5G EDGE NETWORK ACCELERATION FOR CROWD EVENTS

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ABSTRACT

The 5G ESSENCE Project investigates the concept of Edge cloud computing and Small Cell-as-a-Service (SCaaS). One of the selected use cases is called "5G edge network acceleration at stadium", which is focused on content distribution during crowd events. The paper describes the service VNFs and network services for 5G-based video production and video distribution into a football stadium.

KEYWORDS

5G, Cloud-enabled Small Cell (CESC), Network Functions Virtualization (NFV), Radio Resource Management (RRM)

1. INTRODUCTION

The 5G ESSENCE (5GESSENCE, 2017) effort "opens the door" to venue owners (e.g., municipalities, stadiums, site owners) and virtually anyone who manages a property and can install and run a local Small Cell (SC) network, to deploy a low cost infrastructure and to act as "neutral host network and service provider". Although probably none of such entities would offer static network coverage, many of them could foresee adequate chances for profits generated by exploiting the 5G ESSENCE concepts of multitenant small cells, able to provide wireless network coverage coupled with added-value services in close proximity to customers and visitors that belong to multiple network operators and vertical industries.

Broadcasters are looking for new ways to cover events, to offer exciting point-of-view perspectives to viewers on one hand, and to reduce production and delivery costs on the other. At the same time, network operators "target" to increase the usage of their networks and stadium owners have a strong interest in making the spectators' experience "as pleasant as possible", as well as increasing side-revenues through sponsor advertisement. The reception of live content from cameras located in the playing field, replays, and additional contextual information on mobile devices, is a strong use case for all the above actors. The main challenges even with 4G networks are the delay in the delivery of such content in the range of milliseconds rather than seconds, and the considerable strain imposed on the backhaul network. By deploying a 5G ESSENCE network, these challenges can be efficiently addressed.

In this paper, we focus on one of the selected use cases, which considers content distribution during crowd events. We describe the service VNFs and network services for 5G-based video production and video distribution into a football stadium. The paper is outlined as follows: Section 2 describes the considered use case. Section 3 presents the network functions for providing 5G services. Section 4 provides our testbed architecture overview. We conclude our remarks and present our future work in Section 5.

2. USE CASE DESCRIPTION

The 5G ESSENCE delivers benefits to media producers and mobile operators, enabling them to offer a highly interactive fan experience and to optimise operations by deploying key functionalities at the edge (i.e., evolved Multimedia Broadcast Multicast Services (eMBMS) together with multitenancy support from small cells). By

leveraging the benefits of small cell virtualisation and radio resource abstraction, as well as by optimising network embedded cloud, it becomes possible to “ease” the coverage and capacity pressure on the multimedia infrastructure, and also to increase security since content will remain locally.

Furthermore, additional benefits for the operators and the venue owners arise such as: (i) *lower latency, due to shortening the data transmission path*, and; (ii) *increased backhaul capacity*, due to playing out the live feeds and replays locally that puts no additional strain on the backhaul network and upstream core network components. The 5G ESSENCE project will demonstrate a combined 5G-based video production and video distribution towards delivering benefits to both media producers and mobile operators, who will be able to offer enriched event experience to their subscribers. The production/distribution of locally generated content through the 5G ESSENCE platform, coupled with value-added services and rich user context, will enable secure, high-quality and resilient transmission, in real-time and with minimal latency.

In the context of the 5G ESSENCE infrastructure sharing support, each network operator will be in position to optimise his network usage, resulting in lower OPEX. Additionally, network operators will be able to rapidly deploy new services, to deliver directly to users higher Quality of Experience (QoE), and to offer “Content as-a-Service”, increased bandwidth and storage solutions to content providers and venue owners. The content providers will also benefit from reduced latency and improved user QoE by positioning content on mobile edge and, in addition, they can offer augmented services by leveraging the network information. Finally, the stadium owner will obtain additional benefits by leveraging the deployed 5G ESSENCE infrastructure and its functionalities, by capitalising live content to spectators from many cameras, statistics, etc.

