www.cttc.es

SUSTAINABLE ARTIFICIAL INTELLIGENCE

RESEARCH UNIT

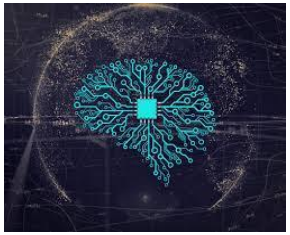
RAÚL PARADA ET AL.

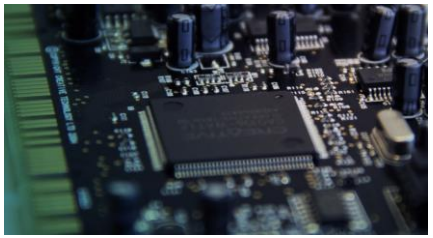
cttc

Centre Tecnològic de
Telecomunicacions de Catalunya

SUSTAINABLE AI @CTTC

- **Our Research**
  - **energy-aware**, **high-performance** and **interpretable machine learning**
    - to support data processing from heterogeneous sources (e.g., sensors, machines, smartphones, mobile networks, satellites, radars) for Cyber Physical Systems (CPS) modeling, control and optimization





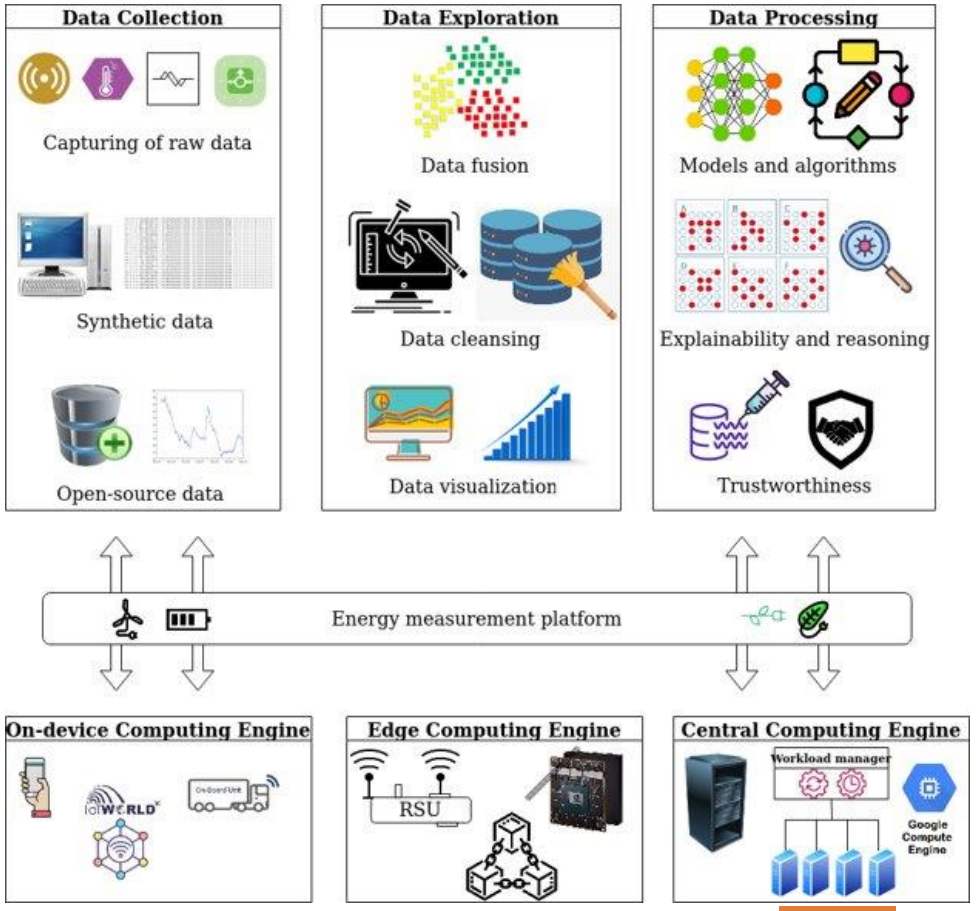
- **Our Team**
  - 8 PhD (5 senior) + 4 PhD students

