large areas
  - Scalability
  - Can support novel applications just by extending the computer vision logics

Smart Cameras - III

Platforms

- Security, surveillance and environmental monitoring
  - Shopping malls, airports, stadiums
  - Automatic detection of threats and anomalous events
- Logistics
  - Freight control and management of goods towards the city
  - Hub monitoring and last mile
- Intelligent systems for urban mobility
  - Vehicular flow monitoring
  - Accident detection
  - Charging station
  - Parking availability



Smart cameras for Smart Parking

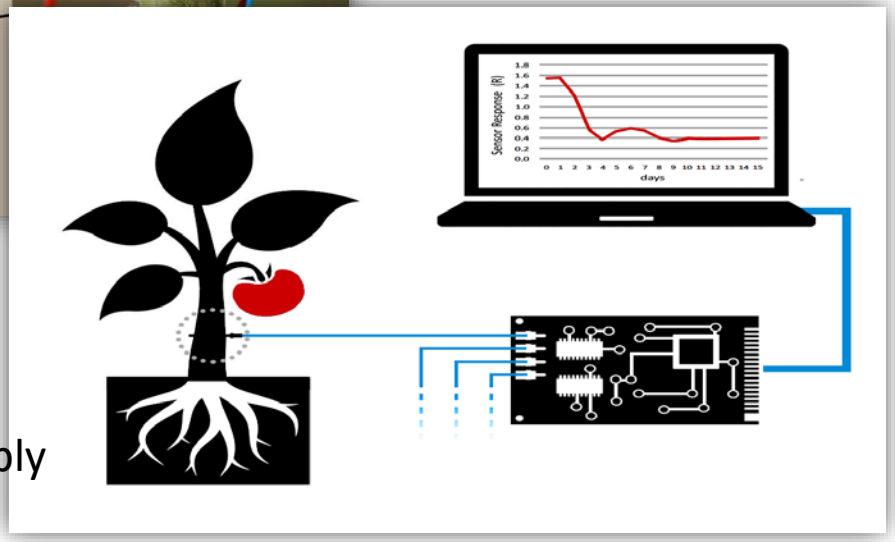
- Tested in real urban scenarios
- Also in self-powered modality
- Two classes of algorithms:
  - Lightweight methods
  - Deep Learning
- New experimentation in Lucca, Italy

Innovative sensors on functional materials

Platforms

Textile biosensors for continuous sap monitoring

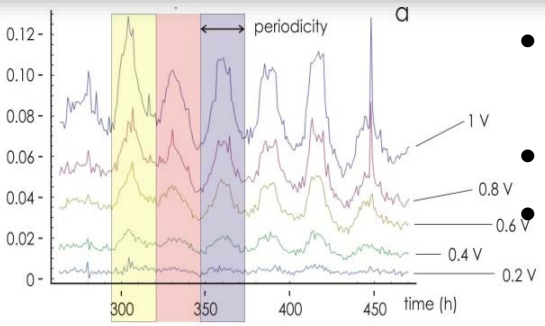
Electrochemical biosensors based on biocompatible textile fibers Noninvasive continuos live measurements



