Enabling flexible and universal message generation between Vulnerable Road Users and Autonomous vehicles leveraging 5G SEAL CCAM technologies

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***Abstract*—Improving communication between Vulnerable Road Users (VRUs) and Unmanned Automated Vehicles (UAVs) promises to significantly improve road safety. Challenges in Connected, Cooperative, and Automated Mobility (CCAM) include the lack of a unified communication stack and the need for a low-latency, edge-based Connected, Cooperative, and Automated Mobility application. This paper proposes to overcome these challenges by integrating CCAM communications directly as a service into 5G and beyond, accessible to any 5G device. Facilitated by the upcoming 3rd Generation Partnership Project (3GPP) release and its Service Enabler Architecture Layer (SEAL) framework, this approach eliminates the need for dedicated Vehicle-to-Everything (V2X) hardware. Using the Edge Network Application (EdgeApp) framework, the Connected, Cooperative, and Automated Mobility communication stack is distributed at the 5G edge. With an emphasis on vertical services, this framework achieves ultra-low latency, high reliability, and high bandwidth. Overall, this paper advocates simplified communications, reduced hardware requirements, and the potential for a safer and more efficient transportation system between VRUs and UAVs.**

***Index Terms*—5G and beyond, CCAM, EdgeApp, 3GPP, SEAL, V2X**

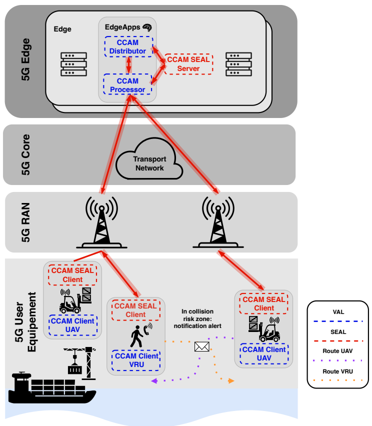

Fig. 1. CCAM communication between VRUs and UAVs enabled by the 5G Edge Network

I. Introduction and Motivation

In the domain of Intelligent Transport Systems (ITS), Connected, Cooperative, and Automated Mobility (CCAM) has emerged as an umbrella term that brings various communication protocols together to facilitate interaction between vehicles. CCAM now operates on technologies such as Intelligent Transport Systems - G5 (ITS-G5) and Cellular Vehicle-to-Everything (C-V2X), providing a foundation for Vehicle-to-Everything (V2X) communication. Standardised CCAM communication relies not only on embedded sensors for environmental perception but also facilitates bidirectional interaction with the environment. European Telecommunications Standards Institute (ETSI) plays a key role in standardising CCAM messages, ensuring interoperability across different communication technologies. These types of V2X messages including Cooperative Awareness Message (CAM), Decentralised Environmental Notification Message (DENM), In-Vehicle Information (IVI), and VRU Awareness Messages (VAM) messages are not widely adopted yet, as most of the vehicles do not exchange messages due to lack of dedicated hardware [1].

Facilitating flexible and universal message generation between VRUs and UAVs holds the potential to break down the current communication barriers between various vehicles and entities on the road, thereby creating a safer mobility environment.

However, two prominent challenges associated with CCAM communication pose significant limitations to realising seamless and safe interactions between various VRUs and UAVs. The first challenge revolves around the absence of a unified communication stack that ensures effective communication among all UAVs and VRUs, irrespective of their make or model. The second challenge pertains to the need for an Edge Network Application (EdgeApp) CCAM application that is edge-based, suitable for mission-critical operations, and characterised by low-latency requirements. EdgeApps are a new generation of applications deployed at the edge of 5G and beyond networks as advanced Virtual Network Functions (VNFs).

As shown in Figure 1, by integrating CCAM communication directly into 5G as a service, allowing any 5G device to access these services, can potentially overcome challenges. This integration is facilitated by the upcoming 3rd Generation Partnership Project (3GPP) release and its development of the Service Enabler Architecture Layer (SEAL) framework initiated in Release 16. The integration of EdgeApps into the SEAL framework eliminates the necessity for specific V2X hardware and simplifies the communication process by requiring only a 5G connection.

II. Service Enabler Architecture Layer (SEAL)

The SEAL serves as a foundational element in supporting the development and deployment of vertical applications. It focuses on providing common support services as a unified layer for vertical applications. Key entities such as Vertical Application Layer (VAL) Client, VAL Server, SEAL Client, and SEAL Server are integral components of this framework. Integration with the Common API Framework (CAPIF) allows VAL Server to function as an API Exposing Function (AEF), enabling deployment scenarios across Public Land Mobile Network (PLMN) and vertical application service provider domains.

The functional architecture of SEAL[1] encompasses essential features such as group management, location management, identity management, configuration management, key management, and network resource management, as shown in Figure 2. Vertical services can leverage these capabilities from SEAL, resulting in a significant reduction in time and cost to market for both existing and future applications.

