A New Method for Measuring Quality of Experience on Mobile OTT Streaming

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***Abstract*—Mobile OTT video services are consumed by users of Mobile Network Operators (MNOs). Hence, MNOs are willing to understand the Quality of Experience (QoE) that is perceived by mobile end-users. For this reason, Customer Experience Management (CEM) tools are traditionally utilized inside mobile network infrastructure. In this paper, we propose a new quality-of-experience (QoE) measurement methodology using only call detail records (CDRs) of MNO. The proposed method is used to measure the mobile customer experience of OTT video services offered to MNO's users with Adaptive Bitrate (ABR) based protocols. Through evaluations on real network sites in Turkey, we show that our proposed methodologies' measured average throughput (a Key Quality Indicator (KQI)) exhibits similar behaviour with observed average throughput (a Key Performance Indicator (KPI)) of base station over an observation period of one-month.**

***Index Terms*—OTT, QoE, measurements, real-time testbed.**

I. Introduction

Quality of Experience (QoE) has become an increasingly popular concept for delivering smooth content and services. Therefore, networking technologies, protocols and algorithms need to be able to incorporate QoE awareness for improving the user perceived quality of services and applications. Proper design of QoE models and monitoring mechanisms are essential for improved performance evaluations and management of services, applications and networks. Adaptive Bit Rate (ABR) based protocols such as Apple HLS, Microsoft Smooth Streaming, etc. provide the ability to switch between different pre-defined speed profiles during the same Transmission Control Protocol (TCP) session, that is flowing from the server to the user as media traffic. When a mobile user equipment (UE) moves to a different coverage zone where mobile network quality is lower, despite poor network performance ABR allows video sessions to continue. However, frequent speed profile changes in TCP sessions make it very difficult to calculate QoE for Mobile Network Operators (MNOs).

Currently, due to obligations of state supervisory bodies, MNOs utilize Deep Packet Inspection (DPI) tools on their mobile network core networks for analysis purposes. These probes are used to derive simple Call Detail Record (CDR) logs containing information about amount of data related to subscriber traffic, the source of the content, replicating the signal streams at the TCP level, etc. Customer Experience Management (CEM) platforms in the market today are able to measure these detailed raw data from probes in high computing power servers for obtaining measurable customer experience metrics. However, in current CEM solutions, since all TCP message flows belonging to the video service need to be analyzed on a packet-by-packet basis, there is a need for a high performance computing server that can be used to perform complex calculations. In addition, since ABR-based protocols can initiate multiple TCP sessions at the same time during a video experience, user experience calculations of CEM solutions need to be optimized to perform packet-based tracking and analysis of multiple TCP flows matched to a single customer experience.

In recent years, MNOs are heavily investing in video service CEM platforms developed by various vendors at considerable high costs that are making QoE measurements [1]. Previously, Standard Developing Organizations (SDOs) such as ITU-T and Broadband Forum have defined measurement points between different domains and a set of performance indicators in an end-to-end IPTV service architecture [2] [3]. QoE management of video transmission over different types of networks and challenges of technical implementations for QoE-oriented services over video communications are highlighted in [4]. Transmission flow factors are defined as a QoE prediction point for wired and wireless IPTV users in [5]. A study in [6] investigates QoE measurement challenges in a real network. Measuring QoE in a HTTP adaptive streaming environment is presented in [7]. Together with implementation of the proposed measurement method developed in this paper, MNOs can perform historical video service quality measurements by simple calculations over the existing CDR data produced within their existing infrastructure. Moreover, costly server and software investments can be restricted. Our contributions in this paper are three fold: (i) We study a new and efficient QoE measurement method for MNO. (ii) Our proposal indicates a cost-effective and easily applicable QoE measurement strategy for a MNO. (iii) We analyze the performance of our solution in a real-test bed in order to demonstrate experimental results of subscriber experience for mobile IPTV service.

II. Measurement System Model and Concepts

A. Traditional Network Architecture for OTT service

Over-the-Top (OTT) is a media distribution practice that allows a streaming content provider to sell audio, video, and other media services directly to the consumer over the internet. Below steps summarize logical flow for a traditional digital TV platform OTT service (as shown partially in Fig. 1): (i) Initially, user authentication process is evaluated by middle-ware server. (ii) Later, if an authenticated subscriber requests to watch a video content, this user is diverted to appropriate Content Delivery Network (CDN) where the video files are stored on. (iii) The streaming is started by the CDN server as unicast traffic and the user buffers sufficient incoming data to enable continuous real-time decoding and playback.

