Demonstration of a V2X Use Case Using MEC-assisted 5G Emulation Framework

Madhuri Annavazzala, Arun Kant Dubey, Supriya Dilip Tambe,
Bheemarjuna Reddy Tamma, and Antony Franklin A
Department of Computer Science and Engineering, Indian Institute of Technology Hyderabad
Email: {cs21mtech02003, cs20mtech12008, cs18resch11002, tbr, antony.franklin}@iith.ac.in

***Abstract*—With the advancements in 5G technology, Multi-access Edge Computing (MEC) has always been at the forefront due to its ability to provide additional computational power with reduced network latency compared to cloud computing. Most applications from the Vehicle to Everything (V2X) and Intelligent Transport Systems (ITS) domains are stringent in latency requirements, for which MEC is an excellent enabler. As per MEC architecture, MEC applications can leverage the benefits of storing essential information as a part of MEC services to further reduce the latency. In this work, we enhance an in-house 5G emulation framework by integrating it with ETSI MEC Location Service API for supporting various ITS use cases. We demonstrate the use case of providing proximity alerts to the drivers using SUMO platform and a mobile application.**

I. Introduction

Advancements in the Vehicle to Everything (V2X) technology have enabled significant progress in autonomous vehicles. Using V2X, vehicles can now communicate information like position, velocity, and other road information in real-time with nearby vehicles as well as with the infrastructure. However, most vehicular applications have strict requirements pertaining to latency. In other words, information arriving from the vehicles needs to be processed, and suitable assistance is to be provided back to the User Equipment (UE) or to the vehicles equipped with On-Board Units (OBUs) within a specified latency. The placement of such a service that provides the needed assistance to the UEs has a significant role in bringing down the latency for communication. This is where Multi-access Edge Computing (MEC) is beneficial because it not only provides extending computational capabilities but also helps in reducing the overall network latency when compared to cloud service [1]. This work demonstrates one such benefit of integrating ETSI MEC Location Service API [2] with the 5G System that has been enhanced with the control-plane LoCation Services (LCS), which provides dedicated location-based assistance to the vehicles using 5G Data Plane (DP) messages when the nearby vehicles are within a vulnerable distance from each other.

Fig. 1 shows the architecture of the proposed MEC assisted 5G-V2X system. Here, the location details of different vehicles are populated at the MEC Location Service using the control-plane-based location service of the 5G emulation framework. ETSI provides MEC platform architecture, which includes different MEC services and MEC applications. APIs use Mp1 interface to communicate between the MEC platform and the MEC applications to support various MEC applications [5]. These service APIs help software developers to build innovative solutions that make use of semantic information available effortlessly at the network edge. The MEC Location Service API [2] is one such MEC service that provides location-related information to the MEC platform or authorized applications. In our use case, we integrate the 5G framework with the MEC components to demonstrate an end-to-end location service.

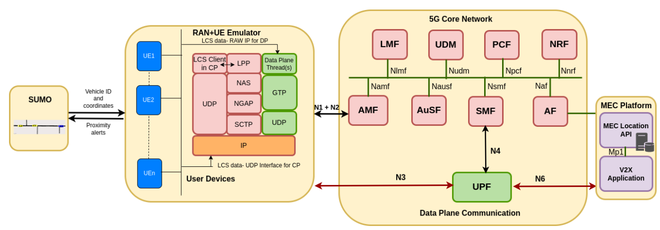


Fig. 1: Architecture of MEC assisted 5G-V2X system.

II. End-to-End Location Service Framework

The proposed MEC assisted 5G-V2X system extends the framework described in [4] by adding the following key components (refer Fig. 2):

- 5G system augmented with location services.
- MEC platform with MEC Location Service API and a V2X application.
- SUMO/UE application interface.

A. 5G System Augmented with Location Services

The Location Management Function (LMF), which is a part of the 5G emulated framework augmented with the support for LCS, interprets the data carrying the location information from/to UEs using LTE Positioning Protocol (LPP) messages in the control plane [6]. RAN+UE emulator builds an LPP message and sends it to Access and Mobility Function (AMF) using Non-Access Stratum (NAS), Next Generation Application Protocol (NGAP) encoding. These messages are sent as a notification response to an Application Function (AF) instance that has subscribed to get the UE location information via AMF. The population of this location information is done in the database located at the MEC Location Service.

