Standardization Initiatives and Market Approaches in Edge Federation

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***Abstract*—The introduction of the sixth generation (6G) mobile communications along with the establishment of Edge Computing and network virtualization motivate the concept of Telco Edge Platform (TEP), which is an effort towards exposing the mobile network capabilities to interested external third parties. Recently, the Operator Platform Group (OPG) has been introduced towards the interconnection and federation of the TEPs. In this paper, we explain in detail the standardization efforts around OPG in the context of the edge federation and we provide a list of innovative use cases enabled by this initiative. Finally, we move our scope to the market efforts, focusing on our state-of-the-art edge orchestration tool (i.e., NearbyOne) and its roadmap towards fulfilling the OPG requirements.**

***Index Terms*—Edge Computing, Federated Edge, Operator Platform Group, CAMARA, TEC, OPG, NearbyOne**

I. Introduction

The sixth generation (6G) mobile communications is just around the corner, after the first commercial 5G deployments [1]. Through new technologies (e.g., cloudification) and tools (e.g., machine learning), 6G is expected to bring a paradigm shift towards automated self-configurable networks of higher capacity and enhanced capabilities that will be capable of supporting innovative services and use cases, including extended reality infotainment, telematic healthcare and automotive applications among others [2].

To support the strict requirements of these new services, Edge Computing has been introduced and already started to be commercially deployed with important standardization progress in ETSI Multi-access Edge Computing (MEC) initiative [3]. In addition, moving towards 6G, Edge Computing seems to no longer be just a means for providing compute resources closer to the user, but it is transforming to an essential concept of the network. The reason for this transformation is mainly twofold: i) the network softwarization and the service-based architecture of the 5G (and beyond) networks, and ii) the increasing requirements for resources at the network edge for the support of the upcoming use cases and the execution of the algorithms that will provide the network intelligence [4].

This Edge Computing evolution has motivated the creation of the Telco Edge Platform (TEP), whose objective is to provide the service providers and the developers a set of tools and Application Programming Interfaces (APIs) to abstract the complexity of the underlying network topology [5]. Hence, through this platform, third parties will be able to consume operators' computing, storage and networking resources. The immediate next logical step after the creation of these TEPs is their federation. In this direction, the Global System for Mobile Communications Association (GSMA) and major operators have led the initiative of Telco Edge Cloud (TEC) or Operator Platform Group (OPG), which aims to federate multiple operators' edge computing infrastructures to give application providers access to a global edge cloud to run innovative, distributed and low latency services through a set of common APIs [6].

The trend towards the edge federation has motivated recent works in the literature to study the dynamics in the relationships between the different participants (e.g., infrastructure providers, service providers, etc.), as well as to propose innovative mechanisms for the optimization of the edge resource allocation in such scenarios [7]- [8]. However, there is still a need for analyzing the standardization efforts in this challenging area that involves multiple stakeholders.

Considering the aforementioned recent developments and the great interest that the federation of the different edge sites has attracted, the main contribution of this article is mainly threefold:

1) We analyze the standardization efforts around the edge federation by explaining the OPG concept and its first implementation initiatives, i.e., the CAMARA and the MobiledgeX APIs.
2) We list a number of innovative use cases that have the potential to be the killer applications of 6G and we connect them with the OPG concept.
3) We present NearbyOne, our state-of-the-art edge orchestration tool and our roadmap towards mapping the OPG requirements.

The remainder of the paper is organized as follows. Section II provides the standardization status of the OPG and the pioneer efforts in the implementation of the edge federation APIs. Section III analyzes the novel use cases and their dependencies on the OPG. Section IV provides the roadmap for one commercial edge orchestration tool towards the edge federation, while Section V concludes the paper.

II. Standardization Efforts in Edge Federation

In this section, we provide an overview of the OPG concept and the first efforts towards the implementation of the involved

APIs.

A. Operator Platform Group (OPG)

OPG is defined as a set of functional elements that enable operators to place the applications of various service providers in a close to their customers proximity [9]. In this way, operators would be able to exploit and monetize 5G era capabilities, including Edge Computing and slicing, in a scalable and federated (with other operators) manner.