The scenario provides the logic for distributing the live video feeds received from the local production room to local spectators in a highly efficient manner. The municipal football stadium “Stavros Mavrothalassitis” will be covered with a cluster of multitenant, eMBMS enabled as CESC (Cloud Enabled Small Cells) and, together with the CESC and the Main DC, they can be connected to the core networks (CNs) of multiple telecom operators. The video content from cameras will be sent for processing locally at the Edge DC (similar to the proposed use case by ETSI MEC). Then the video streams will be broadcasted locally using the CESC and spectators will be able to dynamically select between different streams offered. In this and in similar massive event scenarios, the data traffic will not impact the backhaul connection since it will be produced, processed and consumed locally. Figure 1 provides a high-level architecture of the 5G ESSENCE according. The specific components and the interfaces are described in more detail in (Chochliouros, 2017) and (Kostopoulos, 2018).

Figure 1. 5G edge network acceleration at stadium

3. NETWORK FUNCTIONS FOR 5G SERVICES

3.1 eMBMS Core

The eMBMS, is the simplest and most cost-effective way to deploy LTE Broadcast services to deliver video, software updates and other broadcast applications. The software solution can be: (i) *centralized* to connect to an existing MNO network, or; (ii) *distributed to specific locations* (e.g. in a stadium) to create localized LTE

Broadcast hotspots without affecting the existing network. The eMBMS solution includes the Mobility Management Entity (MME), MBMS Gateway (MBMS-GW) and Broadcast Multicast Service Center (BMSC). It can be deployed in conjunction with our distributed EPC, for best user experience, or as a standalone implementation.

Figure 2. eMBMS core architecture

3.2 vEPC

The vEPC includes the HSS (Home Subscriber Server), P-GW (Packet Data Network Gateway), SGW (Serving Gateway), MME (Mobility Management Entity) and PCRF (Policy and Charging Rules Function). It comes with a fully web-based GUI for ease of configuration and management and extensive set of APIs for simple integration with mobile operator or enterprise OSS/BSS. It can be deployed either centralised or highly distributed on public cloud (e.g. AWS, Azure, Google, IBM, Oracle) or private cloud (e.g. telco cloud), enterprise data centres or on standard COTS servers running on Intel or ARM. Control Plane (CP) and User Plane (UP) functionalities can be distributed between central and edge-clouds or hardware nodes to enable hybrid-cloud, fog-computing or MEC type deployments.

3.3 Edge Video Orchestrator (EVO)

The deployment of the Edge Video Orchestrator service for the use case in stadium, consists of a single VNF. The VNF is running on the main DC. Its network address and ports are transparently seen by the entities that connect to it. The service is implemented with the help of the docker container technology running in a native network configuration within the VNF virtual machine (VM). The EVO VNF is connected to the BMSC. The EVO uses this entity to convey eMBMS traffic to the entities that are receiving the EVO's streams, called "stream-receivers". The entities that provide streams to the EVO, called as "stream-providers", are also connected to the EVO VNF.

Figure 3. Overall service VNF placement

Considering a proper selection from the aforementioned facilities, the selected facility will be covered with a cluster of eMBMS enabled CESC's and, together with the Main DC, can be connected to the core networks of multiple telecom operators. The video content from cameras will be sent for processing locally at the Edge (similar to the proposed use case by ETSI MEC (5GIA, 2019), (ETSI, 2019), (ETSI, 2017a), (ETSI, 2017b), (ETSI, 2017c), (ETSI, 2017d)). Then the video streams will be broadcasted locally by using the 3GPP eMBMS functionality. Spectators will be able to dynamically select among different offered broadcast streams. In this and in similar big event scenarios, massive data traffic will not affect -nor overload- the backhaul connection as it will be produced, processed and consumed just locally (i.e., the case of the 5G MEC scenario, aligned to the 5G 3GPP specifications (ETSI, 2017e), (3GPP, 2017a), (3GPP, 2017b), (DreamChip, 2019)).

3.3.1 Service Overview

The use case provides a set of services related to live video streaming. One of the “key” aspects is the lowest possible glass-to-glass latency of video streams. Glass-to-glass latency denotes the time needed for a scene in front of the camera glass to be detected, encoded, transmitted, decoded and rendered onto the display of the stream-receiver. This, in fact, increases the level immersion into the venue as it allows even distant observers to both see the original scene as well as additional videos of the same at the same instant in time.