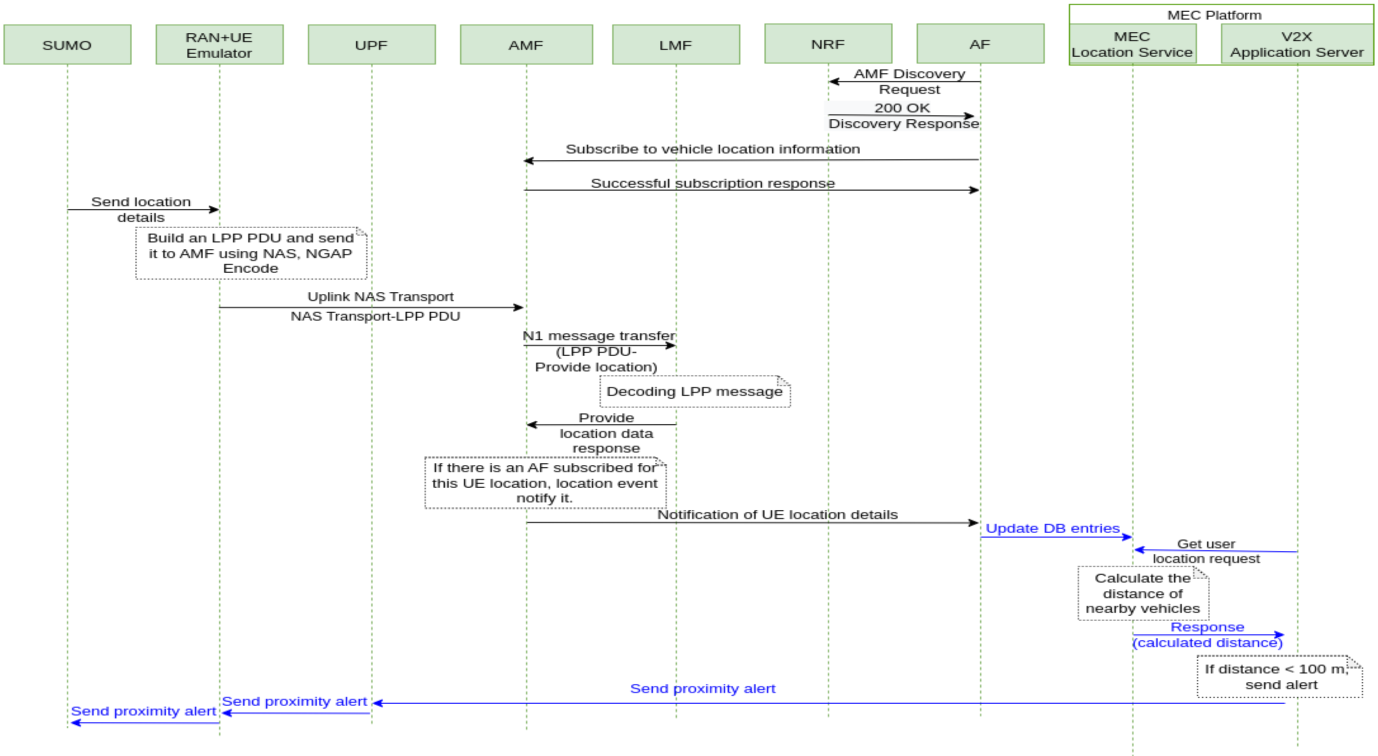
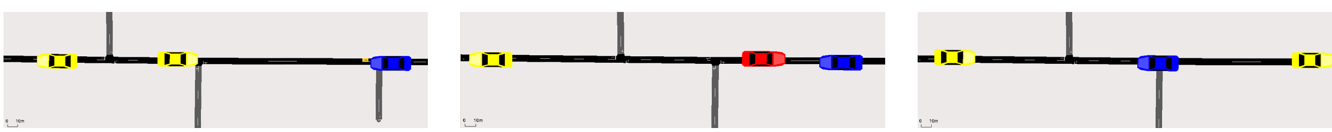


Fig. 2: End-to-end sequence diagram of MEC assisted 5G-V2X location services.



(a) (b) (c)

Fig. 3: Demonstration of the V2X use case in the SUMO platform.

B. SUMO/UE Application Interface

SUMO is an open-source simulator that helps to model different traffic scenarios with automobiles and pedestrians. In our use case, it generates the location information of the vehicles in the traffic scenario such as vehicle ID, latitude, and longitude, and then sends it to the RAN+UE emulator, which is a part of the 5G system emulation framework. Visualization of the calculated distance is done by changing the color of the nearby vehicle to red when the target vehicle is in the vicinity of 100 meters. A mobile application (refer Fig. 4) has also been built which receives the alerts of the proximity alert from the V2X application server in the form of notifications as an alternative means of visualization of the demonstration.

C. MEC Platform - MEC Location Service API and V2X Application

The MEC platform consists of two entities: MEC Location Service and V2X Application [5]. MEC Location Service populates the UE location information from AF into the local database. We have used a NoSQL database constructed using MongoDB, which manages these inserts using multiple threads. The coordinates (latitude and longitude), stored in the JSON format (refer Figure 5), pushed periodically by the AF into the database, are used to calculate the distances between the target vehicle and all other vehicles in the traffic scenario created for testing purposes.

The V2X application server queries the MEC Location Service API to fetch the location distance information periodically or when a particular condition (such as the distance between two vehicles is less than or equal to 100m). The V2X application can use this dedicated MEC Location Service to provide its own functionality, in our case, to provide proximity alerts to the vehicles. These alerts from the V2X application are sent via RAN to SUMO using the data plane consisting of the User Plane Function (UPF).

