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Vulnerable Road Users Accident Prevention via Smart City Data Fusion

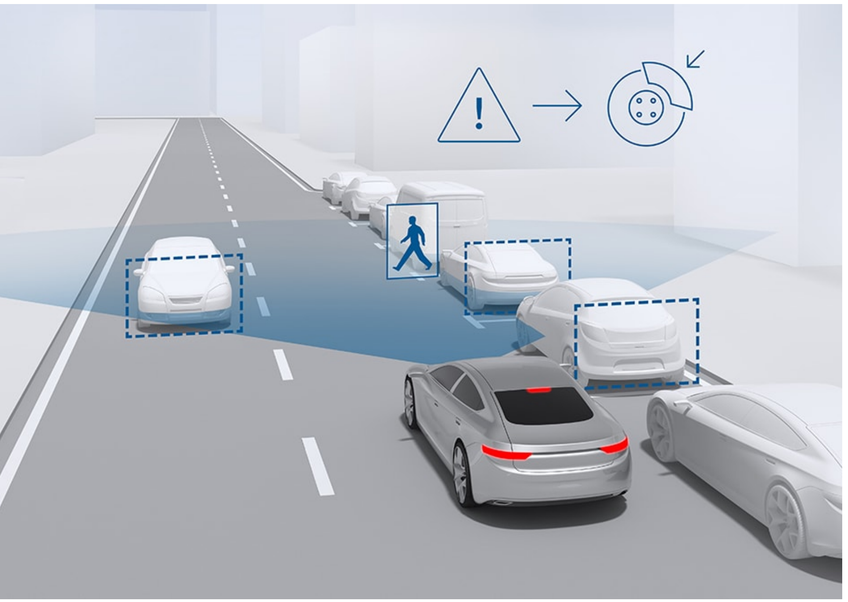
Experimental Evaluation of a 5G MEC Architecture

University of Modena and Reggio Emilia

WHAT'S THE PROBLEM OF OUR CITIES?

CITIES AREN'T MEANT FOR VULNERABLE ROAD USERS

- According to the World Health Organization (WHO), around 280,000 pedestrians were killed in road traffic during 2021.
- From 2010 the number of deaths per year is constantly increasing.

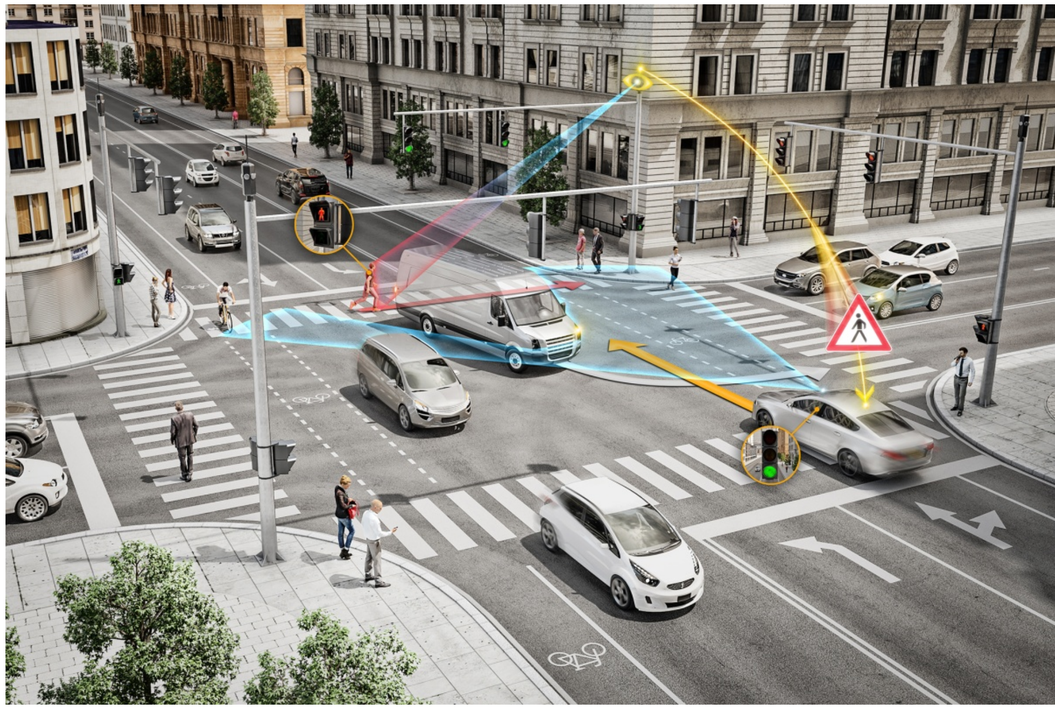


WHAT ABOUT SAFETY ON NEWER CARS?

Cars full of sensor but with limited context

WHAT ABOUT CURRENT RESEARCH?

V2X allows cars to communicate but relies on an inexistent and short-range infrastructure