- **Participation in EU programs**
  - VERGE, 5GMED, 5GCroCo, INSPIRE5G+, PANDORA, DARLENE, FIREMAN
  - Coordination: Greenedge, SCAVENGE, SONATA
  - SPANISH-MINECO Unico 5G: 6G-OASIS, FREE-6G, SUCCESS-6G

EXPERIMENTAL FACILITIES

- **SUPERCOM** (Sustainable and High-Performance Computing) Laboratory & Platform
  - 30m² room
  - Data Processing Centre
  - Edge nodes
  - Different types of sensors (air quality, CO2/humidity/ºC)
  - HD cameras
  - LIDARs
  - 5G connectivity (ORAN)
  - Power measurement

- Multiple **datasets**
  - 4G Mobile data
  - Urban traffic
  - Energy grid
  - Connected vehicles

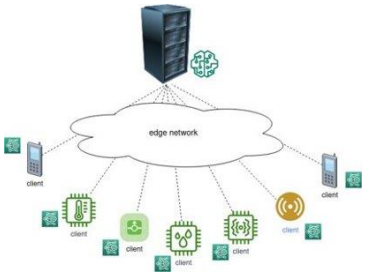


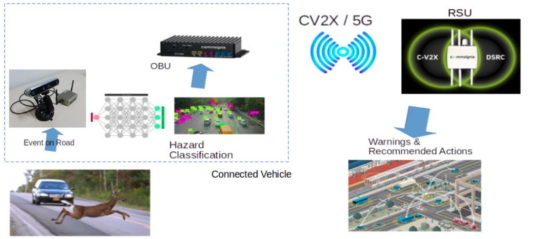
SUPERCOM

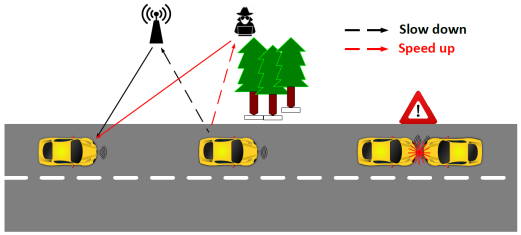
https://supercom.cttc.es

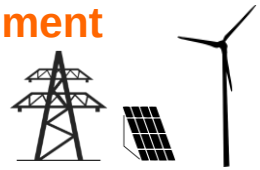
KNOWLEDGE, EXPERTISE & SKILLS

- **Edge Intelligence**
  - Collaborative & Distributed AI
    - Federated Learning, Continual Learning, Transfer Learning
  - Efficiency vs accuracy (Green AI)
  - Explainable AI
  - Application to smart cities, mobile network
- **Industrial IoT**
  - Data reconstruction
  - Explainable AI
  - Adversarial ML
  - Digital twin
  - Applications: Energy system
- **Intelligent transportation systems**
  - Misbehavior detection in vehicular systems
  - Hazard detection (sensors + ML)
- **Mobile traffic characterization**
  - Distributed ML at BS site
  - Traffic prediction, classification & anomaly detection
  - Data from operational networks (our own)
  - Usage of mobile data for smart cities
- **Renewable energy integration & management**

