A Hardware-in-the-Loop Framework for Urban Mobility Scenarios within the 5G Trial in L'Aquila

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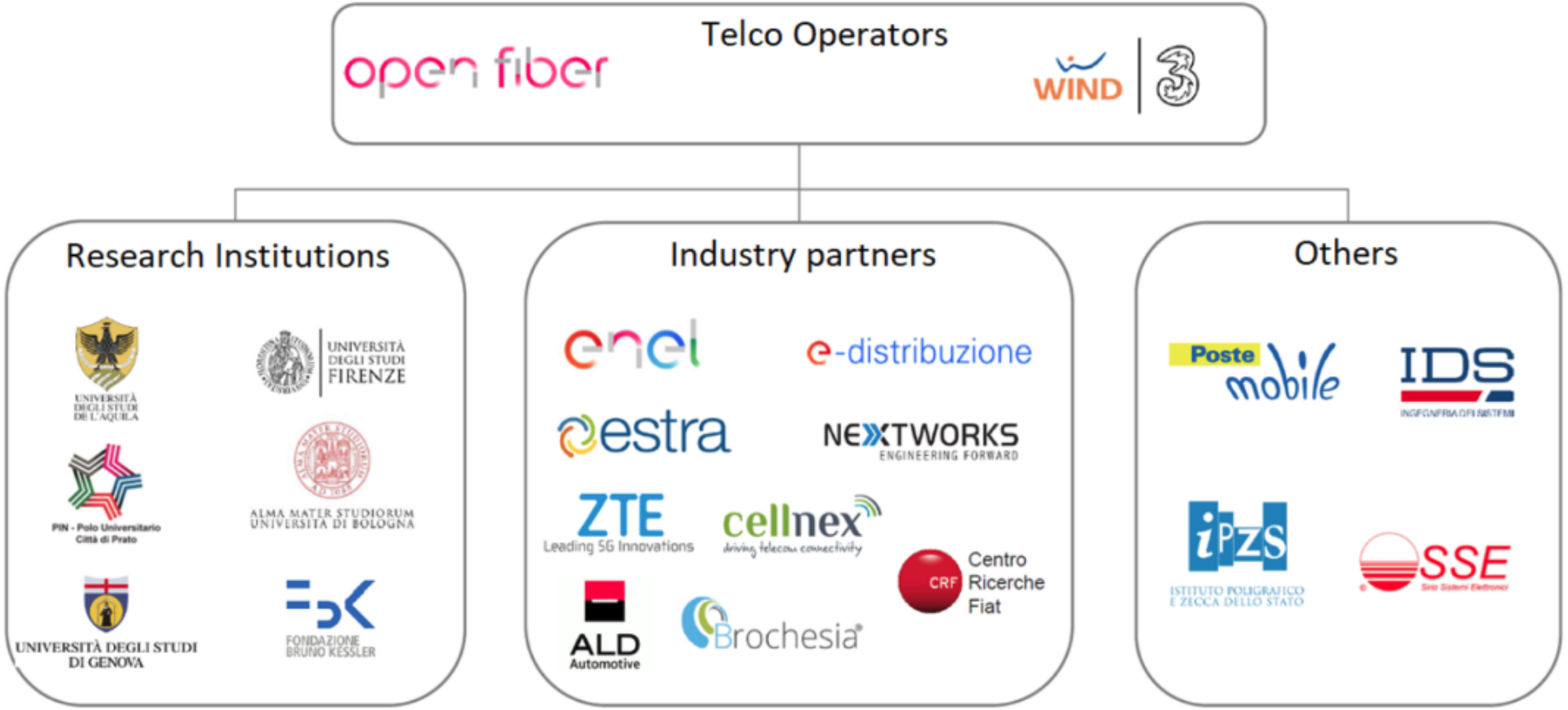
5G Trial in L'Aquila

