Demonstration of 5G-MEC assisted Location Services for Mission Critical Applications

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***Abstract*—Advancements in 5G and edge computing infrastructure increase the need to deploy location-based services for mission-critical applications like Vehicle to Everything (V2X) and Intelligent Transport System (ITS). In this demonstration, we showcase the location service capabilities of our 5G Core (5GC), coupled with Multi-access Edge Computing (MEC) for delay-sensitive ultra-Reliable Low Latency Communication (uRLLC) service types like V2X and ITS. We believe that this work will guide Mobile Network Operators in building a location assistance service system for emergencies and delay-critical applications.**

I. Introduction

5G system enables edge computing applications to leverage the user's location information for improving the user's Quality of Experience in video streaming services, e-health applications for providing emergency alerts to nearby hospitals in case of road accidents [1], etc. 3GPP adds control-plane support (see Fig. 1) to the User Equipment (UE) and Radio Access Network (RAN) assisted/based LoCation Service (LCS) along with LTE Positioning Protocol (LPP) [2] to receive the location information of the UEs. In parallel, ETSI specifies location service for Multi-access Edge Computing (MEC) applications in the MEC platform [3]. In [4], the authors describe the priority and security aspects of the 5G location service, which are not present in the MEC location service for the association. This work addresses the need for location assistance in mission-critical, delay-sensitive, and emergency services like Vehicle to Everything (V2X) by building an end-to-end LCS emulation framework with 5G Core (5GC). Though our LCS framework is flexible to be deployed in the remote cloud and edge environments, in this work, we couple our 5GC with the MEC to meet the lowest possible latency needs. The following are the key features of our 5GC assisted LCS framework that will be demonstrated.

- An emulation framework for end-to-end location service using a 5GC prototype and MEC application.
- Location services via the control plane useful for delay sensitive applications, as well for **control plane only** connected Cellular IoT devices.

II. End to End Location Service Framework

The framework encompasses the following key components (see Fig. 2), as listed below.

- A 5GC prototype and a RAN+UE emulator.
- A trusted Application Function (AF) which connects V2X or ITS MEC Application Servers (ASs) with 5GCś control plane and data plane.

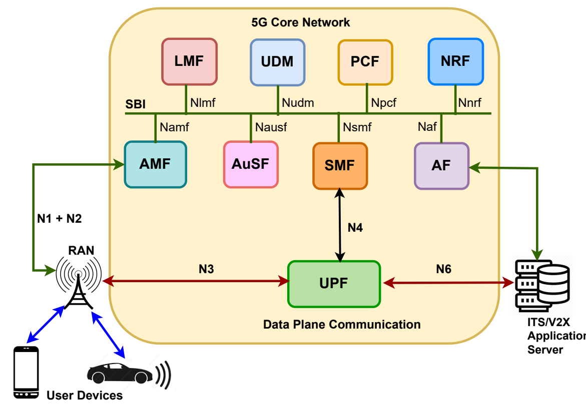

Fig. 1: Location Services Supportive 5G System Architecture.

- V2X/ITS MEC AS interacts with the trusted AF and provides location assistance.
- UE Application for simulating the users/vehicles in need of location services.

A. 5G Core Prototype for Location Services

The developed 5GC prototype for location services is based on 3GPP Rel.16 [5] (see Fig. 1 and Fig. 2). We extended our in-house developed Service Based Architecture 5G testbed emulation framework [6] to facilitate the location services. In this regard, we built a Location Management Function (LMF) [7] in addition to adding the required LCS provisioning at the Access and Mobility Management Function (AMF) of the 5GC. The framework leverages Service Based Interaction between these Network Functions (NFs). LMF helps to interpret the actual location data conveyed to and from the UE using LPP messages. Additionally, a trusted AF subscribes for the location information from different UEs covered by the connected RAN via 5GC to help locally connected V2X/ITS MEC AS. In the data plane, the User Plane Function (UPF) of the 5GC supports end-to-end location data exchange between the UE(s) and the AS via the GPRS Tunneling Protocol User plane (GTP-U) on $N3$ with RAN and $N6$ with the AS.