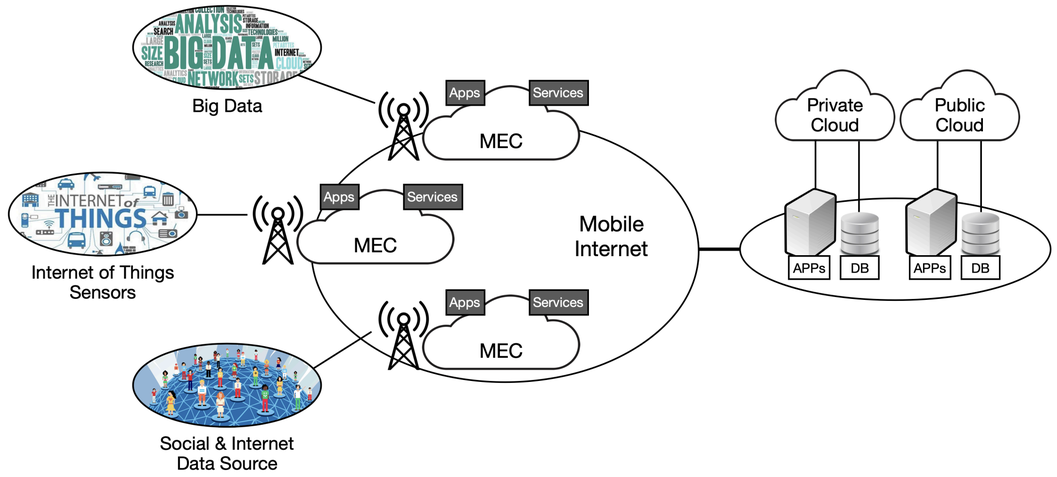
OUR APPROACH: 5G + MEC

5G network ensures:

- Low latencies
- High bandwidth
- High coverage
- Support dense areas

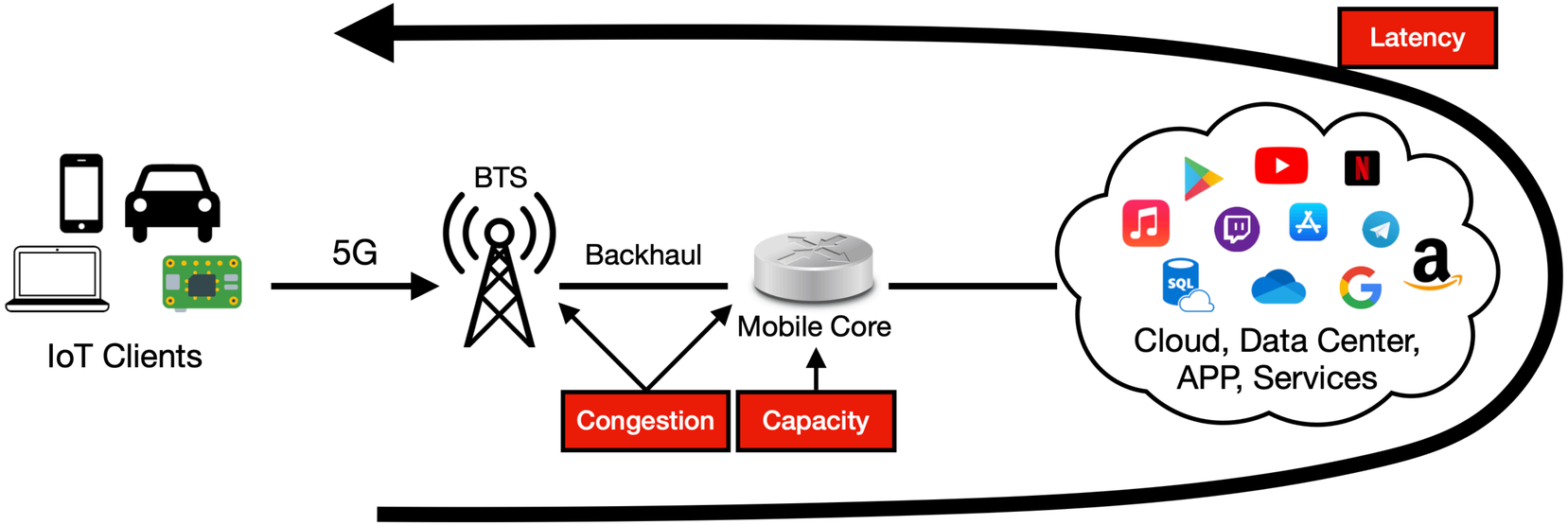
In Multi-Access Edge Computing (MEC):

- Computation is brought ideally to the base of the radio station
- Packets don't flow trough the Internet, resulting in lower and stable latency, as well as higher security
- Will allow external service providers to enable new application scenarios