The observer has a smart phone application which shows those additional video streams. The smartphone app allows the user to see a set of video streams in an overview-like layout. The number of video views in this mode is configurable within the application. The video views have a lower resolution and corresponding bitrate (SD resolution, around 0.8 Mbits/s bitrate) in order to limit the resource usage on the network and on the phone, itself. When touching one of the Multi View videos, an overlay showing stream name and current bitrate appears. On each of the video views, the actual stream to be shown can be chosen by the user. In parallel to switching to the full screen mode, the application stops the preview (SD) version of the stream and internally requests a high bitrate version of the same stream (HD view). Consequently, the user can watch the chosen camera perspective in high quality.

3.3.2 Service End-points

The Edge Video Orchestrator provides a REST API access its services. This REST API is used by the clients to seamlessly integrate with the system. Services offered by the EVO include, but are not limited to:

- Register new cameras;
- Query the list of streams available on the system;
- Request to receive a specified stream, or;
- Simulcast transmission of streams.

The next figure illustrates the overview of the system. Each connection to the EVO consists of two specific types of connections, as follows:

- **Control plane connection:** This connection is always implemented as a unicast connection. It carries control information or control requests that allow the EVO to manage the respective streaming operation. Typical content are authorization data or stream identification information.
- **User plane data:** Here, video and audio data are transmitted by using a connectionless protocol. Real-Time protocol (RTP) is used as a transport protocol. Additional protocol levels on top of RTP might be encryption or forward error correction (FEC) protocols.

Stream-providers typically may be active on the control plane and have several user plane streams, depending on the number of stream that the specific stream-provider announces. Regular encoders do announce the following elementary streams: high bitrate video stream, low bitrate video stream, and audio stream.

Devices integrated with the EVO system contain a software entity that communicates with the EVO with the help of the control plane and provide the correctly negotiated transport mechanisms. In order to have the sources/sinks of the streams not abstracted from the exact nature of the EVO interaction, the EVO Core SDK is introduced. The latter manages all EVO specific actions. The EVO Core SDK can be either directly used as a programming library or it can be embedded into a standalone application (throughout this document called Orchestrator Interactor – OCI). This approach eases the integration of new devices/ use cases into the EVO.

Figure 4. Overall system architecture

3.3.3 Client Types

For the planned use case several types of stream-providers and stream-receivers will be used, as described below.

Encoder types: Encoders of type “Dream Chip - Targa” will be used as stream providers for static cameras. Those encoders are integrated with the EVO system and natively support the EVO control plane interface. Targa transmitter is designed to enable TV broadcasts over LTE networks. This allows real-time video transmission into the cloud or any broadcast studio in the world with an incredibly low latency. Users can watch the content anywhere, anytime and with any device, whether it is mobile phone, tablet, laptop or PC. Targa transmitter is battery powered with a built-in rechargeable battery. It works without any cables to support easy mounting on humans, animals, vehicles or any special equipment. This transmitter has dedicated broadcasting functions and supports simultaneous dual video streaming, meaning one high resolution stream for the broadcast audience and one low resolution stream for preview of, for example, multiple camera views, both H.264 encoded. Additionally, Targa can store both streams on the local Flash Drive for remote playback, if the real-time transmission is interrupted due to unknown reasons.

Decoder types: Targa receiver is a compact video and audio decoder which is designed for TV broadcast applications. It is attached to LAN Networks using its Ethernet port. This receiver can decode SD and HD H.264 encoded elementary video streams and AAC audio streams. It features an integrated deinterlacer and scaler, which automatically upscales SD content to HD resolutions. The receiver supports professional video interfaces like HD-SDI and HDMI with integrated audio output. Additionally, it includes an analog audio output. When used in combination with a Targa transmitter, the receiver has several unique functions:

- *VPN-Tunnel:* The transmitter can connect to the receiver over an encrypted VPN tunnel for data security, and;
- *Audio Return Channel:* The receiver can record from analog audio input and stream it to the transmitter. This can, for example, be used by producers to give directions to the camera operators.