B. RAN+UE Emulator

We extended the lightweight RAN + UE emulator from our work at [6] to facilitate the exchange of LPP messages via the control plane with Next Generation Application Protocol (NGAP) and embedded UE with Non-Access Stratum (NAS)

978-1-6654-0694-9/22/$31.00

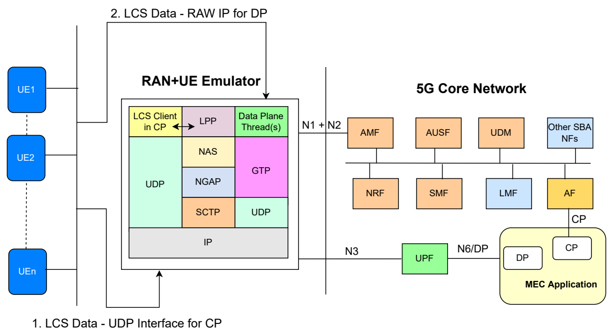

Fig. 2: Emulation Framework for End-to-end LCS.

on $N2$ and $N1$ interface functionalities towards AMF. As shown in Fig. 2, the LCS client in the control plane of this emulator provisions sending the location information received from externally plugged-in IP-based UEs towards the 5GC. Similarly, it forwards the location assistance data received from the 5GC to the respective UE(s). However, in the data plane, the emulator supports the exchange of location information between the UE and AS in raw IP packets via GTP-U with the UPF of 5GC both in the uplink (UL) and downlink (DL) directions.

C. End to End Functioning of Location Services

We now describe the key contribution of this work. i.e., the end-to-end functioning of LCS in the control plane. Unlike the data plane, where the AS and UE can exchange the proprietary data over 5G to support LCS, the control plane of 5G needs to follow the LCS call flow as per 3GPP [2, 7]. Therefore, in this context, our emulation framework supports LCS in two flavors to provide total service availability to the UEs in various needed situations.

- **Network Reciprocated Location Services (NRLCS):** In this flavor (Push Mode), the UE avails the location assistance from the remote AS via the 5GC. The remote AS reciprocates via 5GC by providing the required assistance back. For example, a UE in a remote unknown area pushes its current location to the AS via 5G. AS, in return, can assist the UE in reaching a safe place via 5G. The labeled **Push mode** call flow in Fig. 3 shows the end-to-end functioning of LCS in this flavor, where a UE registers to 5GC and seeks the help of AS via AF and 5GC when needed.
- **UE Reciprocated Location Services (URLCS):** In this flavor (Pull Mode), the remote AS exclusively seeks the location information from the UEs via the 5GC. AS can use this information to assist the other UEs in need of help (e.g., alert them to take the diversion in V2X). The labeled **Pull mode** call flow in Fig. 3 shows the end-to-end functioning of LCS in this flavor, where a UE registers to 5GC first and AS retrieves its location information when needed through AF via 5GC.

In either combination of these flavors, the AMF takes the help of LMF in interpreting the actual location information