Water supply optimization

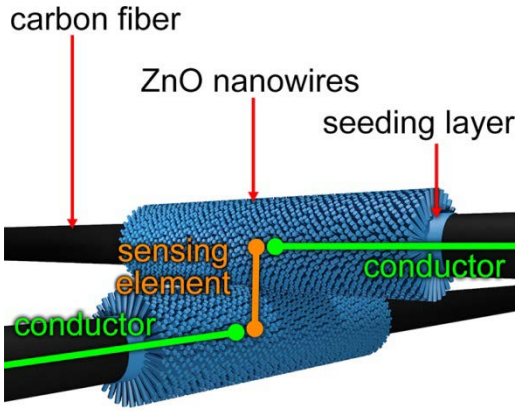
Nutrients supply optimization

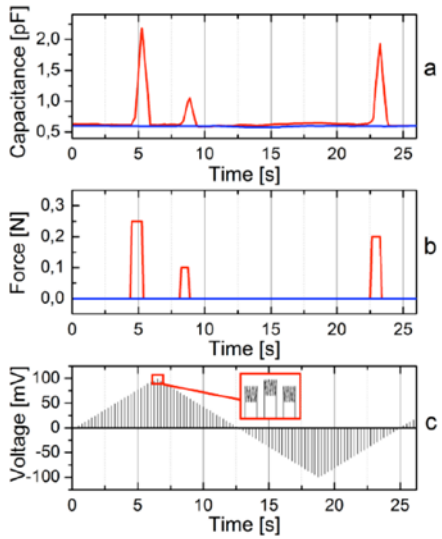
Internet of Plants



- Saline concentration
- Water Stress
- Saline Stress

Carbon fiber pressure sensor





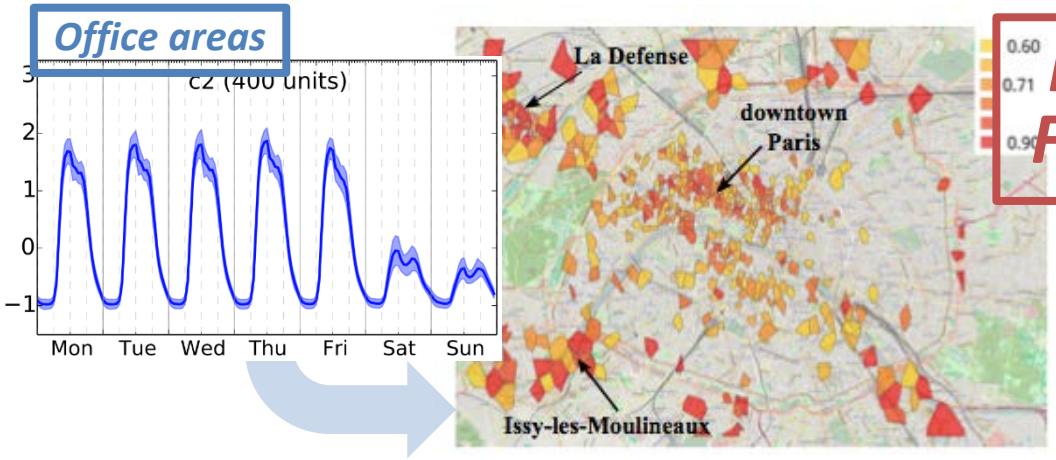
Based on ZnO piezoelectric nanorods on carbon fiber

Urban monitoring with network metadata

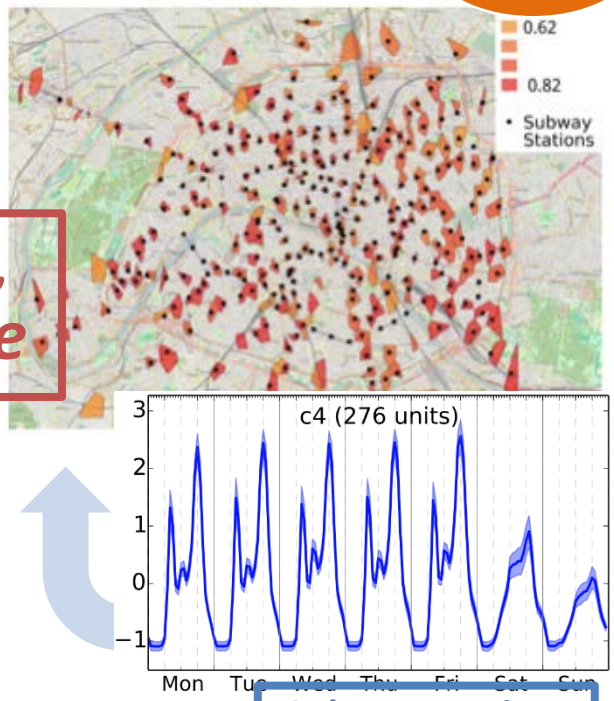
Platforms

1. Land use detection

– Mapping mobile traffic patterns to land use



Paris, France



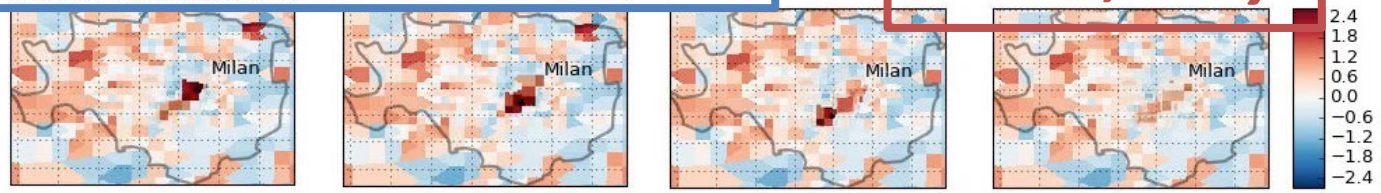
Subway stations

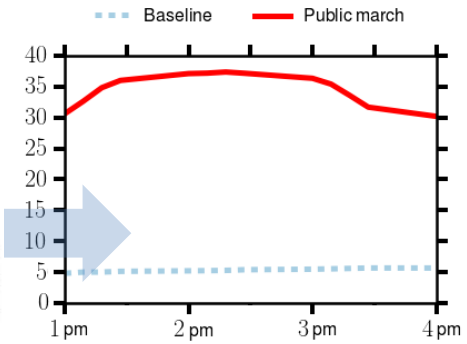
2. Dynamic population estimation

– Determining people distribution within (large) urban areas in real-time, by leveraging their mobile communication activity