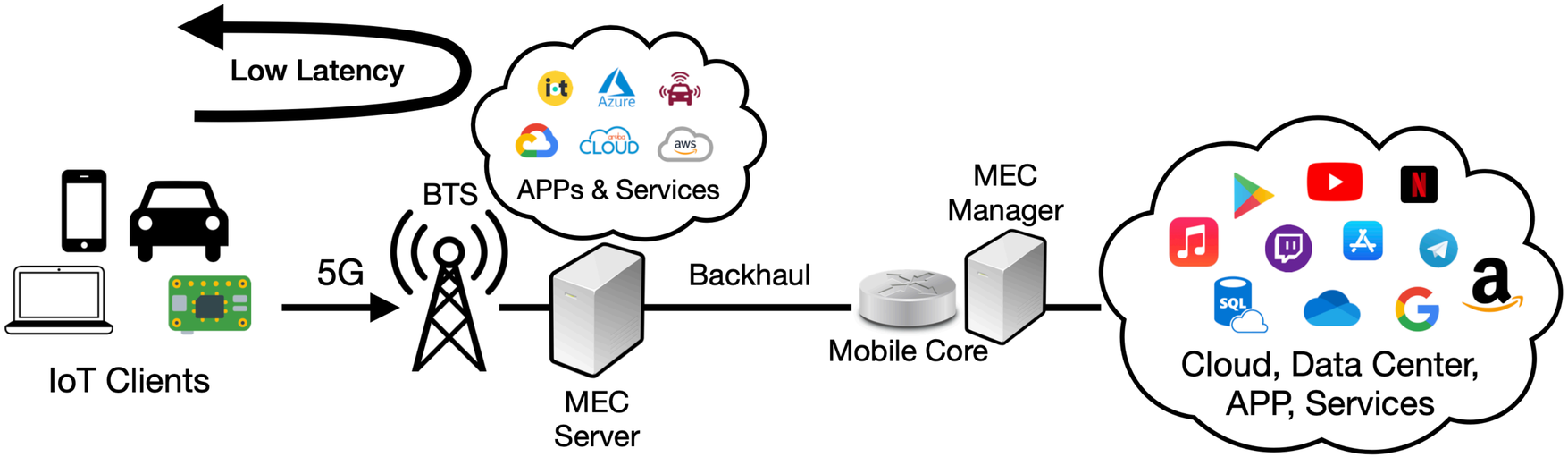


APPLICATION CONTEXT

No MEC



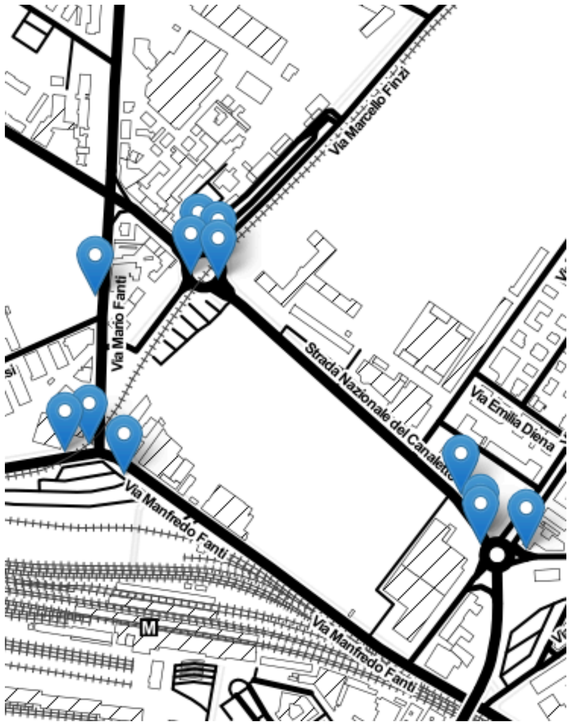
With MEC



OUR TESTBED: THE MASA AREA

The **Modena Automotive Smart Area** (MASA) is:

- located near the center of Modena, Italy;
- a typical mixed-residential zone that is frequented daily by thousands of people;
- equipped with infrastructure for testing connected vehicles and autonomous driving.



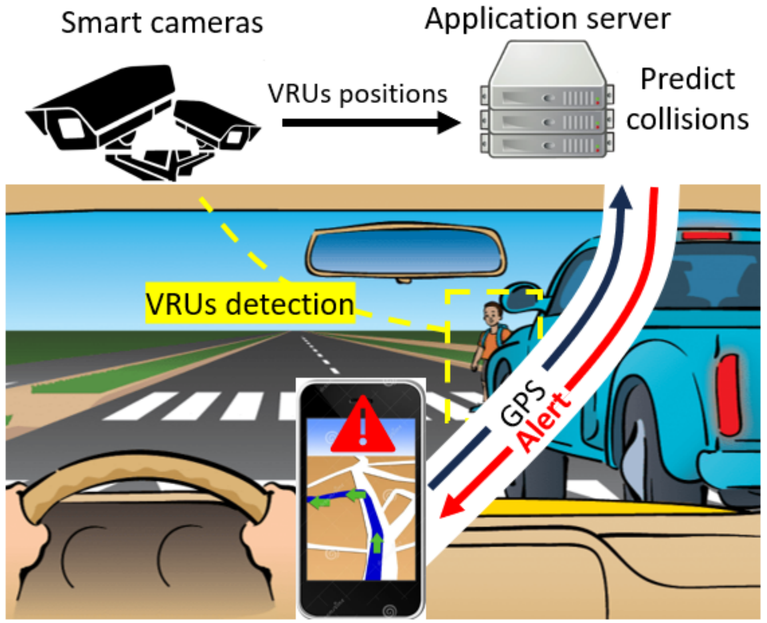
The MASA area and camera locations

THE APPLICATION

- The main goal of the application is to **notify a user about possible collisions** between him/her and other road users

- The location of VRUs and vehicles are:
  - tracked via a GPS-enabled device
  - extracted from the cameras in the area

- Once the application predicts a possible collision, it sends an alert to the user