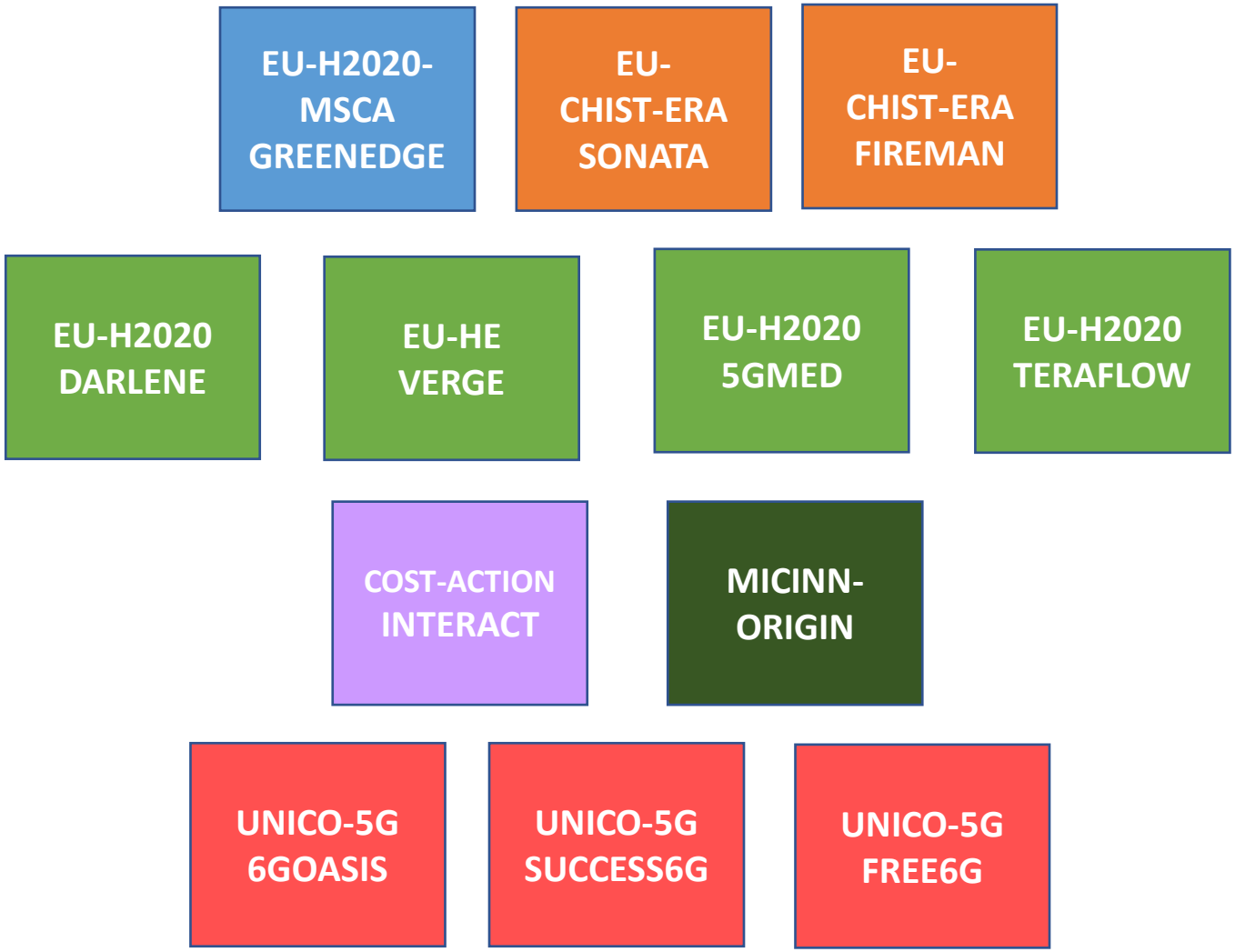








ONGOING PROJECTS



SYNERGIES WITH THE PROGRAM

- **STREAM-B-01-01: System Architecture**
  - AI powered edge cloud continuum
  - Energy efficiency enablers
  - Digital network twinning applied in 6G
  - New communication paradigms with enhanced intelligence (semantic)
- **STREAM-B-01-02: Wireless Communication Technologies and Signal Processing**
  - Novel techniques for integrated sensing and communication (AIoT)
  - Optimal usage of wireless edge caching
- **STREAM-B-01-03: Communication Infrastructure Technologies and Devices**
  - Development of low-energy communication solutions
- **STREAM-B-01-04: Reliable Services and Smart Security**
  - Cooperative holistic E2E security for 6G architectures
  - Zero-touch integrated security deployment
  - Exploitation of (distributed) AI/ML for 6G Infrastructures
- **STREAM-B-01-07: Sustainability Lighthouse**
  - Improving energy efficiency and total energy consumption
  - Investigating network- device performance versus energy consumption trade-offs
  - Developing strategies to ensure that AI/ML to be environmentally sustainable
  - Address energy resilience considering the intermittent availability of renewable energy
- **STREAM-B-01-08: Reliable AI for 6G Communications Systems**
  - Realistic applicability of AI common data sets and/or federated learning methodologies and assessment models, including re-training of models with the introduction/update of the data sets
  - Metrics and models to assess the pros and cons of AI technologies in telecommunications, including aspects as energy efficiency, explainability, reliability, safety and security

Thanks for your kind attention!

Questions?