People at "Liberation Day" public match

Milan, Italy



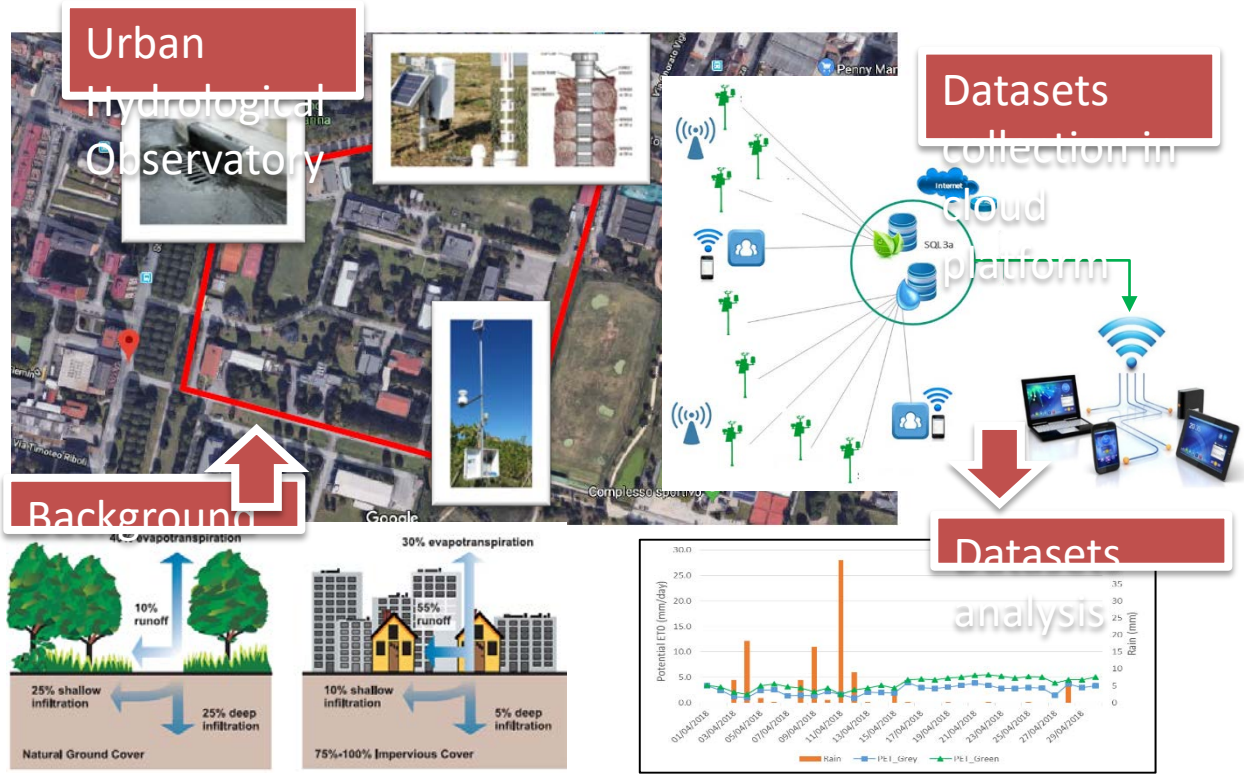


Urban Hydrological Observatory

Platforms

Approach: A Urban Hydrological Observatory (MUrHO) is being setting up in the CNR Turin Campus "Mirafiori". It cover a surface of 42000 m^2 of urban green area and 37000 m^2 of paved areas. It reproduce a urban residential area. MUrHO aimed to collect measurements by network of climate and hydrological sensors, to evaluate the contribution of the urban green area in groundwater recharge and in reducing stormwater runoff, with respect to the water balance obtained in paved areas.

Scientific Impact/Results:
To assess the impacts of different land uses, and specifically of urbanization, on the urban-hydrological cycle and on the response to precipitation events. Datasets will be also available for modelling purposes, that are particularly useful to take into account the climate change effects on urban hydrology. Measured data and results will be also available for local public bodies involved in urban planning and management, in order to implement more sustainable land use and urban drainage systems.



Relationship between impervious cover and surface runoff.
(U.S. Environmental Protection Agency www.epa.gov/nps)

Contributors

- IAC
- IASI
- ICAR
- IEIIT
- IIT
- IM
- IMEM
- INAMOTER
- IREA
- INM
- ISTI
- ITAE