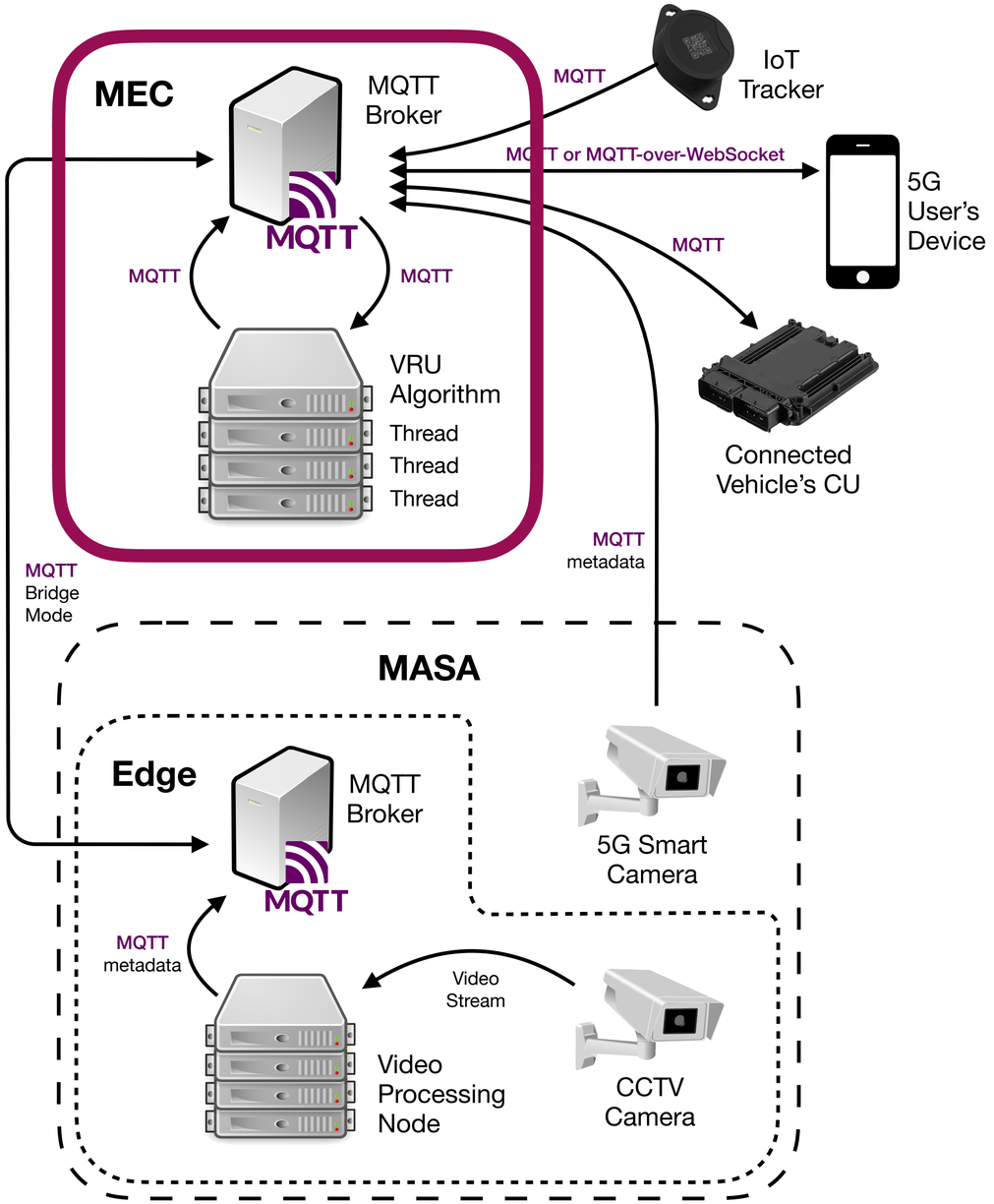


THE INFRASTRUCTURE

MEC Area

- **MQTT Broker**: is the main communication hub and allows clients to communicate their positions to the algorithm and receive alerts.

- **VRU Algorithm**: the newly designed VRU algorithm combines heterogeneous data to identify potential collision risks between vehicles and nearby VRUs. If a potential collision is detected, the algorithm generates alerts for involved entities.