To compete with other major stakeholders in the domain (e.g., hyperscalers), OPG should provide the involved parties with a coherent view of the underlying federated infrastructure, so that the exposed capabilities can be used in a seamless way. OPG is based on the assumption that each operator owns an individual TEP, independent of other operators' deployments. The OPG framework aims at expediting the integration from and towards third parties, such as application providers or third-party enterprises. To that end, the proposed OPG architecture is based on a four-sides approach (as also shown in Figure 1) [9]:

- **Northbound Interfaces (NBIs)** are in charge of service management and enabling the fulfilment of service provider use case requirements. The NBIs will follow and adopt existing cloud API principles to facilitate the use of existing cloud platforms. Application providers or other enterprises could be the consumers of the network and services.
- **East-Westbound Interfaces (EWBIs)** extend operators' reach beyond their own footprint (i.e., towards other operators' platforms), enabling them to exchange information about the network and service status.
- **Southbound Interfaces (SBIs)** connect the operator platform with the specific underlying infrastructure that is going to deliver the network services and capabilities to the end user.
- **User-Network Interfaces (UNIs)** will enable the communication between the user equipment and the operator platform, opening new capabilities at user level, e.g., dynamic service requests or location data.

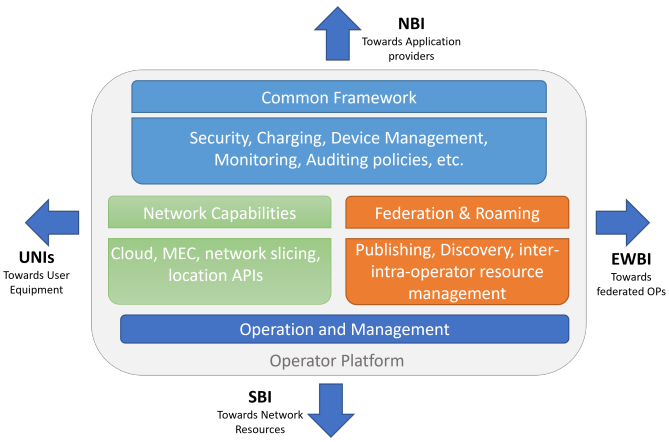

Fig. 1: High-level platform building blocks and APIs

Finally, it is worth noting that OPG defines a Common Data Model (CDM) that introduces a set of standardised data schemes for describing characteristics of the elements of a TEP. The CDM covers elements of an operator platform, including applications and OP roles, as well as functional aspects, such as security. The data model should i) define the information elements required to deploy and manage a TEP, and ii) allow for reasonable default values for these elements to be inferred where they make sense.

B. CAMARA API

CAMARA[1] is an open-source project within Linux Foundation to define, develop and test some of the APIs that are foreseen towards edge federation. CAMARA is collaborating with OPG to align API requirements, publish API definitions and implement the required APIs. Harmonization of APIs is achieved through fast and agile created working code with developer-friendly documentation, while API definitions and reference implementations are free to use (i.e., Apache2.0 license).

From a functional perspective, the scope of CAMARA is limited to telco APIs, i.e., APIs in the domain of telco mobile (or fixed-line) networks or APIs that support these networks. Hence, taking as reference the explanations of the previous section, CAMARA is mainly focused on the NBI between the telco operator and aggregator or capability consumer, while the EWBI will be also considered to enable roaming among the different telco operators.

The scope of the CAMARA project is mainly focused on the following activities:

- Collect API requirements from OPG and other sources
- Define service APIs
- Create test cases from an API consumer perspective
- Develop and test service APIs
- Create developer-friendly documentation for service APIs.

C. MobiledgeX API

MobiledgeX (MEX) was a company founded in 2018 with the support from Deutsche Telekom. Their main business was the interplay between the edge and the user (i.e., the UNI). The Software Development Kit (SDK) by MEX was provided to allow the users to access network information or even specific network slices (if supported by the network). It is worth noting that MEX was recently (2022-Q2) acquired by Google with the aim to open source the code[2].