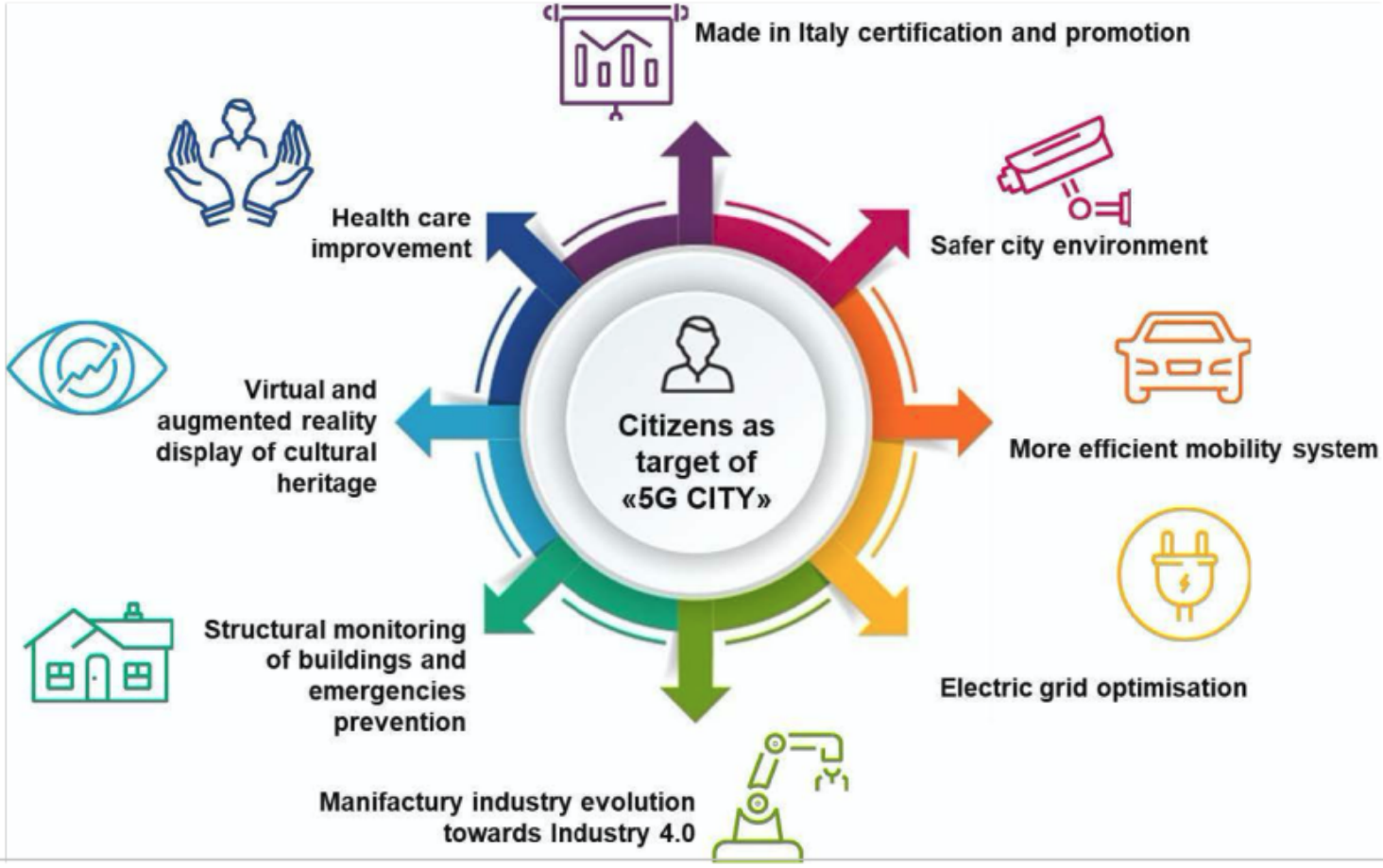
The Italian Ministry of Economic Development (MiSE) on March 2017 opened the call for project proposals for the implementation of pre-commercial experiments for the radio spectrum
3.6-3.8 Ghz.

- Area 1 - Milan - metropolitan area
- Area 2 - Prato and L'Aquila
- Area 3 - Bari and Matera

The Trial Consortium



The “5G City”


Made in Italy certification and promotion
Health care improvement
Safer city environment
Virtual and augmented reality display of cultural heritage
Citizens as target of «5G CITY»
More efficient mobility system
Structural monitoring of buildings and emergencies prevention
Electric grid optimisation
Manifactury industry evolution towards Industry 4.0

5G Trial: Use Cases

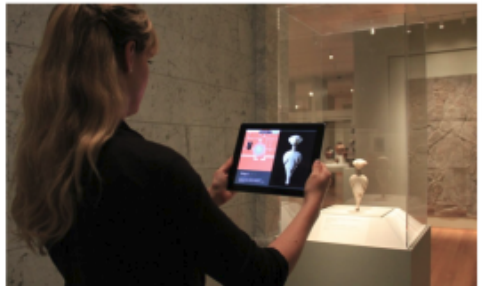
UC #1:Monitoraggio Strutturale

INCIPICT
Innovating City Planning through Information & Communications Technologies