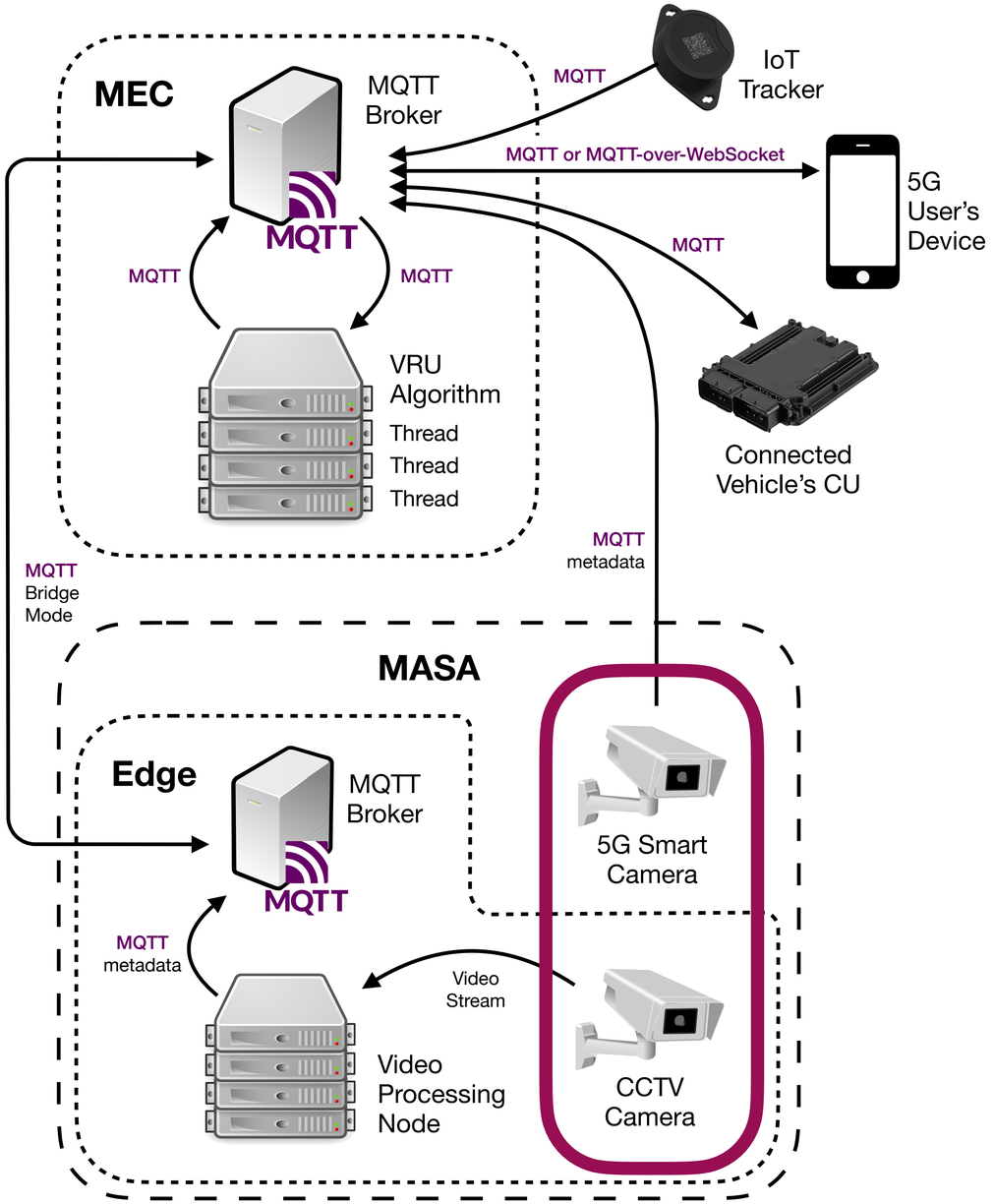


THE INFRASTRUCTURE

MASA Area

- **CCTV Cameras**: video feeds from existing cameras installed by the municipality are processed by the Video Processing Node.

- **5G Smart Cameras**: video feeds are processed onboard, reducing latency caused by data transmission. These smart cameras output metadata that directly feeds the Broker in the MEC via the 5G mobile network.

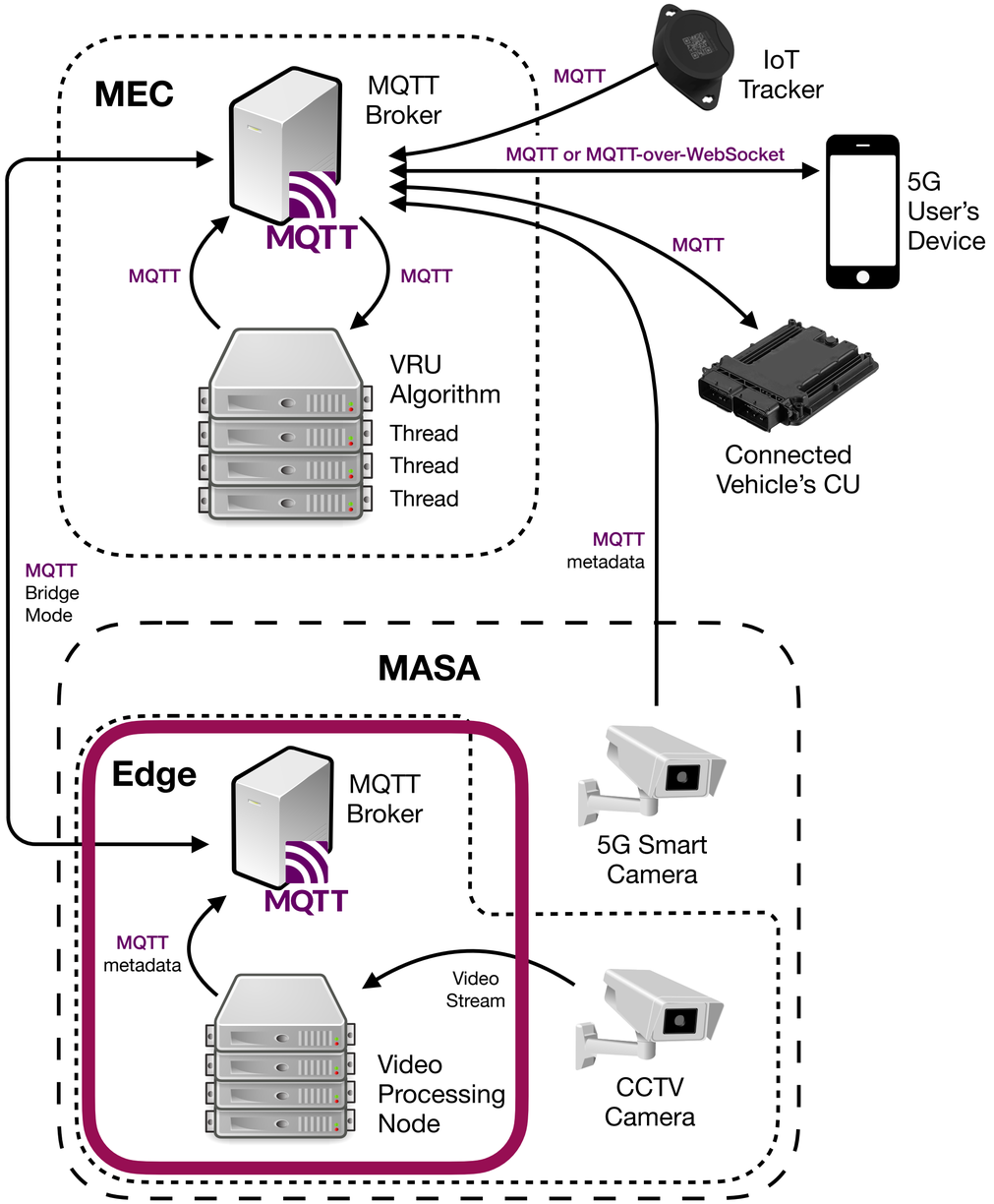


THE INFRASTRUCTURE

MASA Area

- **Video Processing Node**: analyzes the video feeds and outputs position, direction, speed, and type of object or user. The anonymized metadata is send via MQTT to the Edge Broker.

- **Edge MQTT Broker**: essential for having a central point for multiple MEC areas in the future. This central point enables seamless device migration between different MEC areas.