Shortcomings of the existing methods: In a given TCP session packet stream, evaluation of time for buffer overflow is done by analyzing the time when all these packet streams pass until TCP window size becomes zero. These detailed analysis requirements increase the need for a server with high computing capabilities that also have CEM platform software. In addition, since all messages in TCP streams need to be analyzed during calculations, MNO needs to allocate storage space in the Data Warehouse (DWH) environment. Another difficulty is the bias effect of having users using different video players. For example, if the Iphone-7 is filling a buffer after A amount of data, the Samsung S5 device may need an data amount of B amount of data to fill out its buffer. From a different viewpoint, at the beginning of the session, while the IOS devices start the video at the speed of the highest profile, Androids might start it with high profile. Therefore, the video playback program that the ens-users uses can also affect the results. These differences prevent observing real effect of mobile network sites on customer experience.

B. Proposed QoE Measurement Method for OTT Service

A general overview of the measurement points for the proposed method and the sample topology is given in Fig. 1 and Fig. 2. Fig. 1 gives a general mobile network architecture with the proposed QoE measurement methodology. The red dashed line in Fig. 1 represents the ABR video traffic stream flowing from the content provider server located on the MNO's network to a user device connected to the mobile network internally. Fig. 2 shows HTTP Live Streaming Components including a server, a distribution system and user software. A typical flow of measurement method is as follows: A UE acquires the IP address by establishing PDP connection to mobile network via the eNodeB station. Thus, access to the internet is established for UE. If the user video application is started on the UE (for example Digital TV subscription mobile application), the authentication control for the corresponding user is first performed in the main control system. Subsequently, if the UE wishes to initiate any broadcast, this request is forwarded to the most appropriate CDN server located at the Multiprotocol Label Switching (MPLS)/Core Network. Load Balancer located on Headend of Fig. 1 is the first equipment which meets application requests (Video Strorage and Processing Platform (VOD), TimeShift, Catchup, Live TV) of users. The CDN server, with the same ABR initial speed profile for all users, starts unicast transmission to the UE via internet and the Mobile Core Network. While the video traffic is being carried over the Mobile Core Network, streaming traffic is replicated by PS Probe's located at the respective interfaces (Gn, S5) and then this traffic is transferred to the DWH via the probe system. The replicated traffic is analyzed at HTTP level for observing customer experience. In our proposed method, customer experience analysis is done with simple calculations using the existing DWH environment. The basic CDR data of the video service generated by the PS Probe using the DPI method is stored in the DWH environment. Video service customer experience metrics and mobile network site performance are measured by applying the proposed mathematical model which is based on CDR records. Streaming start delay, streaming start success rate, user throughput metrics for each customer session can be calculated by defining these mathematical functions on DWH platform. As a result, customer video experience can be observed.

The designed mobile network video service quality measurement method is summarized in two steps: *In first step,* the application software which enables the OTT video service should not just be the interface (GUI) but should also include a media player program with its own codec structure (e.g. Digital TV service provider's mobile application which can be downloaded). In media player software, parameters such as "starting speed profile (kbps)", "user buffer amount" which are used in ABR based protocols will be evaluated as fixed values. Thus, all users will follow the same rules throughout the ABR-based traffic flow, regardless of brand model, through content provider servers. In this step, the following elements are used: the chunk number transferred by the server until the amount of user buffer is full (number), video duration carried in chunk file (s), algorithm for the function that changes the profile.

Second step is application of the designed mathematical model. These calculations, which can be performed in the DWH environment, are performed on basic CDR rows reflecting the amount of traffic per CDR rows generated by the packet-switched probe as given in Table I. Thus, the similar customer experience metrics can be calculated without following complex TCP flows. For this step, the

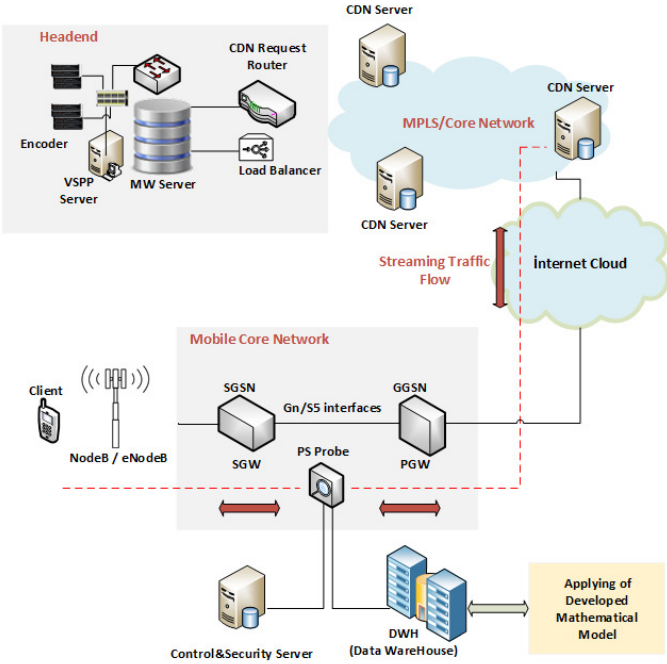

Fig. 1. Mobile Network Architecture and Proposed Quality of Experience Measurement System for IPTV Service.