UC #4: E-Health

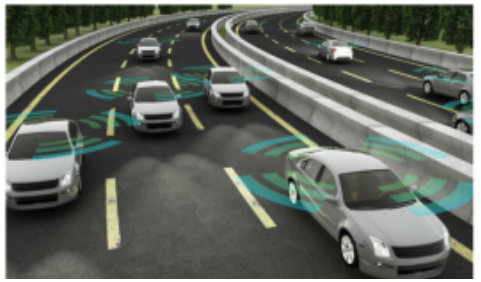
UC #2: Agricoltura 2.0

UC #5: Sicurezza



UC #3: Realtà Virtuale e Aumentata

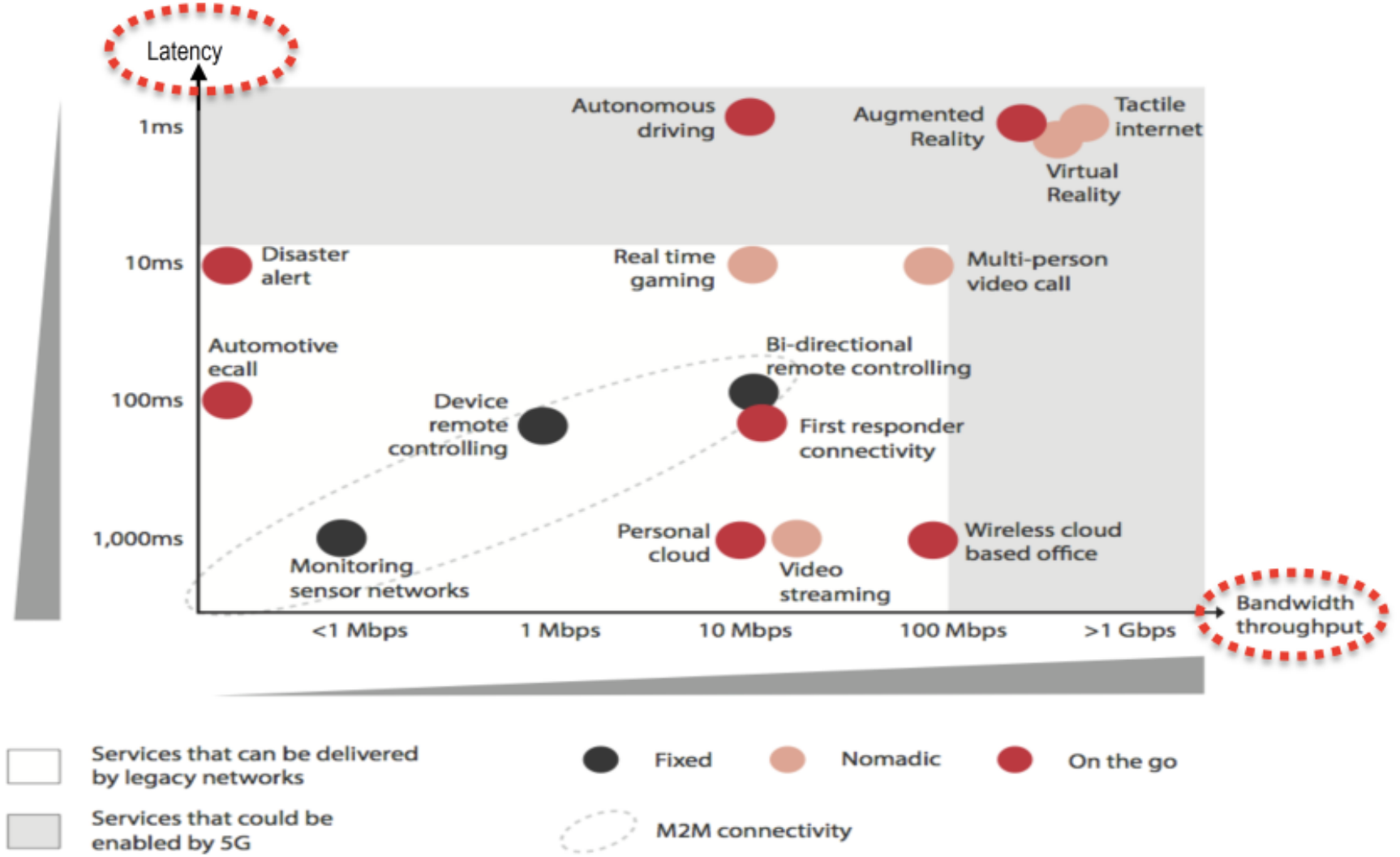
INCIPICT
Innovating City Planning through Information & Communications Technologies



