An SDN QoE-Service for Dynamically Enhancing the Performance of OTT Applications

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***Abstract*—This paper provides a brief overview and a vision for introducing a Quality of Experience (QoE) function for on-demand services or for premium users, based-on Software-Defined Networking (SDN). The proposed "QoE-service" can take advantage of the SDN global resource view and complementary QoE metrics to assure the desired performance for OTT applications by adopting traffic management mechanisms. This paper introduces the QoE-Service concept and SDN architecture and it presents a set of use cases that demonstrate its suitability and applicability to Long Term Evolution (LTE) networks.**

I. Introduction

As Mobile Network Operators (MNOs) are facing a tremendous traffic increase due to the introduction of emerging mobile devices and applications, their revenue remains nearly constant [1]. Over-The-Top (OTT) providers, on the other hand, are gaining momentum with increasing revenues directly from users, while the MNOs that support these OTT services are not involved in such a revenue loop. This paper introduces the concept of "QoE-Service" (called QoE-Serv) enabling MNOs to offer enhanced OTT service performance upon request or for OTT premium users. QoE-Serv is an SDN-based function relying on a global network resource view, while considering particular QoS parameters (e.g., packet delay, loss rate, throughput, etc.) with respect to a specific application or user. QoE-Serv aims at providing an analysis on the selected application/service performance by mapping QoS measures to QoE and triggering traffic management mechanisms accordingly to assure QoE. In this way, QoE-Serv can enable operators to get into the revenue loop between OTT providers and subscribers, either by introducing a charging fee for this service or by offering it as an advanced feature for premium users. This paper provides the QoE-Serv vision, the supporting SDN architecture and a set of use cases demonstrating its applicability in LTE.

II. Related work

LTE networks offer QoS by following the bearer concept [2]. Particularly, MNOs use dedicated bearers for IP Multimedia Subsystem (IMS) traffic and route the remaining traffic in the default best-effort bearer. Establishing a bearer or acquiring a bearer modification is handled by the network or user and is typically based-on the subscriber profile. However, this approach does not allow MNOs to expose their capabilities to third parties; nor can assure QoE for OTT applications. Thus, the goal of this paper is to provide mechanisms that offer such possibilities towards service or user differentiation.

SDN architecture [3] enables this possibility by facilitating OTT service providers with a rich set of APIs that MNOs can use to expose their network capabilities. This allows the latter to perform network programmability making the maximum use out of the network resources and delivering enhanced quality services to their subscribers. A set of network assets that can be used for customizing and enriching the offered services may include service performance related functions, subscriber location and QoE. Effectively, network programmability can create new opportunities for providing QoE with respect to certain applications in a dynamic and flexible manner, where OTT application developers and users have more control.

SDN-based approaches have been used in recent works as the means to monitor and control QoE of the end users. In [4], a QoE API is described, which is implemented on the user device side, and is used to monitor the QoE delivered to various network flows. Through this API, application developers are able to influence the QoE of end users, by dynamically requesting resources from the network. These requests are driven by the users' feedback and the actual network QoS provided to them. Moreover, in [5], a commercial SDN platform is used to improve the QoE of video streaming applications, by monitoring video QoE metrics at the client side and dynamically changing routing paths. In this paper, we elaborate a more generic solution, which combines user and network-side measurements, and is neither restricted to a specific service, nor dependent on a unique traffic engineering technique. Specifically, we introduce a QoE-Serv at the OTT side that takes care of the performance of various services, on-demand, or for premium users that reside in 3GPP LTE networks.

III. SDN-based QoE-Serv: Concept & Mechanisms

A. *QoE-Serv Concept*

With the recent popularity of different applications, the LTE architecture is no longer sufficient to enable neither a fine personalization of customers' requests nor a quality differentiation for the plethora of offered services. LTE networks use, as of today, the default bearer for OTT data traffic, without being able to preserve a customer-centric service quality. On the other side, OTT providers are unable to influence the quality of their offered services, since there is no standardized interface between these two entities. To fill this gap, we herein propose a QoE-Serv and a supporting architecture based-on SDN. The QoE-Serv enables OTT players to monitor QoE and ensure QoE requirements regarding their offered services. It collects information from the application layer of the User Equipment (UE) belonging to an MNO as well as from various network nodes in the access (E-UTRAN) or core (EPC) network. By leveraging the collected information, policies/rules can be imposed by the SDN controller in specific points of the network, as the means to perform traffic management. In this architecture, QoE supervision can be either requested directly by the OTT, or indirectly by the user.

B. *SDN Architecture for QoE-Serv*

In this section we describe the SDN architecture for supporting the QoE-Serv, as illustrated in Fig. 1. The SDN controller can install on-demand rules at monitoring agents inside selected base stations (i.e., eNBs and HeNBs), UEs, as well as EPC network elements, in order to measure particular performance parameters that can be used to calculate QoE with respect to a specific service and/or user.