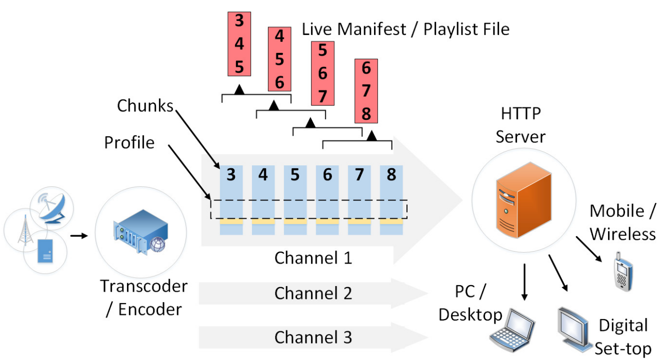

Fig. 2. HTTP Live Streaming Components.

following notations are used: **R (kbps):** start up profile for the video streaming, **C (s):** the video length that is carried by each chunk file, **A:** quantity of chunk file required to transfer by the server until the client buffer is fulfilled, $\mathbf{T}_i$ (s): total amount of time for customer video session on i-th CDR row, $\mathbf{V}_i$(byte): total amount of downloaded video data on i-th CDR row, **B (byte):** the amount of data that must be transferred by users until the buffer is full, **S (%):** average streaming start success rate for customer sessions, **P (s):** average streaming response delay, $\mathbf{t}_i$ (s) required start time until user buffer is full for i-th CDR. **L(byte):** data amount for video streaming start success , $\mathbf{\Omega}$: achieved customer video experience throughput, **K** : total number of CDR rows of a given user. Based on these definitions, we can calculate

TABLE I
A SAMPLE CDR USED IN OUR METHOD

i	Start Time	MSISDN	Site Name	$\mathbf{V}_i$ (kbyte)	$\mathbf{T}_i$ (ms)
1	2018-05-21 22:43:38:950	5080072451	WIS084334	12024	114020
2	2018-05-21 22:54:35:863	5080072451	WIS084334	31082	223057
3	2018-05-21 22:54:35:863	5080072451	WIS084334	721	52011

$$\mathbf{B}(byte) = \mathbf{R}(kbps) \times \mathbf{A} \times \mathbf{C}(s), \tag{1}$$

After calculating the **B** value, we can find out the number of CDR rows that satisfy $\mathbf{L} > \mathbf{B}$ for all CDRs which is also named as **Y**. We can also calculate the throughput for **Y** number of CDR rows as follows,

$$\mathbf{\Omega} = \frac{1}{\mathbf{Y}} \sum_{i=1}^{\mathbf{Y}} \left(\frac{\mathbf{V}_i}{\mathbf{T}_i}\right) \tag{2}$$

Example: In step 1, let's imagine that the operator application software starts data streams for all user types over the HTTP Live Streaming (HLS) protocol with the following values: **R:** 500kbps, **A:** 3, **C:** 5s. In this case, using (1), $\mathbf{B}$ = 500 (kbps) $\times$ 3 $\times$ 5 (s) = 938 kbytes.

B value (938 kbytes) is the amount of data that is transferred to the smartphone for the duration of the video after the customer presses the play button for content on the screen of the smartphone. In the same way, the transfer of this amount of data will be done in each digital TV channel change. **B** values which are only calculated once, will be used as fixed values for all customer experiences in subsequent calculations. Assume that the PS Probe, which is located in the mobile core network of the MNO, CDR records of three CDR rows of Table I of a subscriber are derived from the DWH platform.

To calculate the start time of the streaming for the different records in CDR, we use the numerical values in Table I together with **B** value calculated using (1). Hence, for first CDR where $\mathbf{T}_1 = 114(s)$, $\mathbf{V}_1 = 12024$, the start time can be calculated as

$$\mathbf{t}_1(s) = \frac{\mathbf{B} \times \mathbf{T}_1}{\mathbf{V}_1} = 8.89(s) \tag{3}$$

and for $\mathbf{T}_2 = 223(s)$, $\mathbf{V}_2 = 31082$

$$\mathbf{t}_2(s) = \frac{\mathbf{B} \times \mathbf{T}_2}{\mathbf{V}_2} = 6.72(s) \tag{4}$$

