Addressing Bitrate and Latency Requirements for Connected and Autonomous Vehicles

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***Abstract*—Autonomous and connected vehicles are becoming the next piece of the 5G connectivity puzzle. Dealing with a diversified set of use cases, ranging from manoeuvrer negotiation to infotainment, autonomous and connected vehicles call for a radically new approach to mobile networking. Multi-access Edge Computing (MEC) and network slicing have emerged to address such a challenge. The former, MEC, allows offloading computationally intensive tasks to nodes located very close to the vehicles. Slicing, in turn, allows instantiating multiple virtual networks, each of them tailored to meet the requirements of a specific service class, e.g. low latency, on top of the same infrastructure. In this paper, we introduce a novel design for a 5G network for autonomous and connected vehicles combining MEC and network slicing. The resulting solution allows features like lane tracking and object detection to be safely offloaded to the 5G network without impairing their effectiveness.**

***Index Terms*—5G, RAN Slicing, MEC, Connected Vehicles.**

I. Introduction

Although 4G seems to have *"just arrived"*, the transition towards 5G mobile networks has already started. 5G aims at enabling a connected world where multiple verticals (e.g. automotive, industry, and health), each characterized by different performance targets in terms of bitrate, latency, and reliability, can coexist on the same infrastructure. This scenario calls for advanced isolation and resource management mechanisms. Several technologies have recently emerged to address these challenges. Radio Access Network (RAN) slicing, a non-native concept of 4G, enables dynamic partitioning of dedicated RAN resources into isolated virtual networks. Conversely, Multi-access Edge Computing (MEC), allows offloading computationally intensive tasks to computing nodes located in the RAN, and thus very close the mobile terminals.

Building on these concepts, in this paper we introduce a novel design for a 5G network for autonomous and connected vehicles combining MEC and RAN slicing. The prototype builds upon the 5G-EmPOWER platform [1], a Mobile Network Operating System supporting active slicing, lightweight virtualization, and transparent edge computing through local breakout. The proposed solution allows tailoring certain network slices for latency-sensitive applications (e.g. lane tracking) while others can be optimized for bitrate demanding applications (e.g. video streaming). All software is released under a permissive APACHE 2.0 license for academic use[1].

[1]Online resources available at: http://5g-empower.io/

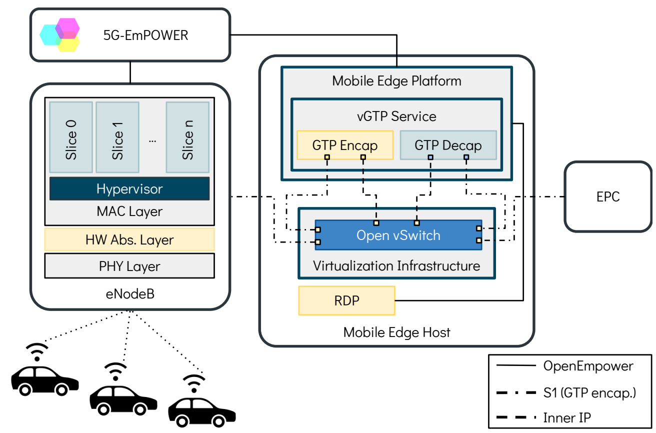

Fig. 1. The platform for connected and autonomous mobility.

II. Connected and Autonomous Vehicles Platform

The design of the system is based on the software-defined network architecture sketched in Fig. 1. As can be seen, the system includes the 5G-EmPOWER controller, an eNodeB, a Mobile Edge Host (MEH), and a core network.

The eNodeB is based on srsLTE [2], which has been extended to support RAN slicing. A programmable hypervisor situated at the MAC layer of the eNodeB is the core of the system. Sitting over a hardware abstraction layer in charge of decoupling the complexities of the underlying radio access technology from the MAC layer, the hypervisor is responsible for creating, monitoring, and scheduling the slices based on the instructions received from the controller, as well as for ensuring performance and functional isolation between the slices. Communications between the eNodeB and 5G-EmPOWER happen using the *OpenEmpower* protocol [3]. Notice that a 4G software stack has been used in this prototype given that, at the time of writing, no open-source 5G stack is available. Nevertheless the principles presented in this work are general and can be easily extended to 5G networks. The core network is implemented using srsEPC [2].