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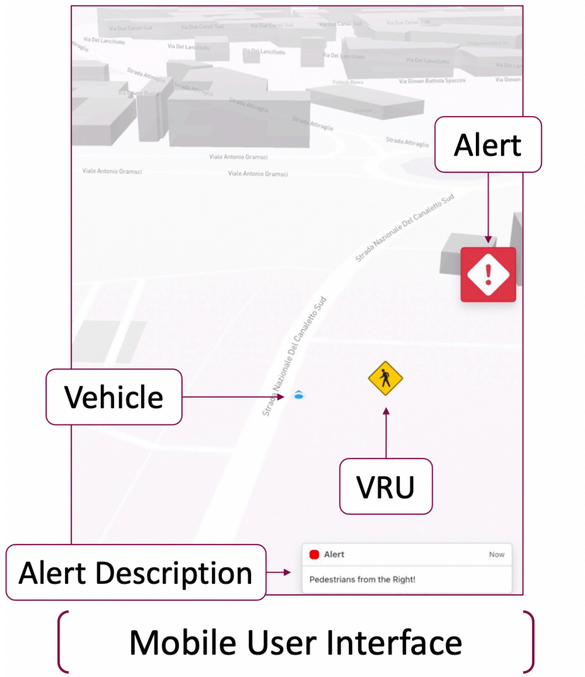
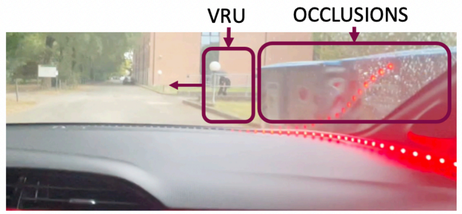
INTERFACES

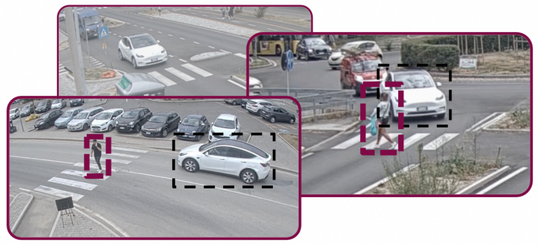


Mobile User Interface

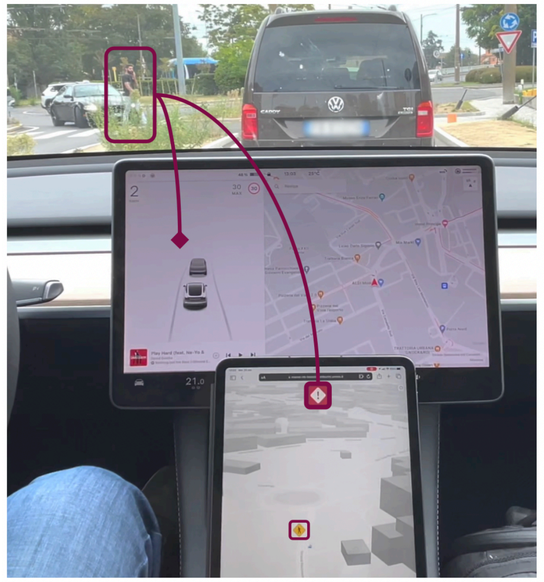


Experimental Human-to-Machine Interface without application

EXPERIMENTS



Distributed Smart City Sensing



VRU's Alert Notification

CONSTRAINTS

End-to-End Delay

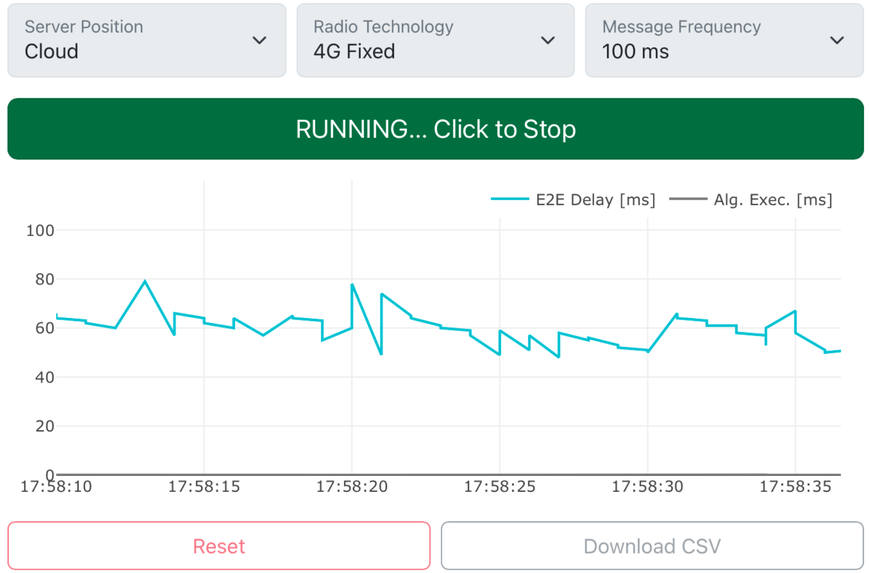
We tested the latency between sending location packets and receiving response messages with alerts

EXPERIMENTAL EVALUATION

We evaluated the application on **two different** hardware **platforms**:

1. 