Based on (3) and (4), customer experience metrics can be calculated for **Y** number of records as follows:

$$\begin{aligned} \mathbf{P} &= \text{average}(\mathbf{t1}(s), \mathbf{t2}(s)) \\ &= \text{average}(8.89(s), 6.72(s)) = 7,8(s) \end{aligned} \tag{5}$$

$$\mathbf{S} = \mathbf{Y}/\mathbf{K} * 100 = (2/3) * 100 = 66\% \quad (6)$$

Finally, the experienced user throughput can be calculated as,

$$\mathbf{\Omega} = \text{average}[(12024 * 8/114), (31082 * 8/223)] = 979.4 kbps \quad (7)$$

Above example can be generalized for all users that are served in a given site. Although above three metrics (**P**, **S** and Ω) can be used for observing the QoE of users, in the next section, our focus is on performance comparisons using the throughput metric.

III. Experimental Results

For experimental results and validation, we have compared our proposed user experience measurement method results with real-world Key Parameter Indicator (KPI) results of eNodeBs over one month duration deployed in two different geographical areas in Turkey one in Yenimahalle, Ankara and the other one in Bakirkoy, Istanbul in Turkey.

Fig. 3 and Fig. 4 show two examples of average user throughput values of the proposed mobile OTT Key Quality Indicator (KQI) and eNodeB's KPI values. We can observe from those figures that eNodeB based KPI values are in parallel with the proposed user experience measurement value of (2). For example, for eNodeB located in Yenimahalle district of Ankara in Fig. 3, mobile OTT average user throughput that is calculated using (2) for all users is monotonically increasing with eNodeB's average user throughput values over the observed one month duration. Similarly, for the eNodeB located in Bakirkoy district of Istanbul in Fig. 4, similar trends of ups and downs over a month between the proposed methodology and the eNodeB's throughput values can be observed. For example, on week 2, there exists a sudden quality-of-service (QoS) drop in terms of throughput values in both KPI and KQI metrics, i.e. proposed methods throughput drops from 1.271 kbps to 1.253 kbps and the observed eNodeB's throughput also drops from 10.758 kbps to 9.939 kbps.

As shown in Fig. 3 and Fig. 4, in comparison with KPIs, OTT video service customer experience calculations can be customized using the proposed methodology. Therefore, MNOs can pave the way for obtaining similar and comparable calculations (mobile network and customer basis) with CEM tools by building simpler and more efficient mathematical models in the DWH environment.

IV. Conclusions and Future Work

In this paper, we have proposed a new method for measuring QoE of mobile users using OTT video streaming service. The proposed method is used to measure the mobile network customer experience for OTT video services in selected two sites located in different cities in Turkey.

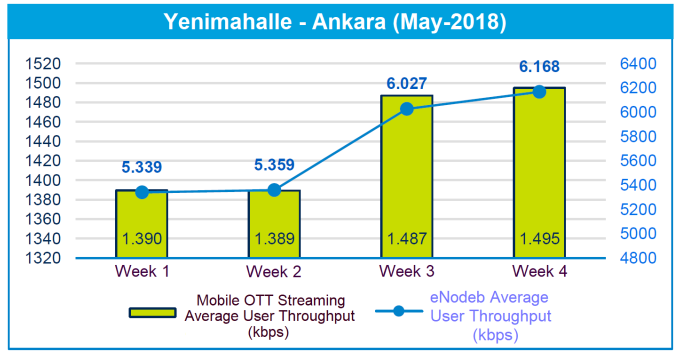

Fig. 3. Comparison of Average User Throughput (May Results obtained for eNodeb located in Yenimahalle/Ankara)

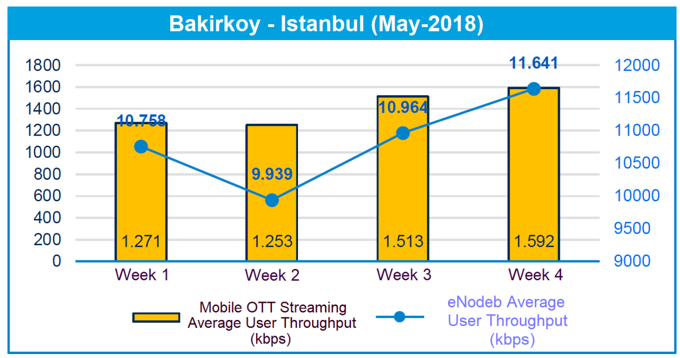

Fig. 4. Comparison of Average User Throughput (May Results obtained for eNodeb located in Bakirkoy/Istanbul)

Our results indicate that simple calculations on CDR can yield a quantifiable measure of QoE of mobile OTT users. As a future work, collected mobile OTT performance data can be used to create an indexing system to provide fault location detection, capability monitoring and optimization processing in the mobile network. This work can also be regarded as a part of converged fixed and mobile network.

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