The MEH [4] implements the local breakout, allowing computationally demanding applications to be deployed inside the RAN. The MEH embeds an OpenFlow Switch and a Mobile Edge Platform (MEP). The MEP, implemented using the Click Modular Router [5], runs the vGTP service. This service

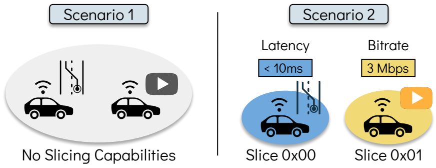

Fig. 2. Scenarios showcased in the demonstration.

intercepts the traffic between the eNodeBs and the EPC. When the vGTP service receives a packet from the eNodeB, the packet is passed to the `GTPdecap` element to remove the GTP header. The inner IP packet is then forwarded by the OpenFlow Switch to the relevant Mobile edge Application (MAP). Later, the `GTPEncap` element re-encapsulates the output produced by the MAP into a GTP tunnel and forwards it to the eNodeB.

In this paper, the MAP is an application named Road Data Processing (RDP), which is in charge of analyzing the video stream received from vehicles. To this end, a machine learning model based on OpenCV is designed for road and traffic-sign recognition, and for lane tracking. If an operation is needed (e.g. emergency braking), the MEC server instructs the corresponding command to the vehicle. The RDP application is running as a container on top of Docker.

III. Radio Access Network Slicing for Connected and Autonomous Mobility

The RAN slicing solution implemented in this work aims at allowing slice customization and performance isolation while at the same time ensuring efficient utilization of the radio resources. Slices are created by 5G-EmPOWER starting from a slice descriptor. The parameters defining a slice are:

- *Slice ID*. Unique slice identifier.
- *Resources*. Indicates the number of Physical Resource Blocks (PRBs) that must be allocated to the slice every N Transmission Time Intervals (TTI), which are 1ms long.
- *UE Scheduler*. Indicates how the UEs in a slice should be treated. By default, UEs follow a Round Robin fashion.
- *UE List*. The list of UEs that belongs to a certain slice. Notice how UEs are identified using their International Mobile Subscriber Identity (IMSI) number.

When instantiating a new slice, 5G-EmPOWER verifies if the resource configuration requested can be admitted on the basis of the available radio resources in a certain radio node. It is also worth mentioning that different radio nodes can have different configurations for the same slice.

IV. Demonstration

In this demo, we illustrate the isolation capabilities offered by the slicing solution and how the MEC server can be used to offload lane tracking and object recognition tasks from the vehicles to the network. The demo showcases two scenarios, sketched in Fig. 2, with the purpose of proving the relevance of supporting various requirement categories in the context of connected vehicles in use cases such as autonomous driving and entertainment.

The first scenario presents a system without slicing capabilities comprising two cars connected to the same eNodeB, and thus sharing radio resources with each other. The first car is equipped with a video camera and location sensors, and transmits this data to the RDP application with the aim of obtaining assisted-driving orders (e.g. lane-tracking and emergency braking). It is worth noting that this scenario imposes strong latency constraints, as the assisted-driving instructions need to be transmitted in the shortest time possible. Conversely, the second car plays a high-resolution video. Due to the lack of isolation, the video stream takes a significant amount of resources. Consequently, the driving directions generated by the RDP application are received late, which results in the car failing to follow the correct trajectory.

The second scenario introduces the proposed RAN slicing solution and defines two slices. The first slice is tailored to assisted driving and is allocated 5 PRBs per TTI based on experimental tests. By contrast, the second slice targets entertainment and is allocated 15 PRBs over 5 TTIs. Following this approach, the hypervisor is in charge of guaranteeing isolation between the two slices and of ensuring that the UEs with strong latency constraints are scheduled more often. This, in time, allows the vehicles to receive accurate and on-time assisted-driving instructions.

V. Conclusions

This demo shows that the proposed design for a 5G network combining MEC and network slicing is an excellent solution for connected and autonomous vehicles, enabling the offloading of assisted-driving functions, such as lane tracking and emergency braking, to a MEC-enabled 5G network without impairing their effectiveness.

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References

[1] R. Riggio, M. K. Marina, J. Schulz-Zander, S. Kuklinski, and T. Rasheed, "Programming Abstractions for Software-Defined Wireless Networks," *IEEE Trans. Netw. Service Manag.*, vol. 12, no. 2, pp. 146–162, 2015.

[2] "srsLTE: Open source SDR LTE software suite," Accessed on 02.03.2019. [Online]. Available: http://www.softwareradiosystems.com/

[3] "The OpenEmpower Protocol," Accessed on 02.03.2019. [Online]. Available: https://github.com/5g-empower/5g-empower.github.io/wiki/EmPOWER-Protocol

[4] T. Subramanya, G. Baggio, and R. Riggio, "lightMEC: A Vendor-Agnostic Platform for Multi-access Edge Computing," in *Proc. of the IEEE CNSM*, Rome, Italy, 2018.

[5] E. Kohler, R. Morris, B. Chen, J. Jannotti, and M. F. Kaashoek, "The click modular router," *ACM Trans. Comput. Syst.*, vol. 18, no. 3, pp. 263–297, Aug. 2000.