3.3.4 Transcoding Services

The EVO architecture foresees the transmission of two quality versions of a stream in order to manage wireless bandwidth usage in case of unicast transport. The encoding systems seamlessly integrated with the SML approach support this simulcasting already on the camera/encoder devices. However, in use case demonstration we will use an off-the-shelf 360° camera device and, therefore, the SD version of the stream has to be created elsewhere. For simplicity purposes, we chose to run the transcoding process on the EVO VNF itself. The transcoding process takes the original 360° video stream and forwards it to the normal EVO switching engine.

However, it also downscales the video of 3460x2560 to a low-resolution SD variant. It also reduces the bitrate from 8 Mbits/s (or higher) to 0.8 Mbits/s. The transcoder is connected to the EVO via an edge OCI process handling the EVO communication and protocols.

For this use case, we chose a transcoding process implemented in pure software. This simplifies the platform choice for the demonstration. In a real application it would be much more efficient to employ specific HW enabled encoding through graphic cards. This dramatically increases the capacity of the overall system and logically separates the CPU-intensive transcoding work from the network-centric EVO operation.

Figure 5. Transcoding for 360° video

3.3.5 Streaming to External Sources

The EVO-MO can also be configured to stream-to-stream receivers which do not support the EVO CP protocols natively. For example, the streams can be transcoded and transmuxed, such that *Facebook/YouTube* streaming servers can receive it.

3.3.6 Recording

The EVO system has the notion of “decoders”; those are virtual software entities or can be represented by hardware entities to which streams can be sent. Recording decoders are software entities which store the streams into .mp4 files. By this mechanism, all streams can be recorded for later payout or inspection.

3.3.7 Monitoring

The EVO system has several monitoring levels for performance verification. The provided figures help the operator to identify potential resource shortages, such as CPU or memory overload. This information is available by REST APIs and can be used in other management tools to visualize long-term trends or to be used in billing processes. In use cases with bigger number of users, this information is also used for load balancing between different EVO instances and/or to decide whether additional EVO instances need to be created. It is also possible to use this information for load management with the EVO instance itself. The EVO-MO supports to limit:

- The number of outgoing streams in order to limit the outgoing network occupancy, or;
- the number of users connected to an EVO instance. This is mostly used implicitly to limit the number of streams, but also to limit the control plane load on the EVO.

When a load limit is reached, new stream-receivers are rejected with an error code that the system capacity has reached.

4. TESTBED ARCHITECTURE OVERVIEW

The local video production and distribution through eMBMS will be ultimately performed in the Egaleo Stadium. However, the integrations, development and testing along the 5G ESSENCE project will be performed across testbeds made available by selected partners and connected among each other. The cloud testbed that will be used for the duration of the 5G ESSENCE, to enable this use case, consists of three different site deployments: the interconnected sites are located approximately 10–15 kilometres apart and their interconnection is based on microwave links. All three sites use a common base infrastructure, but each one has different features.

Figure 6. Map of the three testbed sites for the 5G ESSENCE pilot

The campus of NCSR “Demokritos” (NCSR), in north-east Athens, is a 150-acre area, combining indoor and outdoor environments, covered by five software-driven 5G wireless nodes and supported by an optical backbone. In particular, the experimental setup at the campus of NCSR “Demokritos” comprises five main parts: the core network; the backhaul network; the access network; mobile terminals connecting to the access network, and; distributed cloud deployments with computing, storage and networking resources.

The infrastructure provided by NCSR consists of a macro-cell located at a high mast, covering a wider area, within the campus and three small cells that serve focused coverage areas. Both the macro-cell and small cells are purely software-defined (SD), in the sense that: (i) they are driven by fully reconfigurable and open SDR equipment, and; (ii) they also feature edge computing equipment (“light Data Centres”) for hosting virtual appliances. All radio access points are connected to a core facility (currently based on LTE EPC) through dedicated fibre links. The testbed also features micro-servers integrated in each macro/small cell, according to the Cloud-Enabled Small Cell (CESC) concept. These micro-servers create a distributed Network Function Virtualisation Infrastructure (NFVI). In this manner, CESC are both edge computing-capable and multitenant, enabling a small cell infrastructure to be shared among multiple tenants. Edge services deployed in the CESC include several VNFs (vDPI, Security Appliance, Network Monitoring) as well as of virtualized appliances (Transcoder, Video analysis for object recognition).