Raspberry Pi 4 with a Cellular 4G/5G module and a Python script

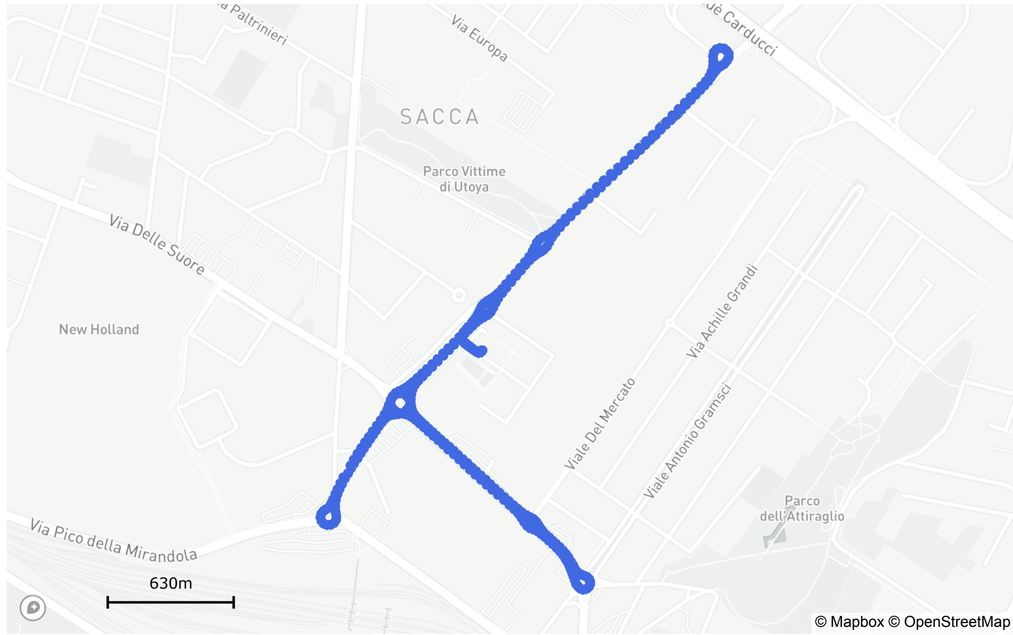
2. 

Android **Tablet** with a web-based benchmarking application

EXPERIMENTAL EVALUATION

The **benchmarking applications** perform similar operations as the VRU app while returning messages with computation and transmission times for each step in the chain.

Experiments have been conducted using different data frequencies, connection technologies (4G or 5G), and server locations (MEC or Cloud).