@sustainable_ai_

Sustainable Artificial Intelligence RU

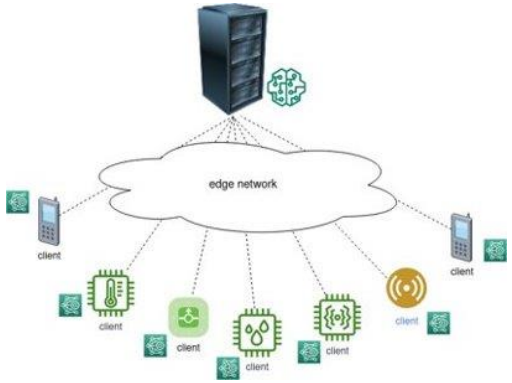
Paolo Dini (coordinator)
paolo.dini@cttc.es

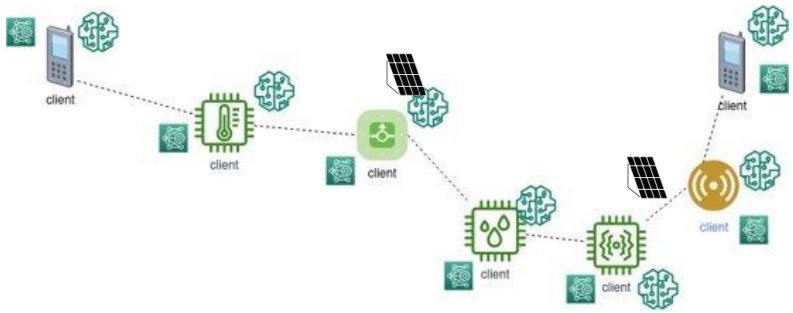
Raúl Parada
raul.parada@cttc.es

ANNEX

COLLABORATIVE & DISTRIBUTED ML

- **Scenario: edge devices w. constrained capabilities and renewable energy**
- **Distributed Training**
  - Learning across the edge devices exploiting the distributed nature
  - ML Solutions: Federated plus Continual, Transfer, Meta
  - Enablers: Orchestration with data Entropy, Value of Information, energy, accuracy

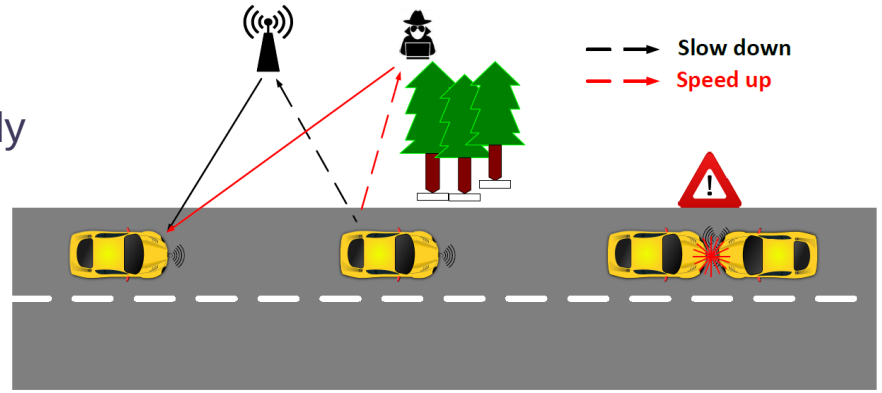




- **Distributed Inference**
  - Goal: increase the efficiency of the models
  - Model adaptation: Gradient compression/quantization, NN splitting
  - Attention mechanisms
  - eXplainable AI

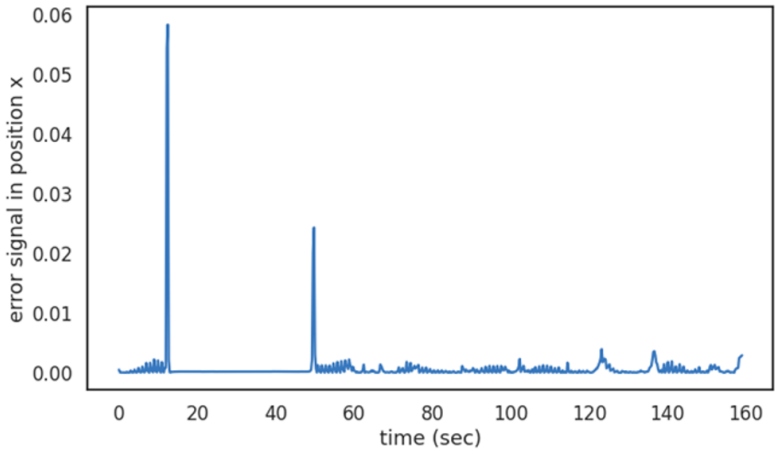
MISBEHAVIOR DETECTION IN VEHICULAR SYSTEMS

- **AI-based solutions** for the detection of highly sophisticated attacks:
  - Deep reinforcement learning
  - Ensemble learning