UC #6: Veicoli connessi

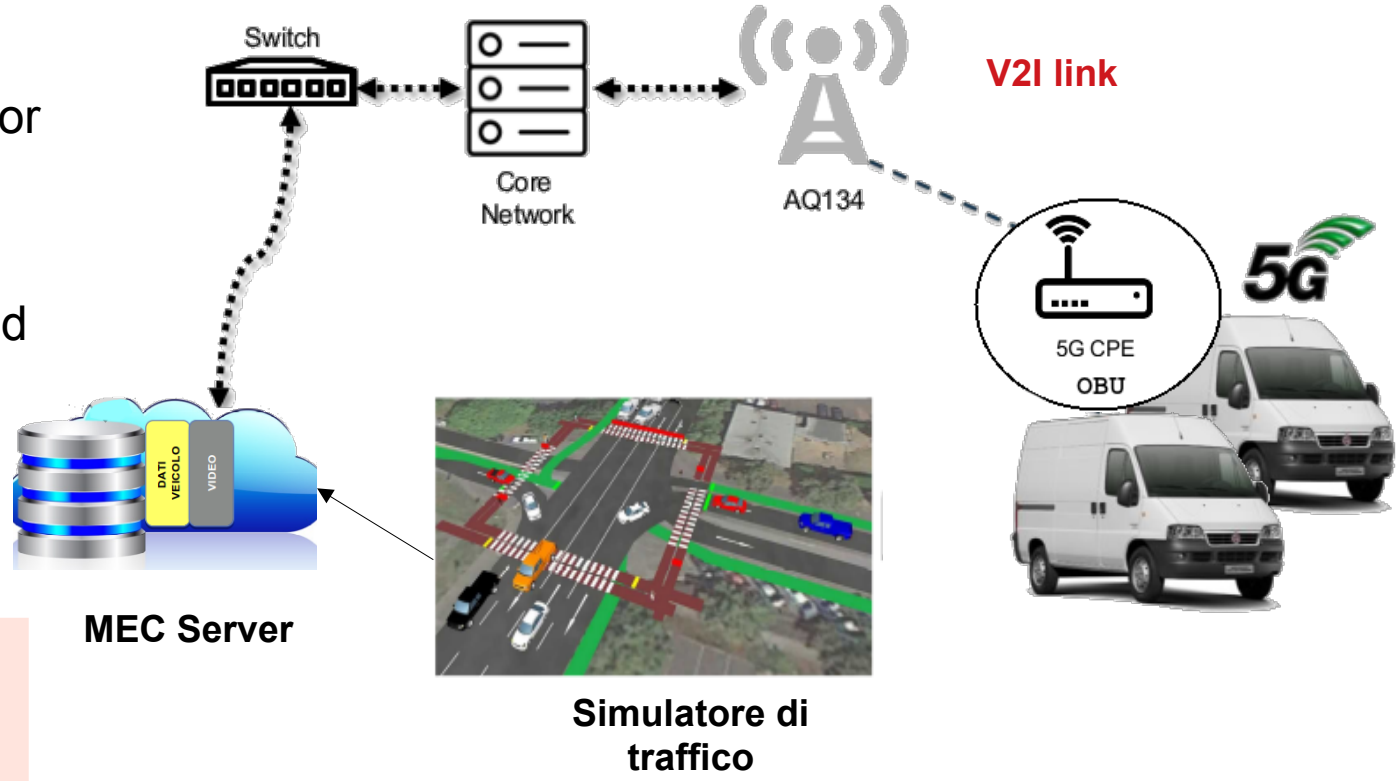
EMERGE

5G Use Cases - Overview



5G Smart Mobility Use Case: Goals and Architecture

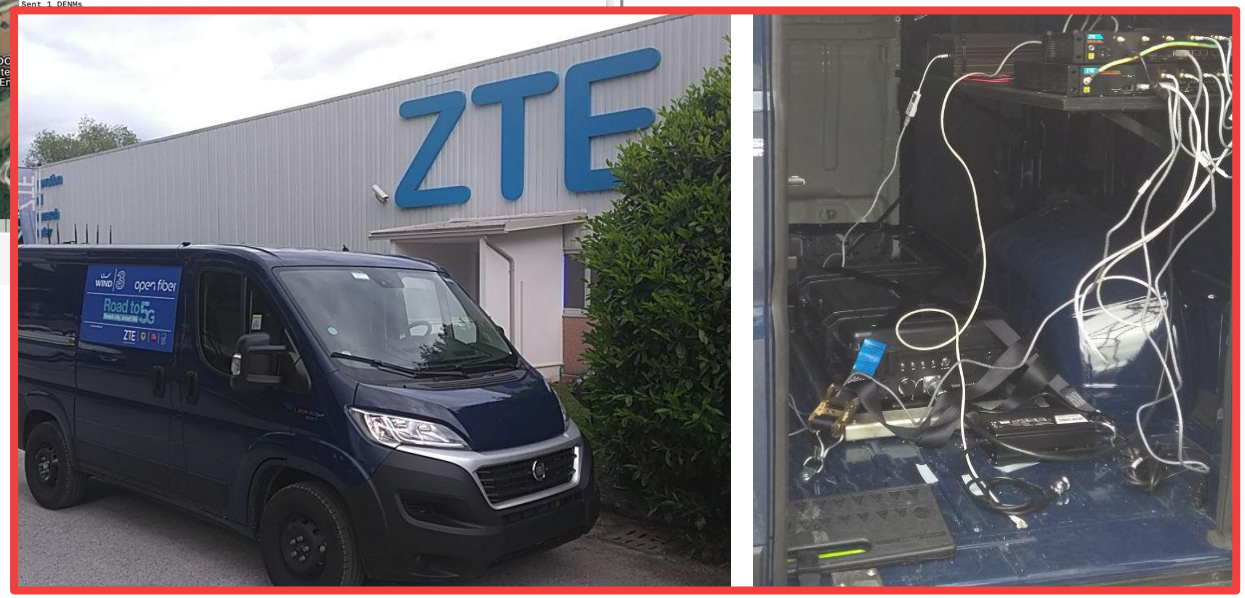
- Exploitation of 5G technology for the **V2I communications**;
- real-time detection of road hazards for users safety and **dynamic maps update;**
- application of **predictive models** and **machine learning** techniques for reaction/avoidance of critical situations.



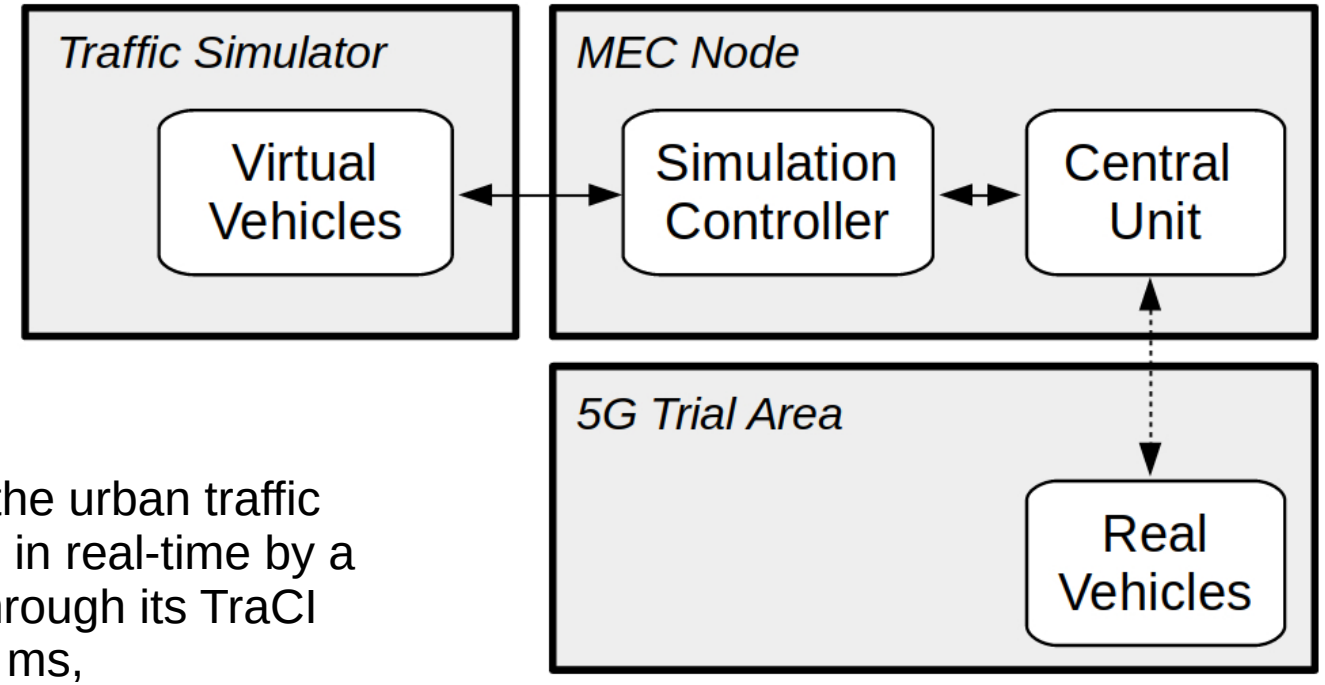
The solution implemented for the field trial relies on the integration of:

1. 5G infrastructure (provided by ZTE)
2. Central Unit (provided by CRF)
3. traffic simulator

5G Smart Mobility Use Case:
Operative Centre and Connected Vehicle

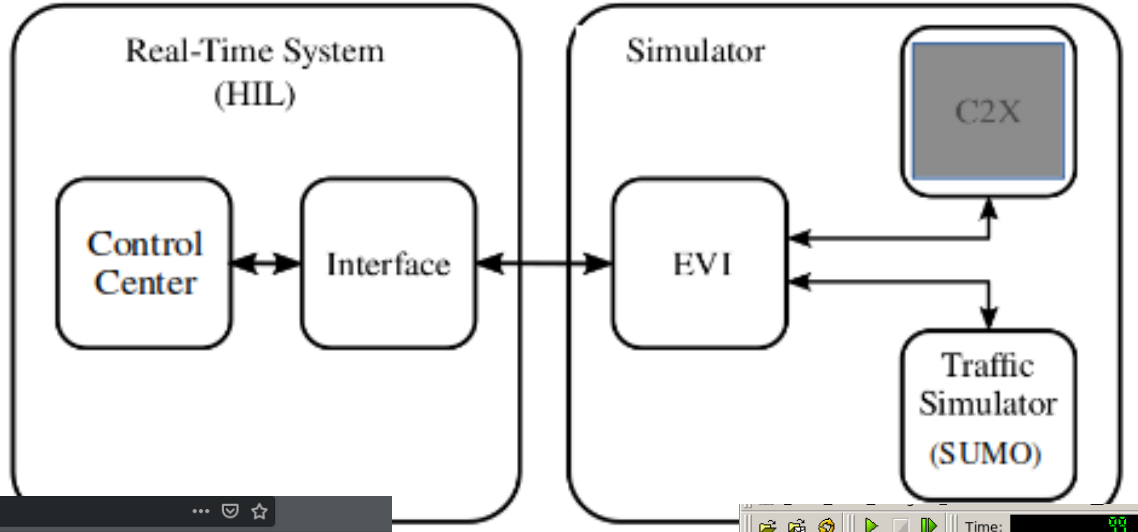


Hardware-in-the-loop Architecture 1/2

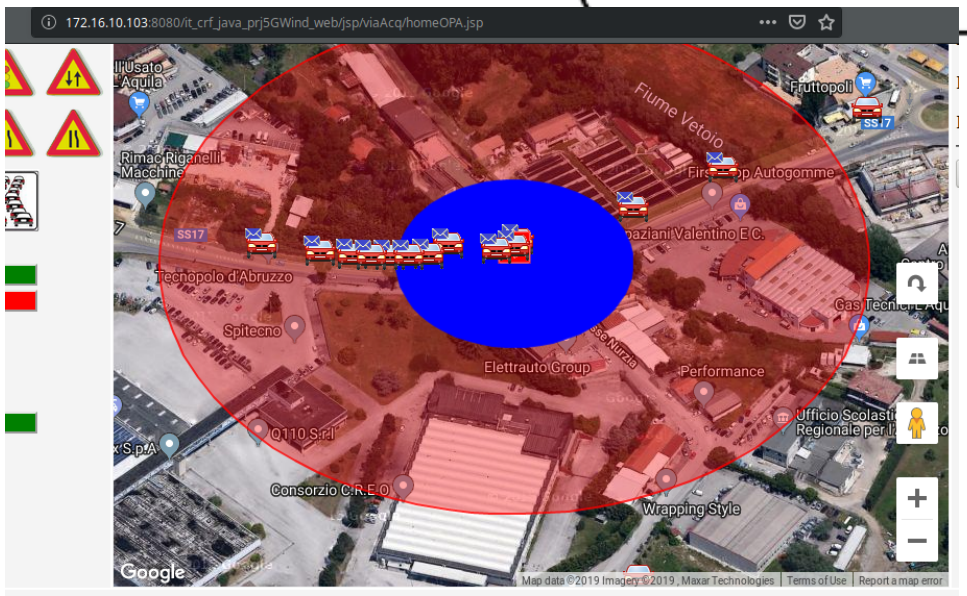


SUMO tool is used for the urban traffic simulation orchestrated in real-time by a Simulation Controller through its TraCI interface → Every 100 ms, the controller drives the simulation a step forward, to keep the model aligned with the real time.