The proposed QoE-Serv provides the parameters for such rules and QoE estimations, based-on different models per application type. Furthermore, it is open for incorporating new innovative QoE measurements and models for forthcoming applications and services. The QoE-Serv may operate as follows: (1) It periodically and/or on-demand requests specific QoS parameters or other assets from the MNO, through the SDN controller, to be used for the purposes of QoE monitoring; (2) These requests are translated by the controller into plausible rules/requirements for the MNO; (3) The MNO collects the

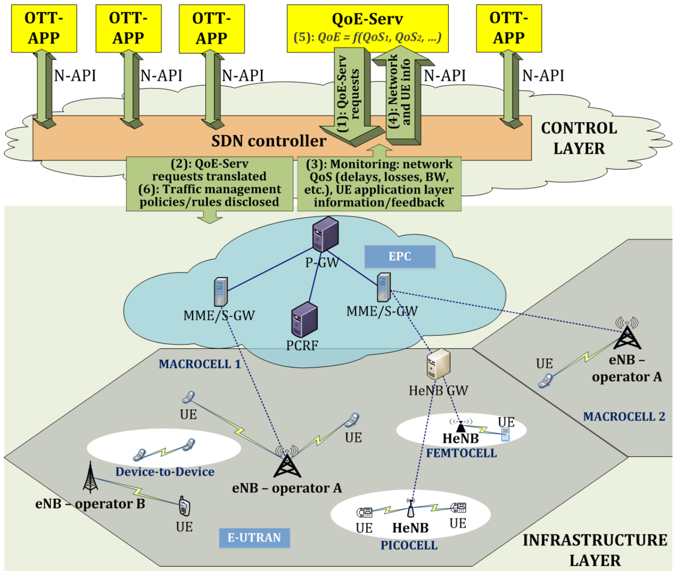

Fig. 1. SDN-based QoE-Service.

respective data by the most appropriate network nodes as well as the UEs and reports them back to the controller. Optionally, any "context" information may be revealed to the controller, to enable smarter OTT decisions, if required; (4) This information is communicated back to the QoE-Serv, where it is translated to QoE "language"; (5) Based-on the current use case, the SDN controller might then decide that the QoE of specific services or users needs improvements; (6) Finally, such a decision may trigger traffic management options (i.e., application of policies/rules in step (2)) to enhance the QoE.

C. QoS to QoE Mapping

The QoE-Serv is responsible for mapping various QoS parameters to application-specific QoE metrics or scores reflecting the anticipated momentary customer experience. Each OTT provider will implement different mapping functions, dependent on the offered service. For instance, for video conferencing applications (e.g., Skype) with a resolution of 640x480, the proposed QoE metric is: $3 + F/35fps + (2I - 1)$, where F is the frame rate (fps) and I is the image quality (between 0 and 1) [6]. This QoE metric can be checked in comparison to a required threshold, or can be further mapped to a Mean Opinion Score (MOS), i.e., a 1-5 ordinal scale. Regarding the QoE of on demand video applications (e.g., YouTube), the key influence factor is the number and duration of stallings. Thus, it is recommended to monitor the current buffered video playtime, to prevent imminent stallings [7]. For cloud gaming, the key QoS factors that need to be monitored by the QoE-Serv are UL/DL delays and packet losses [8]. Similarly, appropriate QoE metrics or models may be found for other OTT services too. Overall, if the respective QoE metric or MOS exceeds/fails a certain threshold, or if it is predicted that this will happen promptly with a certain probability, measures will be requested by the QoE-Serv from the MNO through the controller.

IV. Elastic Traffic Management Mechanisms

Based on particular QoE indications, the SDN controller can trigger traffic management mechanisms to ensure the desired service quality. To achieve this, different mechanisms and strategies can be adopted. The objective is to apply congestion control in the default bearer by limiting the data rate of certain type of subscribers, traffic types or applications, etc. The SDN controller can provide update policies to the PCRF for particular users. Then the PCRF may forward the information to the P-GW to provide the appropriate marking of selected traffic e.g., get the desired treatment at the access network. As a complementary approach, the SDN controller can let the Mobility Management Entity (MME) know about the QoE of a particular user/session, so it can select the appropriate S/P-GW that can satisfy the desired QoE [9]. Alternatively, the MME can create room by shifting other traffic away from specific S/P-GWs, kept for selected services or premium users.

V. Use Cases

Apart from the technical novelty of the proposed QoE-Serv, significant business value is also expected. We may describe for instance various use cases, where the introduction of the QoE-Serv has an impact not only on the users' satisfaction (i.e., reducing customer churn) but also on the MNOs' revenues.

Many OTT providers, offer a contract-based subscription to their customers, differentiating among bronze, silver and gold users (e.g., Netflix). Except for adapting the resolution of the streamed video, or ensuring proper interconnections with the MNO's infrastructure, there is not much power left to Netflix to really control the offered quality to its subscribers. However, a QoE-Serv can really enable a boost of the QoE of important customers, as long as this is triggered by the OTT's policies and executed by the MNO. Other OTT providers offer token-based solutions to their customers: either in the form of time-bounded purchased tokens, or as rewards from the OTT. In both cases, a token will automatically "wake-up" the QoE-Serv, which will immediately dictate the MNO to boost the QoE of this customer. Similarly, pay-as-you-go solutions with respect to a specific service will have the same effect. For instance, a customer playing an online and highly interactive game will automatically receive a QoE enhancement, for guaranteeing a seamless gaming experience.

VI. Conclusions & Future Work

This paper introduces the concept of an SDN-based QoE-Serv, as a way to guarantee the required QoE level for on-demand services or premium users of OTT applications. This is enabled through the monitoring of specific network parameters by the SDN controller, and the mapping of these parameters to QoE values inside the QoE-Serv. Elastic traffic management decisions can then be requested, to impact the experienced quality of selected users. The introduction of such a QoE-Serv in LTE networks will be able to "unlock" additional business value both for OTT providers and MNOs. In future works, we plan to analyze the overhead caused by applying and running periodically the QoE-Serv into the network and ways for performing smoothly the elastic resource provision to the end-users.

Acknowledgment

This work is supported by the European Commission under the auspices of the FP7-PEOPLE MITN-CROSSFIRE project (grant 317126).

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