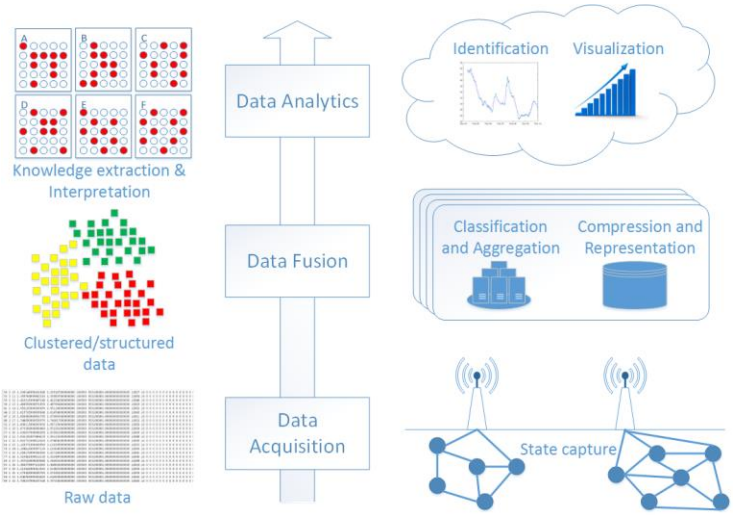
- Lightweight and **online** attack classification for streaming vehicular data (open-source)

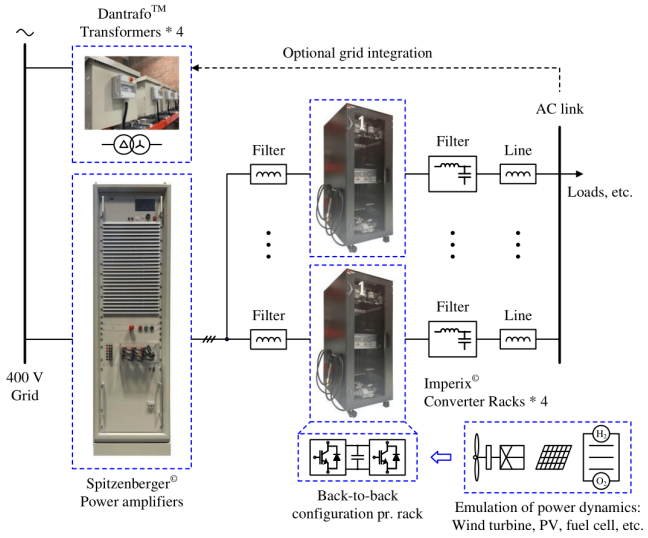
- **Mobility model-agnostic** approaches in th absence of prior knowledge associated with physical traffic phenomena:
  - Spike-based novelty detection
  - Quickest change detection

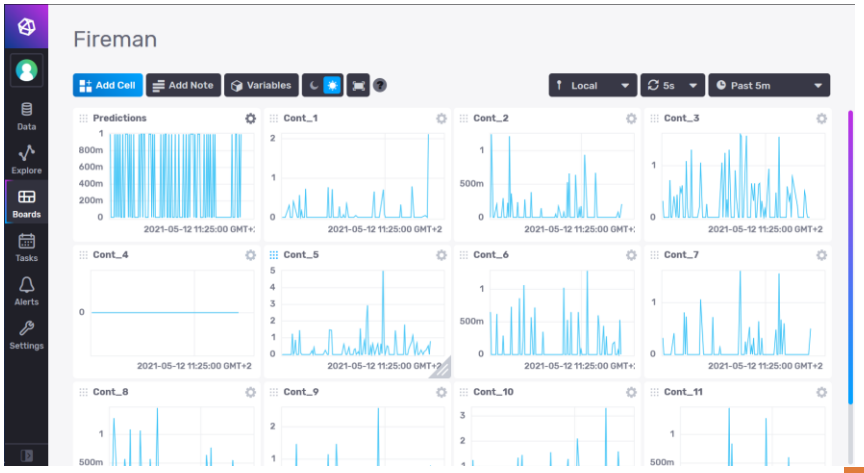


DATA-DRIVEN OPERATIONAL PRINCIPLES OF NETWORKED INDUSTRIAL SYSTEMS

- **Physics-informed** sensor sampling strategies
- Data **reconstruction** of missing sensor observations
- **Explainable AI (XAI)** approaches for regression/classification tasks
- **Beyond-5G** connectivity enablers
- **Digital twin** for fault diagnosis
- **Open-source** end-to-end monitoring solution