Hardware-in-the-loop Architecture 2/2

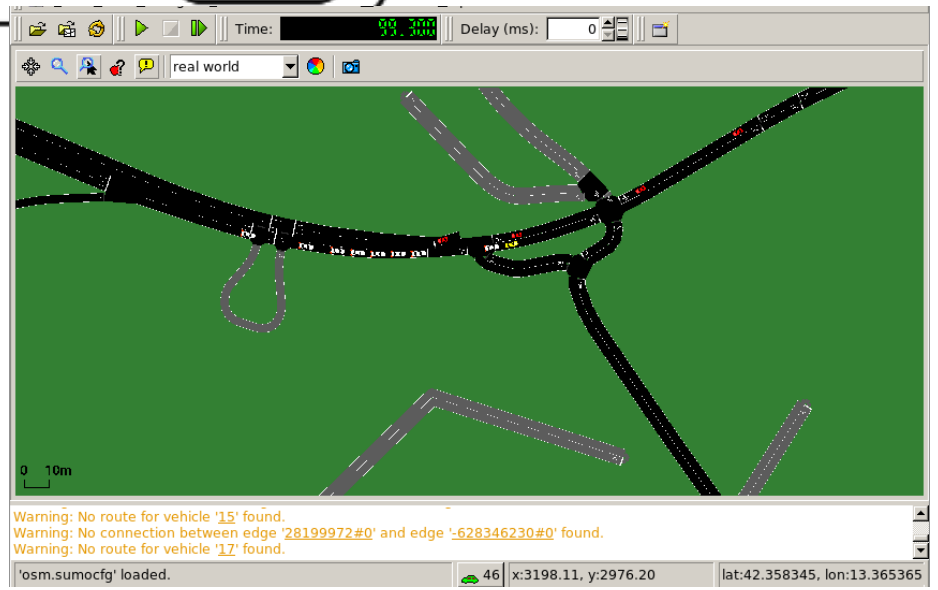


Control Center

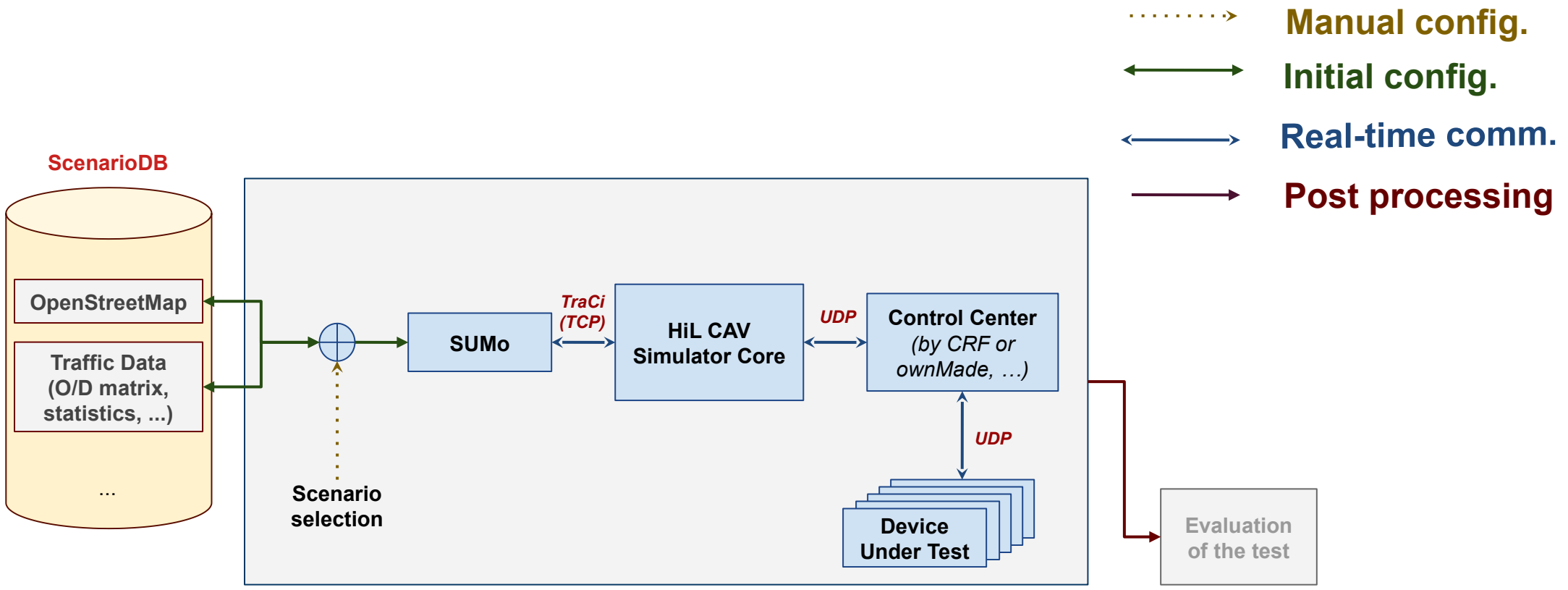


TraCI

Simulation



Hardware-in-the-Loop Framework - Overview



Model Predictive Control: idea

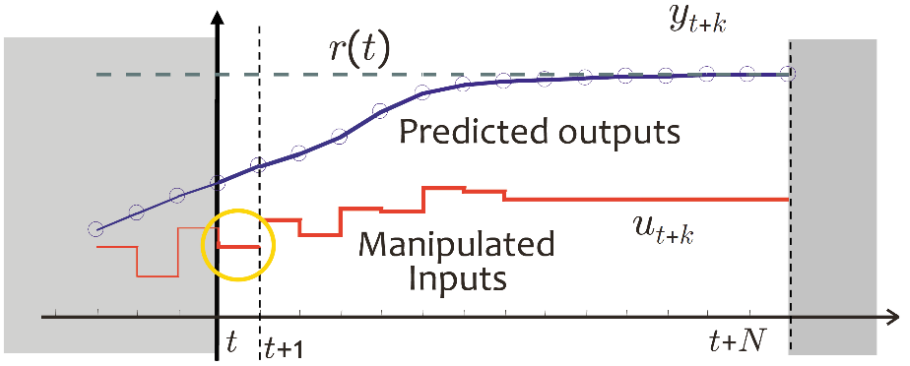
What's the best move considering opponent's intention?