The core functions (EPC) are also located on site. The EPCs from different vendors have been tested. The eNodeBs (Small Cells and Macro-Cell) are connected to the EPC over different types of backhaul links (fibre, RF, copper). User Equipments (UEs) of various types have been tested (mobile phones by various vendors, laptops equipped with appropriate dongles, software-defined UEs based on SDN platforms). All types of UEs have embedded USIMs, appropriate for authentication to the EPC. The testbed also hosts a core Cloud/SDN experimental platform for the experimentation needs of the 5G ESSENCE project. The cloud infrastructure is based on the OpenStack Cloud Operating System, comprising of 18 compute nodes and storage system supporting SAS (Serial Attached SCSI) and iSCSI (Internet Small Computer System Interface).

The NCSR testbed also features SDN-enabled network devices, as well as legacy devices including firewalling and routing equipment. Finally, the NCSR site connects to the Internet via the national NREN (GRNET), using a dedicated hardware firewall whose rules are fully customizable. VPN access is possible, via SSL and IPSec connections.

The OTE building (OTEAcademy), to the north of the Maroussi-Athens city is a multi-functional complex, combining various indoor and outdoor usage scenarios. The testbed includes an OpenStack-based cloud infrastructure, consisting of 1 gateway, 5 controllers, 4 x86 + 2 ARM -based compute nodes, a VPN Server, switches/routers, while being interconnected to OTE’s labs, providing thus additional capabilities for testing

new technologies either for PoC or for field trials. The OTE testbed includes eight Nokia 4G/4G+/Wi-Fi small cells, a flexible end-to-end (E2E) IoT platform, as well as a broadband connection over GRNET [10], serving as backhaul link.

The *Egaleo stadium*, in west Athens, is going to be an actual “field” testbed, supporting a wide variety of real-life scenarios, ranging from massive MTC to flash crowd events. The Egaleo municipal stadium “Stavros Mavrothalassitis” is a football ground located in Egaleo, in the west of Athens. The stadium was built in 1966 and totally renovated in 2006. The stadium belongs to the Municipality of Egaleo (MoE) and its capacity is 8.217 (seated) spectators. The stadium is used by the football team of Egaleo (Egaleo FC). In addition to the football matches, the stadium is used for various events, such as music concerts. In general, the Egaleo municipal stadium is a modern stadium and has all the appropriate facilities and infrastructures. The infrastructure at the Egaleo municipal stadium aims at showcasing the value of 5G in big sports and/or cultural events. The access part of the infrastructure is based on three low-power cells, covering the entire stadium, integrated with local virtualization-capable IT resources, thus forming CESC. The capability of the CESC to be multi-tenant and to host edge services enable a new business model, under which the CESC infrastructure is owned by the stadium operator (rather than by MNOs), who, in turn, leases slices to MNOs, MVNOs and enterprise users. The stadium is connected to the main site of the testbed (NCSR “Demokritos”), where the core functions are expected to reside, with a backhaul point-to-point microwave link. A VPN over the Internet also exists, as a fall-back solution.

5. DISCUSSION

5G ESSENCE has focused on preparing an inventory of assets and resources which will be available during the integration and validation of the “5G Edge Network Acceleration at a Stadium” use case. Moreover, the preparation of the demonstration campaign has taken place. During this period, the *service VNFs* (i.e., hardware-accelerated video encoder/decoder, virtual Caching, transcoding, etc.) and *network services* for 5G-based video production and video distribution into a football stadium have been developed and fine-tuned, in order to “match” the stadium use case specific requirements. Also the setup, the demo configuration and the integration of 5G ESSENCE specific tools to the adjusted testbed that will be deployed at the football stadium have been finalized.

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