The functional model for SEAL is structured into generic and specific SEAL service functional models, offering a comprehensive set of services towards the vertical application layer. These services essentially encompass data delivery, notification management, network slice capability enablement, and application data analytics enablement.

Each SEAL service offers Application Programming Interfaces (APIs) on a service-based interface to its consumer entities, with vertical applications consuming these services in the form of APIs. The detailed specification of SEAL services, such as data delivery and application data analytics enablement, is provided in 3GPP technical specifications.

In essence, the SEAL functional architecture provides a robust framework to address the diverse requirements of vertical applications, offering essential services and enabling seamless integration and deployment across various domains. It is important to highlight that while SEAL holds great promise for enhancing communication, it is not yet fully standardised. The combination of the SEAL framework with CCAM technology has the potential to enable the following scenario.

A. Use case

As shown in Figure 1, a practical use case for SEAL could be its implementation in a busy harbour environment. With everyone equipped with smartphones and connected via 5G, along autonomous trucks or forklifts with 5G modems, SEAL can potentially facilitate seamless communication among pedestrians, and workers moving containers. It is worth noting that SEAL does not require dedicated hardware, as most people have a smartphone with 5G capabilities.

Real-time notifications can be enabled for VRUs to avoid areas where containers are being moved, enhancing safety and preventing accidents, as shown in Figure 1. This monitoring can be facilitated by EdgeApps positioned at the edge of the network. In the event of a potential collision between a VRU and a UAV, these EdgeApps can intervene by requesting the UAV to stop completely, thereby avoiding a collision. Likewise, workers operating forklifts can receive alerts about the presence of VRUs, reducing the risk of collision. More specifically, the CCAM SEAL Clients can continuously transmit CAMs, maintaining the awareness of each other. This data is transmitted over the 5G Radio Access Network (RAN) and then through the 5G Core transport network to eventually reach the edge where EdgeApps are used to process the data. If necessary, these EdgeApps can generate and transmit the required messages.

This envisioned system, illustrated in Figure 2, consists of core functions, VAL, and SEAL. The VAL CCAM client serves as a lightweight application for sending CCAM messages on UAVs and VRUs, while the VAL CCAM distributor spreads these messages to other VAL servers and clients. The VAL CCAM processor is designed for intelligent processing of CCAM messages, with the aim of improving environmental perception and facilitating optimal decision-making.

The ultimate objective is to contribute to the progress of 3GPP SEAL, by addressing the gaps in CCAM communication and the potential gaps in SEAL. The paper aims to showcase an edge-based EdgeApp system that can support mission-critical operations and meet low-latency requirements. Figure 2 portrays the interlinked functional architecture that identifies the functions of the various components within the SEAL framework. However, note that the CCAM SEAL Client(s) and CCAM SEAL Server(s) components do not currently exist. The intended research aims to create these as generic SEAL services, suitable for CCAM communication purposes.

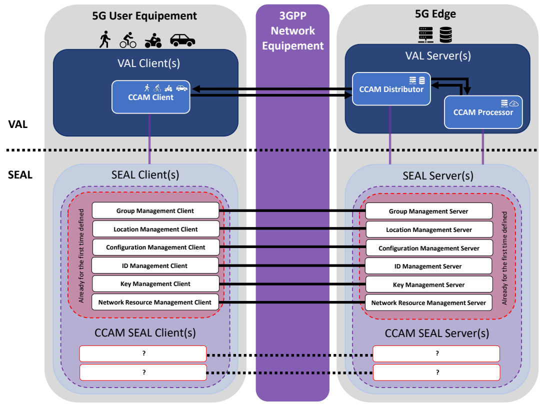

Fig. 2. Functional architecture of EdgeApp CCAM communication system making use of SEAL framework

III. Conclusion and Future Work

The envisioned development of integrating CCAM in SEAL to facilitate universal message generation between VRUs and UAVs has the potential to break down the existing communication barrier, enabling a more secure mobility environment. The prevailing communication challenges within the CCAM domain, in particular the lack of a unified communication stack and the need for edge-based applications, may find a possible solution by integrating CCAM as a service into the SEAL framework of 5th Generation (5G) and beyond. This approach, complemented by the incorporation of EdgeApps in CCAM communication, removes the dependency on specific hardware and simplifies the system to require only a 5G connection. The inclusion of SEAL facilitates the efficient use and deployment of vertical applications, providing ultra-low latency, high reliability, and high bandwidth for optimal CCAM communications. The resulting streamlined communication framework and reduced hardware requirements offer promising prospects for the development of a safer and more efficient transport system.

IV. Acknowledgement

This work has been performed in the framework of the European Union's Horizon 2020 project VITAL-5G co-funded by the EU under grant agreement No. 101016567.

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