How far ahead can I look?

$don't\ crash$

$stay\ on\ the\ road$

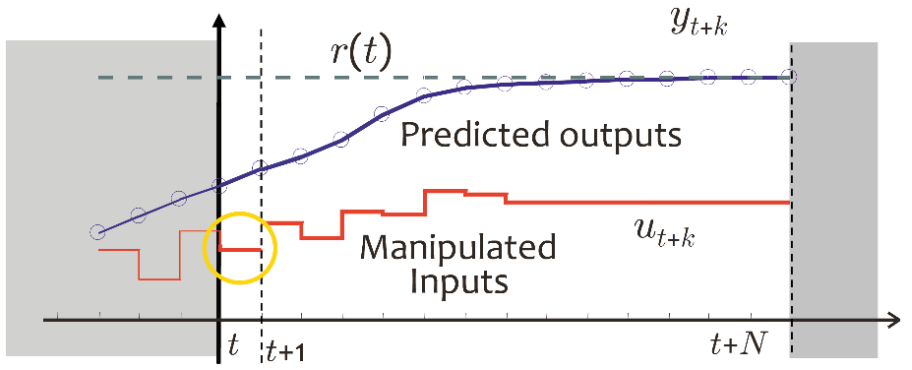
Model Predictive Control Approach

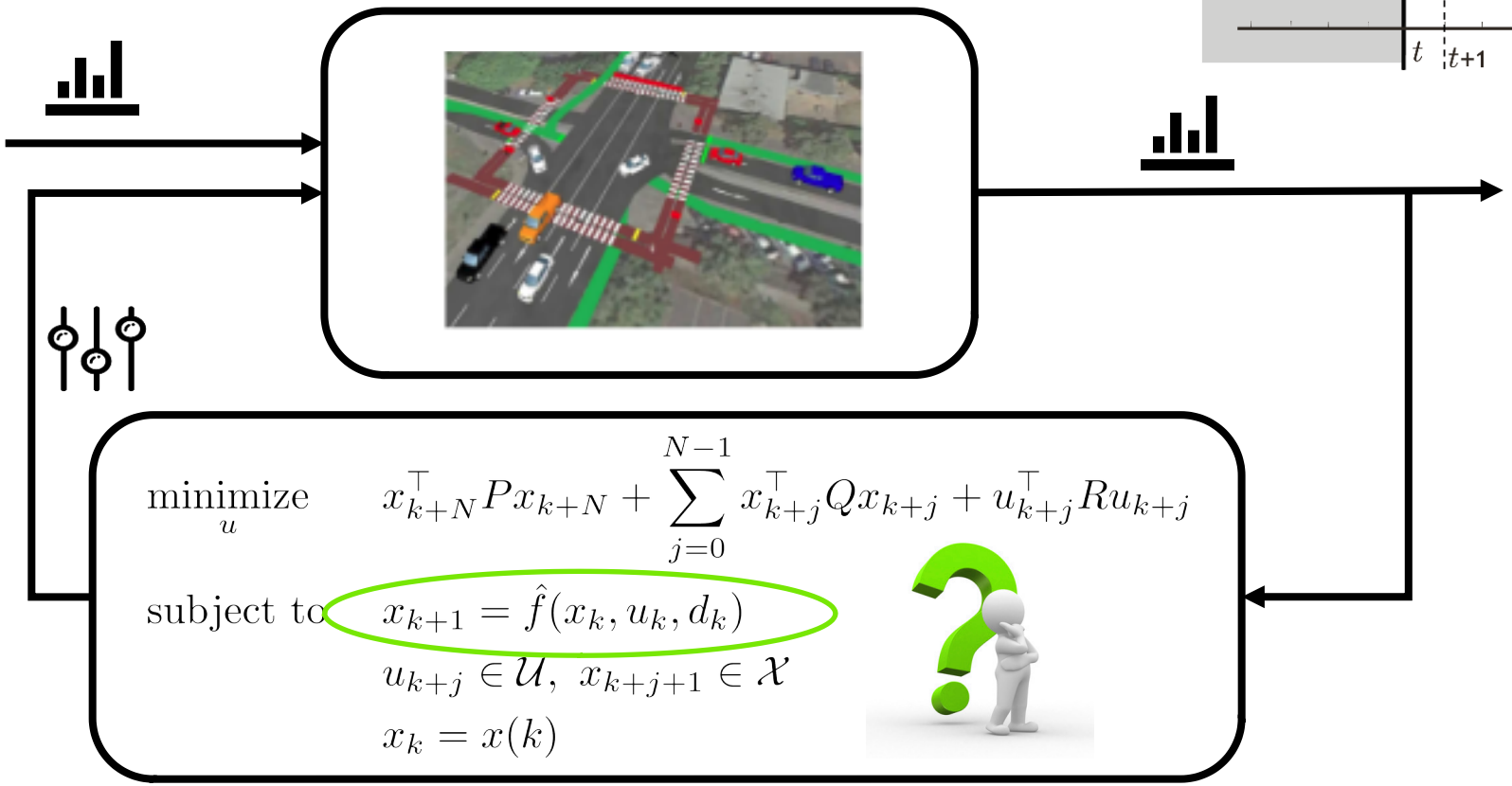


$$x_{k+1} = f(x_k, u_k, d_k)$$

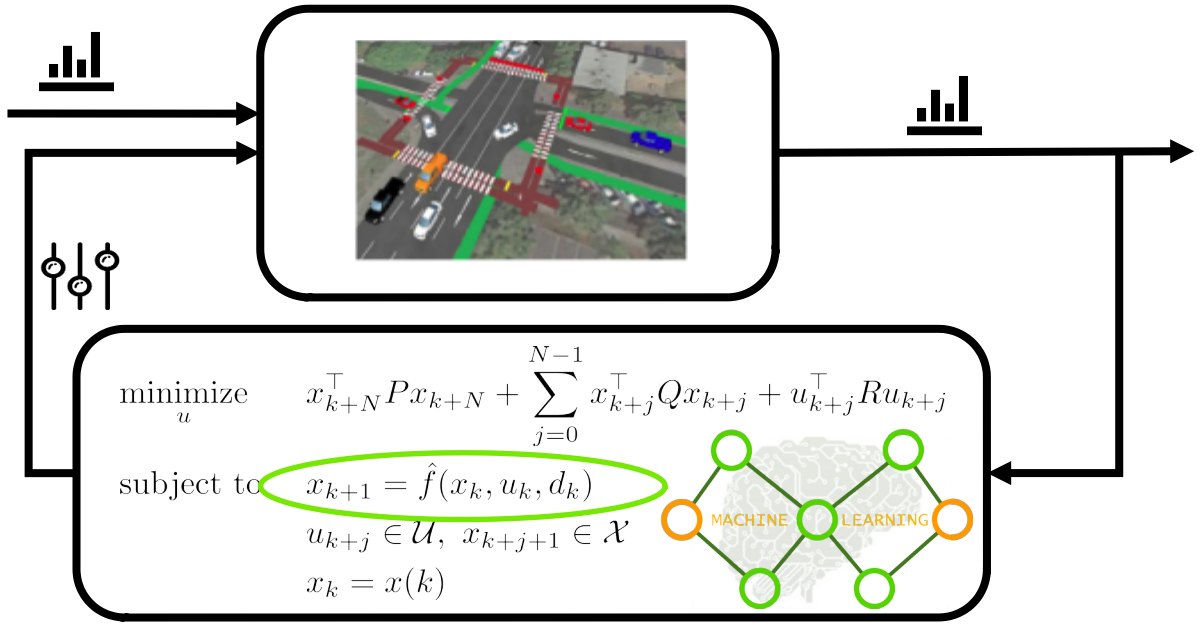
$$\begin{aligned}
\underset{u}{\text{minimize}} \quad & x_{k+N}^\top P x_{k+N} + \sum_{j=0}^{N-1} x_{k+j}^\top Q x_{k+j} + u_{k+j}^\top R u_{k+j} \\
\text{subject to} \quad & x_{k+1} = \hat{f}(x_k, u_k, d_k) \\
& u_{k+j} \in \mathcal{U}, \;\; x_{k+j+1} \in \mathcal{X} \\
& x_k = x(k)
\end{aligned}$$

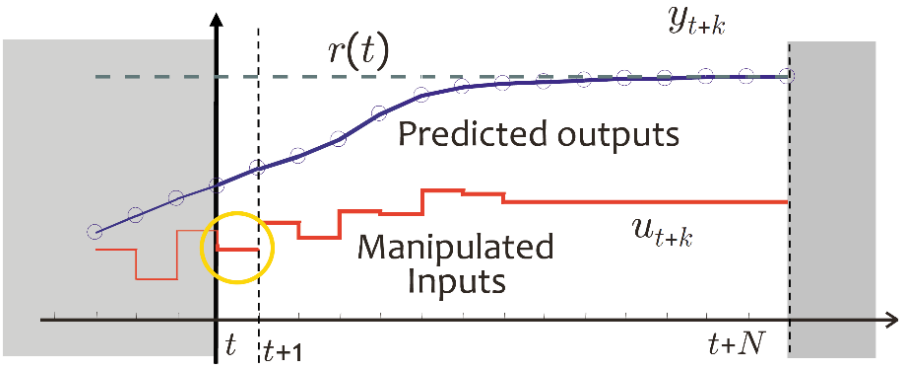
Model-based identification issues





Data-driven Model Predictive Control Approach





ML techniques to fit the output prediction over a horizon of N steps as a function of the current state, of the control moves, and of the disturbances

To sum up…

5G MISE Trial towards applications for C-ITSs:

- 5G based C-V2I communications to make a Central Unit (CU) constantly aware of the street-level status in a given area
- the CU is allowed to send DENM messages back to the vehicles

The hardware-in-the-loop framework:

- mobility simulator SUMO is exploited
- the CU is able to receive CAM messages from both real and simulated vehicles and vice-versa
- information coming from the real scenario are exploited to update the simulation environment

A **Regression Trees (RTs)-based approach** is proposed to predict critical congestion scenarios.

Future work: simulation techniques to implement dense scenarios with realistic mobility patterns, in order to develop and validate the proposed RTs-based strategy.

Thank you for your attention

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