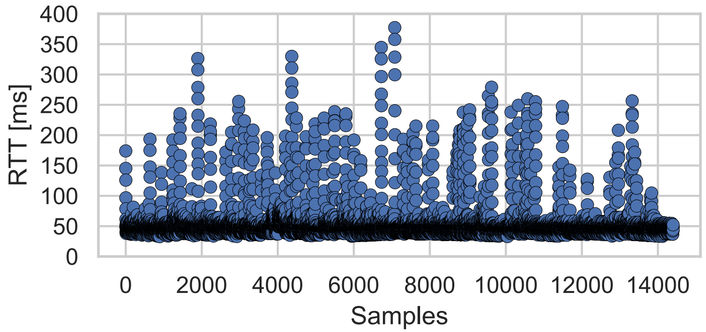
The closed loop used for the tests

EXPERIMENTAL EVALUATION

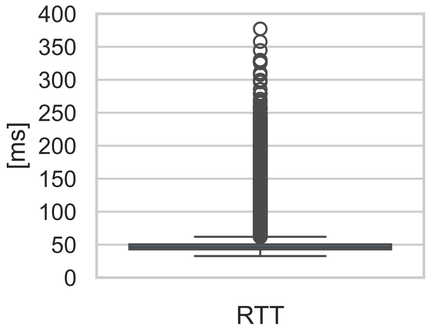
Device: **Raspberry Pi**

Connection: **4G**

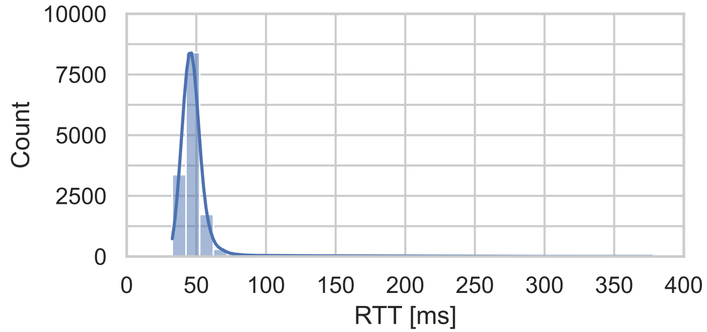
Frequency: **40Hz**



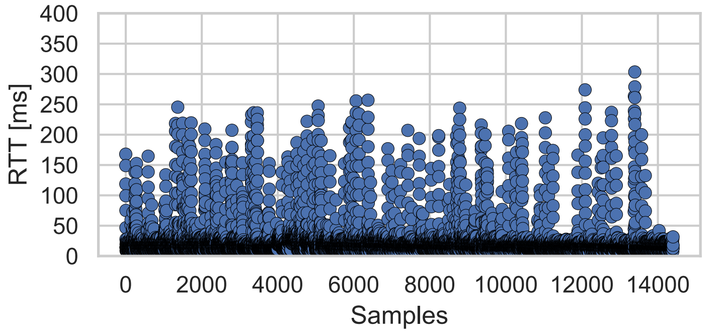
RPi - **Cloud** - Measurements



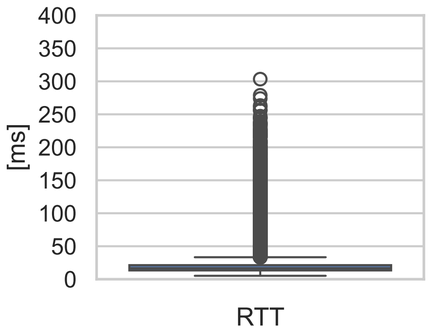
RPi - **Cloud** - AVG Value



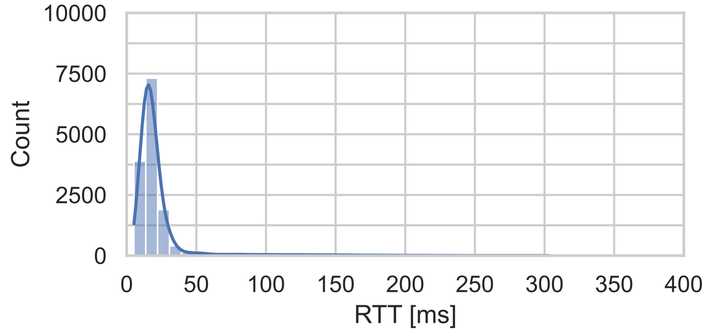
RPi - **Cloud** - Distribution



RPi - **MEC** - Measurements



RPi - **MEC** - AVG Value



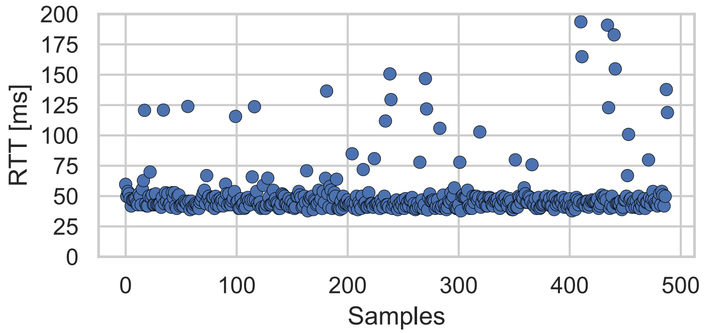
RPi - **MEC** - Distribution

EXPERIMENTAL EVALUATION

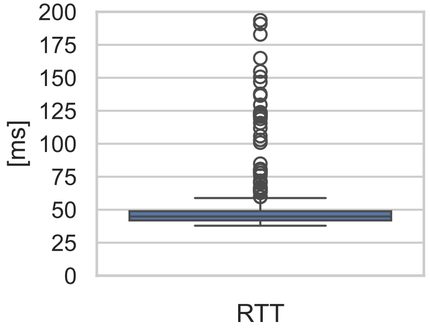
Device: **Tablet**

Connection: **5G**

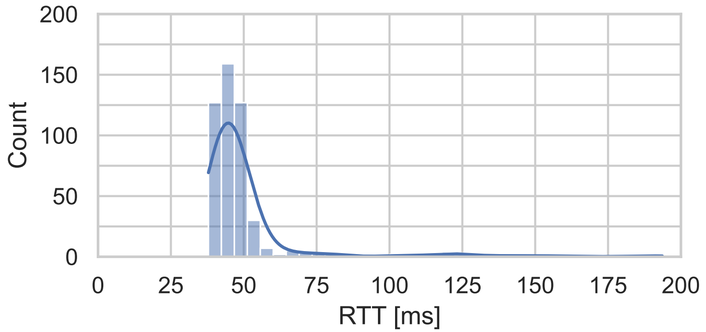
Frequency: **10Hz**



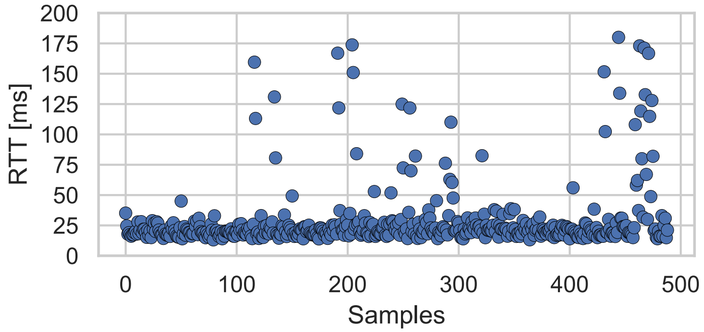
Tablet - **Cloud** - Measurements



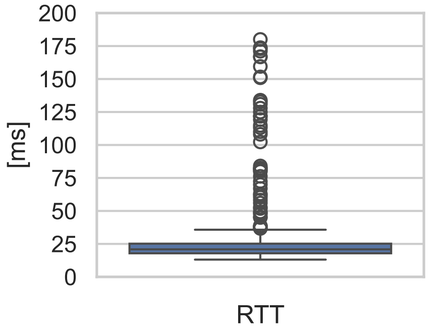
Tablet - **Cloud** - AVG Value



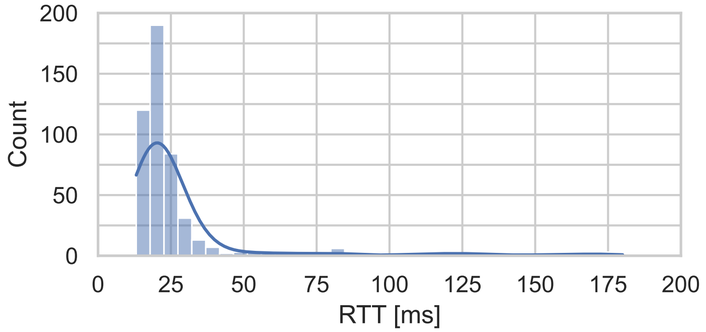
Tablet - **Cloud** - Distribution



Tablet - **MEC** - Measurements



Tablet - **MEC** - AVG Value



Tablet - **MEC** - Distribution

EXPERIMENTAL EVALUATION

Raspberry Pi - Cloud Server

Raspberry Pi - MEC Server

Geographic areas where the delay is consistently above 100ms may be associated with infrastructure load or radio communication interference at the access network stage.

RESULTS

The application showcases a solution that:

- Is capable of potentially reaching a wide number of users;
- Don’t requires additional hardware;
- Is cost-effective and deployable in various environments.

Initial experimental results show that **the use of MEC facilities** notably supports the deployment of this kind of application by **reducing communication latency** between the users and the infrastructure.

FUTURE WORKS AND CONTACTS

- **The current** geometric nature of the collision prediction **algorithm is limiting**; future works include a more advanced ML algorithm.
- We plan to measure the end-to-end (E2E) **delay of the entire loop**, from the detection of dangerous situations by the camera to the alert provided to the driver.

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