III. Location-based services: A Demonstration

For the demonstration of the proposed end-to-end framework, vehicle UEs (realized using SUMO), 5G Core, RAN+UE emulator, MEC location service, and MEC server application are hosted on a computer with Intel i7-7500U CPU 2.70GHz with 4 cores and 8 GB RAM. AF subscribes to

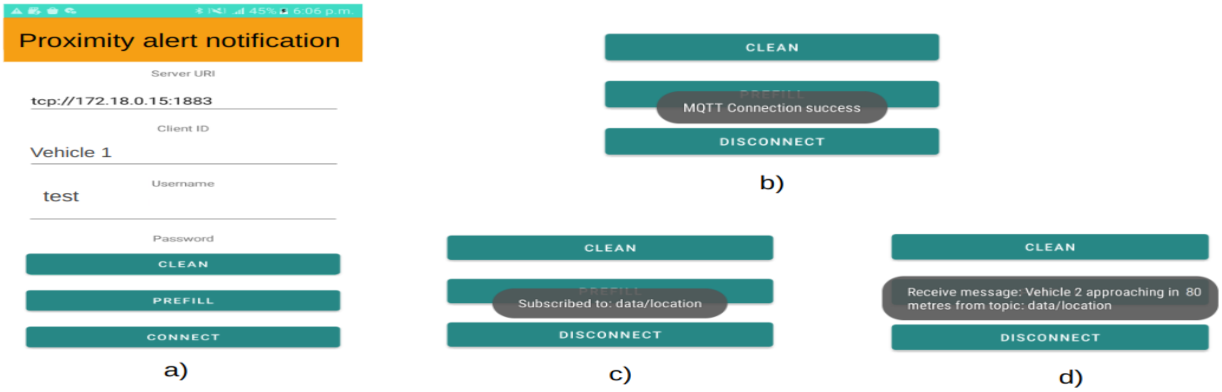


Fig. 4: Mobile application for proximity alert notifications: a) User registers in the app by entering the MQTT broker address, b) MQTT connection on successful authentication, c) Subscribing to the "data/location" topic to avail location services, and d) Notification message indicating the vehicle ID of the approaching vehicle and distance from it.

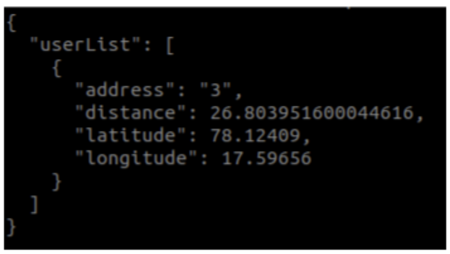


Fig. 5: JSON format consisting of vehicle ID 3, its distance from the target vehicle, latitude, and longitude.

the Location services at AMF. Once the RAN+UE emulator function gets activated, we initiate the vehicular scenario simulation using SUMO. SUMO interface connects to the RAN+UE emulator on an IP socket. The traffic scenario consists of three vehicles. Initially, in Fig. 3a, the vehicle in blue represents the target vehicle, and the other two in yellow represent other vehicles passing by on the same lane but in the opposite direction.

As the simulation progresses, the target vehicle moves forward in the lane, and it encounters a nearby vehicle. As soon as this vehicle comes into the vicinity (vulnerability distance of 100 meters or less) of the target vehicle, the nearby vehicle's color changes to red (Fig. 3b), indicating that the driver's attention is needed to avoid any risky situation. This distance calculation is done periodically at the MEC service and sent to the V2X application. V2X application sends the alert to the user (SUMO) over the 5G network based on the vulnerability distance set according to the use case. The color of the nearby vehicle changes back to yellow as soon as the nearby vehicle crosses the target vehicle. (Figure 3c).

The same use case has also been realized by developing a mobile application. We establish a connection between the V2X application server and the mobile application with the help of an MQTT broker. The mobile application subscribes to the "data/location" topic to avail the services offered by the V2X application server after registering in the application. As soon as the condition for the vulnerability distance is satisfied, an alert sent to the driver, as shown in Fig. 4. The time to generate an alert from the V2X application server till it reaches SUMO via the DP is 30ms. This system is scalable for real-like applications with a large number of vehicles, with the only bottleneck being the multiple HTTP connections created in REST based 5G core framework. To avoid distractions to the driver due to recurrent alerts in dense vehicular scenarios, we combine alerts into a single notification, in which only the nearest vehicle details in proximity would be shown, along with the number of vehicles within range.

IV. Conclusions

In this work, we demonstrated a V2X use case by integrating ETSI MEC location service API with our emulated 5G system framework. The usage of MEC services in realizing the V2X application such as the one demonstrated will help in significantly reducing end-to-end latency. This work can be considered as a proof-of-concept to integrate and realize dedicated MEC-based services with 5G to realize any such V2X applications in future.

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