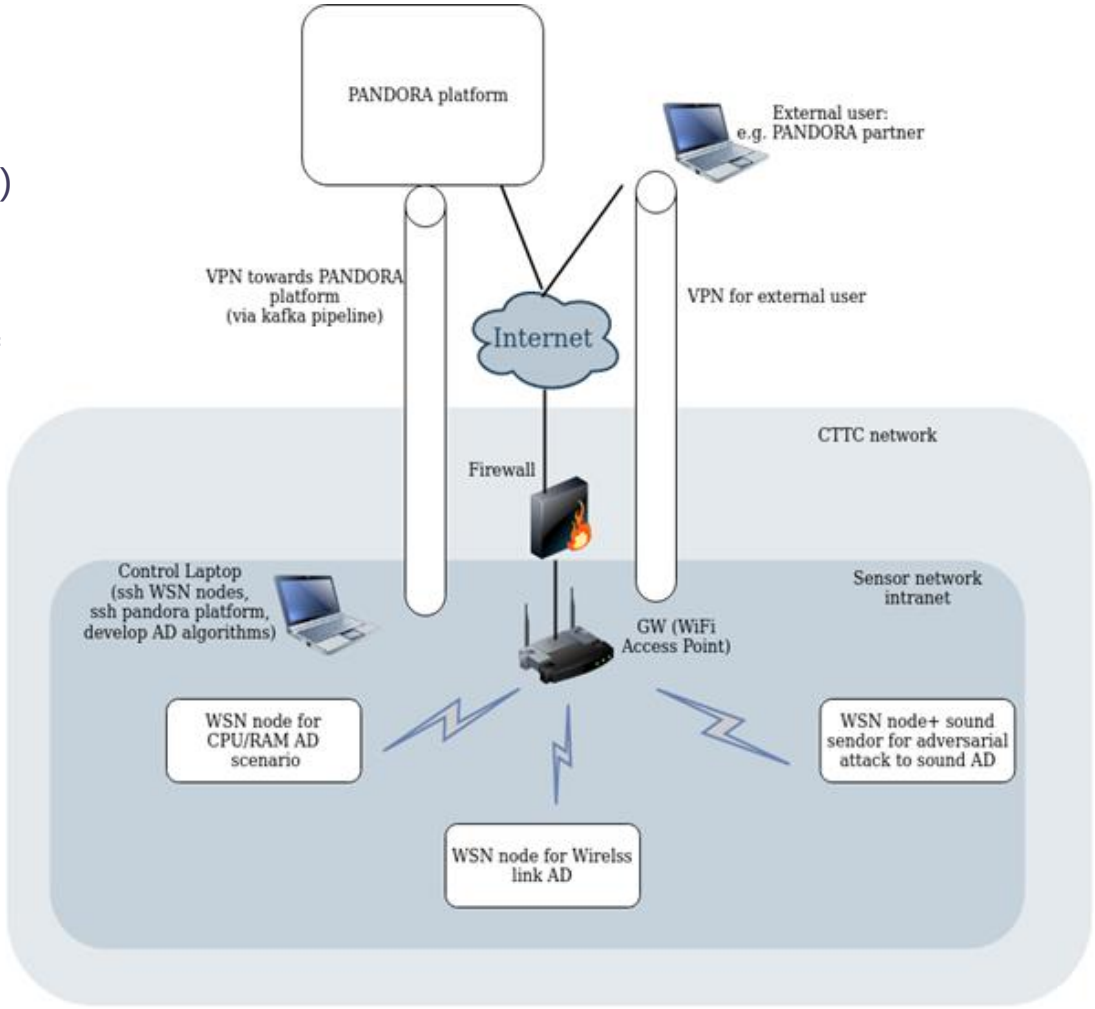




ADVERSARIAL ML FOR IOT

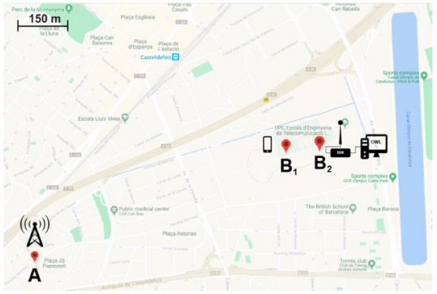
Cybersecurity in IoT:

- A WSN is monitoring and protecting a critical infrastructure (e.g. sound sensors)
- Potential Cyber attacks
  - Attack to the WSN node's resources
  - Jamming attack to the wireless link of a WSN node
  - Adversarial attacks to the information gathered by the WSN
- **ML-based Detection and mitigation of cyber attacks**
  - Time-series anomaly detectors for different data modalities (cpu, ram, RSS, loudness data). E.g. autoencoders
  - Robust ML to adversarial attacks

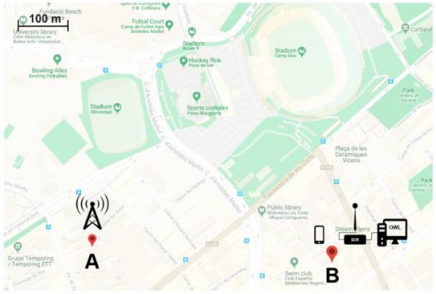


MOBILE TRAFFIC MODELING

- **Physical control channel fingerprinting**
- **Distributed learning** at BS site



(a) Castelldefels: suburban area with a university campus.

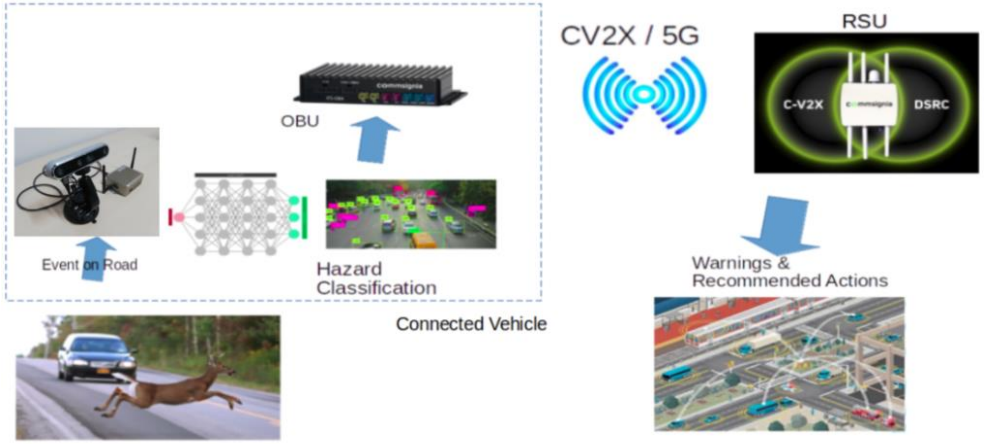


(b) Camp Nou: mainly residential area with Barcelona FC stadium.

- **Traffic prediction** based on RNN and CNN models and with transfer learning
- **Traffic classification:** app identification based on active measurements
- **Joint traffic prediction and classification** using multi-task learning
- **Traffic anomaly detection** for identifying of urban anomalies
- Usage of **transfer and federated learning** to build a general model from multiple cells