III. OPG-enabled Use Cases

In this section, we focus on some innovative use cases that are expected to be highly benefited by the OPG concept [10]. In particular, we stress different use cases of important vertical domains and innovative concepts (i.e., automotive, infotainment, healthcare, infrastructure sharing) and we examine their dependencies on the OPG.

[1]https://camaraproject.github.io/index.html

[2]https://www.gsma.com/futurenetworks/latest-news/google-acquires-edge-computing-company-mobiledgex/

A. Automotive

Drivers can receive context information about their vicinity, e.g., slippery road, other slow-moving vehicles, traffic jam, red traffic lights, etc. A driver's ability to "see beyond their reach" could enable safer and more economical driving.

OPG dependency: The service could be delivered through an edge application server that collects information from roadside units and neighboring vehicles. The application server would aggregate and analyze the collected data before sending notifications (and possibly predictions) to the vehicles. The accuracy and the timeliness of these notifications would substantially increase if the application server was able to get information from all vehicles and also from different mobile operators. Edge federation would enable such information exchange between application servers on different operators.

In addition, the specific service has fundamental strict security requirements for the information received by roadside infrastructure as well as by other vehicles, while the data analysis in the application server should be trustworthy. An operator platform that offers authentication and verification services will provide the guarantees required for the execution of the service.

B. Online Gaming

Multiplayer Augmented/Extended Reality (AR/XR) games would be another timely use case. In such games, players participate in the real world, supplemented by online digital features. Therefore, the players could be physically located in the same zone area, while being associated to different mobile operators.

OPG dependency: In this type of games, players should ideally share the same application server, which is placed on a local edge. For instance, a "first-person" game is latency-sensitive, while fairness between players is very crucial, i.e., all players should get almost identical user experience and network performance. A federated edge that enables the edge node interconnection would be able to meet these strict requirements.

On top of this, some applications need special hardware (e.g., GPU). Following the OPG whitepaper [9], a federated model may require alignment between the federated operators to ensure that they offer similar resources. Hence, the service providers can consider these infrastructure/compute capabilities in the different networks for the design and dimensioning of their applications.

C. Privacy-preserving Health Assistant

Nowadays, there already exist health-related personal monitors, such as smartwatches. In addition, in the very near future, it is expected that there will be a variety of actively controlled devices to provide personal services, e.g., automatically adapt a medicine dose based on the patient's current condition. These devices provide their data to their dedicated servers, usually without any user control over the handling of the provided data. Therefore, an edge-based health assistant could act as an intermediate trusted third-party, capable of aggregating the data from different devices and providing access control to these data.

OPG dependency: Through the edge federation, when a user is roaming to a new network, the trusted home operator would have the option of installing its application server on the "new" edge, without losing the control capabilities. As a result, the user would experience the same quality of service, without revealing sensitive information to untrusted third parties.

D. Infrastructure Sharing

Infrastructure sharing, which enables operators to use the infrastructure provided by other operators or infrastructure providers, is a concept that attracts increasing attention, with research focusing on different infrastructure sharing models and mechanisms [11]. Some possible examples of infrastructure sharing among two operators would be as follows:

- Two operators with individual mobile networks that cover the whole country could agree to share their edge compute infrastructure to reduce their costs (e.g., by deploying edge infrastructures in different parts of the country).
- A virtual operator could rent/buy access to compute infrastructure and networking capacity from a real mobile operator.
- An operator has its own "basic" edge infrastructure, however it lacks special hardware that some service providers require, hence there is a need of having access in such infrastructure of other operators.
- An operator whose edge compute infrastructure is currently short of resources could temporarily offload any new edge service requests to another operator.

OPG dependency: As in other infrastructure sharing scenarios, to enable the edge infrastructure sharing, there would be a need for a commercial agreement that covers topics related to security, service level agreements and billing between the involved operators.