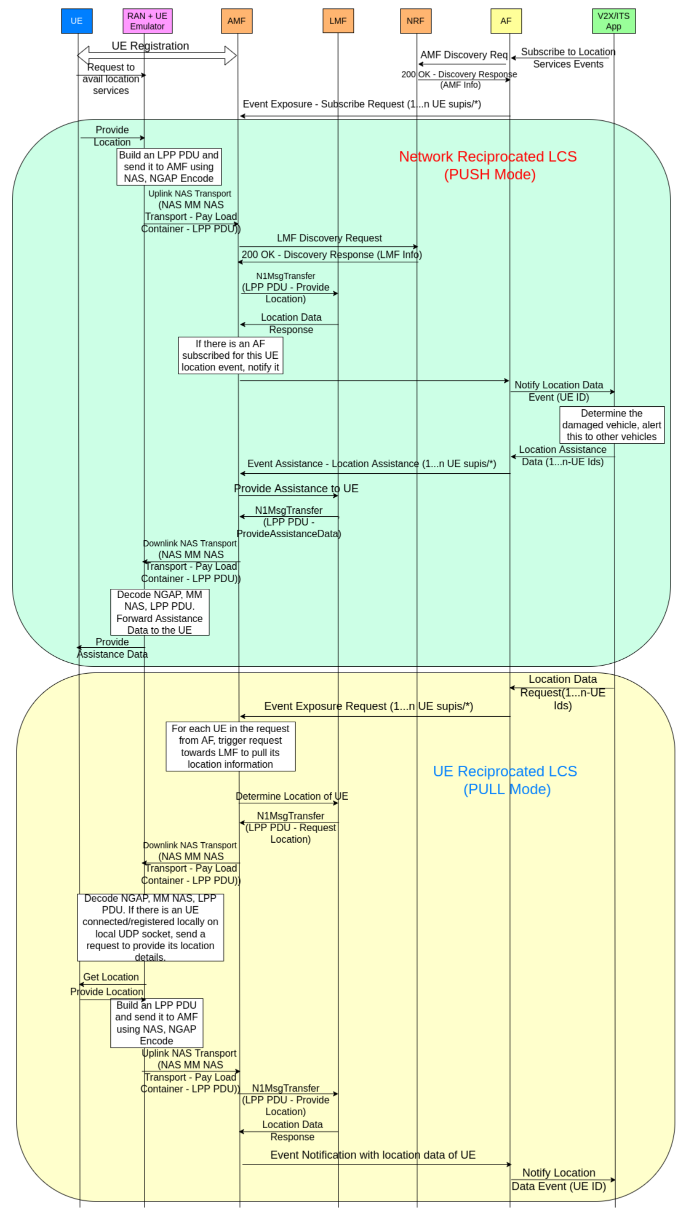

Fig. 3: End-to-end flow of Location Services.

in both UL and DL directions. Hence, they can be configured to support the complete LCS to the end-users.

III. Location Services Demonstration

For demonstrating the end-to-end LCS (see Fig. 2), the 5GC, RAN+UE emulator, MEC V2X AS, and UE interface are hosted on Intel® Xeon® CPU E5-1650 v4 @ 3.60GHz with 6 CPU cores and 32GB RAM. At first, the 5GC NFs are brought up where each of them gets ready to serve the UEs. AF subscribes to the location services at the AMF for all the registered UEs. Once the RAN + UE emulator function gets active, it emulates the UE activities by registering a pre-configured number of UEs to the 5GC. The emulator then allows for LCS via the control and data planes. During this, we demonstrate

(a) (b)

Fig. 4: Vehicles in the SUMO simulator a) before and b) after the location services assistance from the AS via 5GC.

the functioning of LCS and the assistance provided by the V2X/ITS AS via our 5GC emulation framework.

For the UE interface, we plug in the Simulator of Urban MObility (SUMO) [8] to the RAN + UE emulator on an IP socket. SUMO is an open-source, highly portable, and continuous road traffic simulation package designed to handle road networks on a large scale. Upon starting the simulation, the vehicles registered to the 5G through the internal IP interface program connected to the RAN + UE emulator. Then, the location of various vehicles from the SUMO is retrieved and communicated to the RAN + UE emulator. Further, the emulator forwards this information to the 5GC on standard (NGAP + NAS) communication. The AMF takes the help of LMF in retrieving the actual location data and then notifies the AF. V2X/ITS application here uses this received location data from the vehicles (UEs) for additional calculations, like finding the nearby vehicles for assistance or alerting them back to take a diversion.

Fig. 4a and Fig. 4b show an instance of road traffic with ‘5’ vehicles from SUMO, before and after the location assistance from the MEC V2X AS via our 5GC. Here, we simulate the failure of one vehicle in the lead. The location information from all the vehicles is notified to the V2X AS via our 5GC. Further, the V2X AS advises the other vehicles to take a diversion and notifies the subscribers, like the police station and the rescue team, to reach the location of the failed vehicle for assistance. It is to be noted that all the LCS interactions between the RAN and 5GC here are happening on the control plane itself, without the need for a data plane path. This is very helpful in emergencies, where the UE only needs to register to 5GC to avail the LCS without requiring an exclusive Packet Data Unit (PDU) session to be established for data plane interactions. However, the data plane can also be leveraged to exchange the location information in cases where the control plane is highly overloaded, like in the massive Internet of Things (mIoT) service.

IV. Performance Analysis

Since this work focuses mainly on emergencies, we measure the end-to-end latency incurred by the UE in availing LCS assistance from the remote AS via the 5GC control plane with immediate registration. Similarly, in URLCS, the latency at the V2X AS is measured as the total time to send the request to relevant UE(s) and availing the location information back from them. Based on the application requirements, additional time at the MEC AS may be considered for computation in both flavors. Table I lists these measurements done in the demonstration setup for different flavors. We plan to revisit the current control plane processing in our 5GC to reduce the end-to-end latency in our future work.

TABLE I: End to end latency in different flavors of LCS

LCS flavor	**Average latency (in milli seconds)**
URLCS	50
NRLCS	50 for registered users. 90 for casual users requiring immediate assistance.

V. Conclusion and Future Work

In this demo, we demonstrated the functioning of LCS from our 5GC framework coupled with MEC AS, which can support a wide variety of mission-critical, delay-sensitive, and emergency applications in the V2X and ITS domain. In the future, we plan to extend our LCS framework capabilities by coupling it with MEC Radio Network Information Service APIs and V2X Information Service APIs to build an efficient V2X AS that can consider the network congestion conditions to improve the performance of V2X infrastructure in serving the delay-critical applications.

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