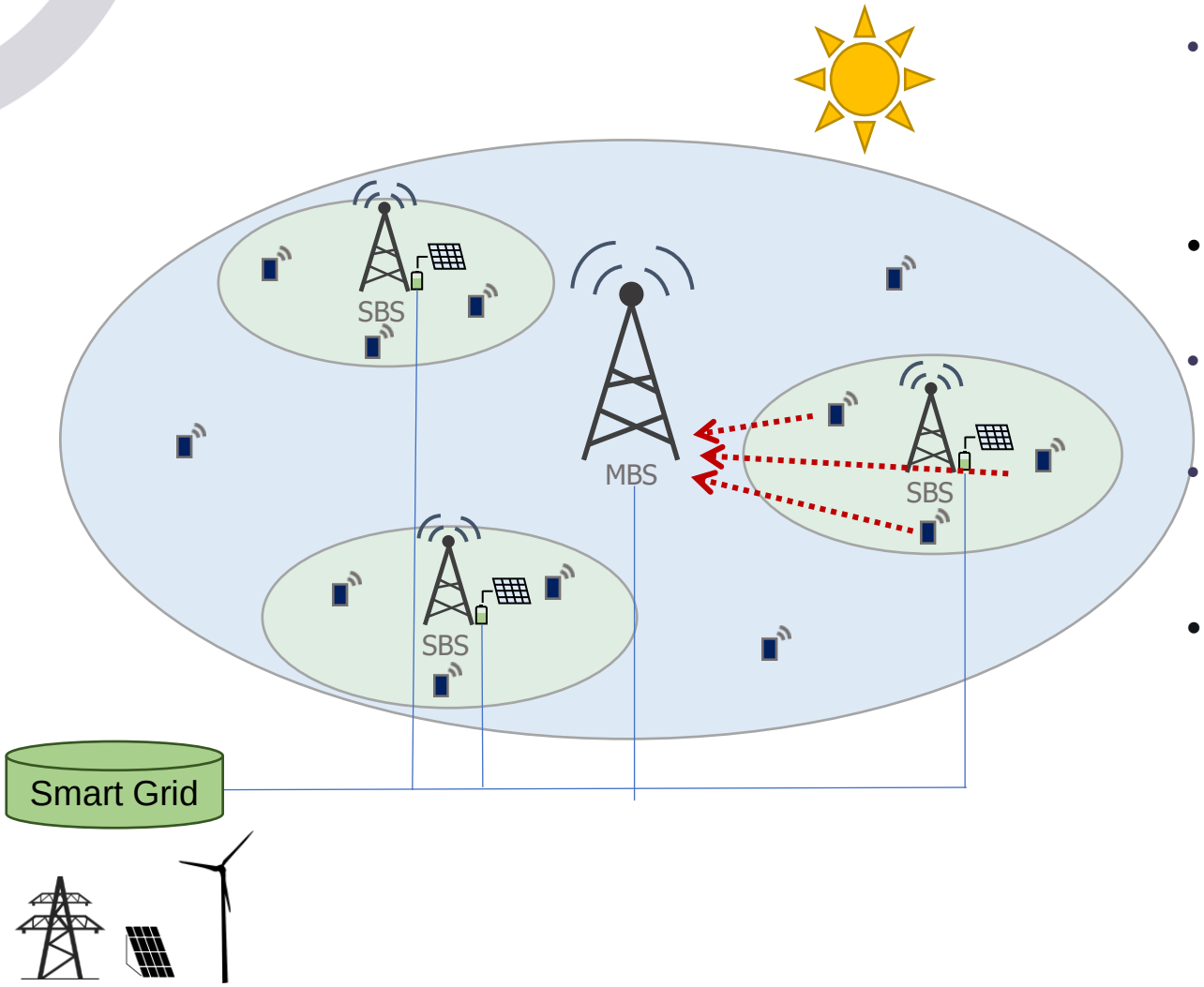
ML BASED AWARENESS FOR INTELLIGENT TRANSPORTATION SYSTEMS

- Solutions for **intelligent transportation systems (ITS)** require understanding (i.e. awareness) of complex dynamics for providing effective solutions.
- **ML algorithms coupled with sensor** networks could provide accurate modeling of traffic and urban environments to enhance road-safety, security, intelligent mobility, etc.



- Example:
  - **V2X-Eyeguard** is a ML solution for real-time video segmentation and object tracking applied to evaluation of hazards in roads
  - V2X integration makes the base for **cooperative awareness** by providing inputs to a distributed model of road traffic. This model could be used to provide traffic **recommendations and warnings, increasing safety and traffic efficiency**
  - Awareness provided by model would be the base to **more complex applications** (e.g. autonomous driving).

ENERGY HARVESTING MOBILE NETWORKS



- **BS (macro and small) are powered with smart grid and local energy harvesters**
- Small BSs perform **traffic and energy offloading**
- **Throughput-energy trade off**
- **Design of agents enabling different BS operation modes**
- The energy harvested at the SBS sites can be **transferred** to other BSs or used to provide **ancillary services**

cttc

Advanced research for everyday life

tecnio catalonia
ACCIÓ
Generalitat de Catalunya
Fins a 31/12/2023

AENOR
Gestión I+D+i
UNE 166002
IDI-0024/2011

HR EXCELLENCE IN RESEARCH