IV. NearbyOne federation

This section breifly presents NearbyOne and describes its mapping with the OPG requirements, as well as the future roadmap to follow existing standard initiatives for the implementation of the necessary APIs on top of the service layers of the product.

A. NearbyOne Edge Orchestrator

NearbyOne[3] is one of the most complete edge orchestration platforms in the market today. It offers end-to-end and cross-domain orchestration capabilities, covering the entire lifecycle management of distributed systems, networks and applications, encompassing all layers, from the edge to the cloud. NearbyOne addresses all the aspects related to an advanced orchestration platform (NFV, applications, edge) that enables edge computing in various scenarios, while it can integrate multi-vendor software components to build solutions for the

[3]https://www.nearbycomputing.com/wp-content/uploads/2021/09/Product-Data-Sheet-NBYCOMP.pdf

edge quickly. Therefore, besides the core components, the proposed solution provides a path to integrating an external ecosystem of service providers' solutions.

B. NearbyOne Compliance to OPG

Nearby Computing joined the GSMA group in 2021, following all activities and documents generated with regard to OPG, while the underlying requirements have been considered during the design of the NearbyOne.

Nearby Computing has kept track of the requirements identified by the OPG to enable the edge federation in an effective manner. Therefore, based on the CDM proposed in [9], it has been identified which resources are already tracked and managed by NearbyOne and which ones require additional features to be added on top of the product.

In particular, most of the relevant resources needed to enable federation, according to the OPG requirements document, are already part of the data model maintained by NearbyOne to deliver edge services to its customers (either by the product descriptors or by the architecture building blocks). As the product has been deployed in different environments, mainly targeting private networks, a technological base is available that facilitates the path to meet OPG requirements.

C. Roadmap

Two main activities are foreseen towards our effort to make NearbyOne fully compliant with OPG and the edge federation concept: i) compatibility with CAMARA API and ii) compatibility with the MEX API. Regarding the first activity, the objective is to integrate CAMARA API on top of the OPG resource model to enable federation. As most of the resources are already available in NearbyOne, the expectation is that the effort to expose and manage them through the CAMARA API is going to be smooth, and the expectation is to complete this task during 2023-Q1.

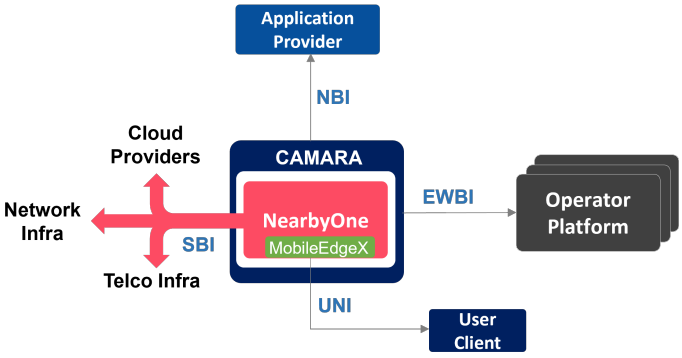

Fig. 2: CAMARA in relation to NearbyOne

The second activity to be developed is the integration of the MEX APIs as part of an extension to NearbyOne. This effort is mainly reserved for the integration of the API backend to enable orchestration actions to be triggered and statuses reported through the MEX APIs. This task is expected to be completed before 2023-Q2.

With these two activities, we expect that NearbyOne will continue to be a reference tool for operators when deploying edge services, not only for enterprise deployments, but also for the TEC space.

V. Conclusions

In this paper, we have focused on the standardization efforts around OPG in the context of the edge federation. In particular, we have provided the most recent advances and initial implementations on this topic through the CAMARA and MobiledgeX API initiatives. In addition, we have discussed a list of innovative use cases enabled by OPG, while we also analyzed the current market efforts, focusing on one state-of-the-art edge orchestration tool (i.e., NearbyOne) and its roadmap towards fulfilling the OPG requirements. In our future work, we are planning to actively contribute to CAMARA API and extend NearbyOne to achieve compliance with the OPG according to our roadmap.

Acknowledgments

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