Abstract—MPEG-DASH has become one of the mainstream methods for streaming video over unmanaged networks, as it enables users to receive this video at the best possible QoE level the network capacity and the users’ terminals capabilities allow. However, it has been observed that when MPEG-DASH users, sharing the same access network, request, in parallel, the offered video content, QoE unfairness occurs: some users receive video content that corresponds to a high QoE level whereas all others do not. As a reason for this result, literature points out the inter-dynamics between TCP’s congestion avoidance mechanism and the on-off operational pattern of MPEG-DASH switching logic. In this paper, we try to shed some more light on this QoE unfairness issue by investigating how the segment duration of the video content can effect the MPEG-DASH users’ QoE level. In this paper, we try to shed some more light on this QoE unfairness issue by investigating how the segment duration of the video content can effect the MPEG-DASH users’ QoE level. Towards this, we designed a number of experiments where two identical users request, concurrently, the same video service, but utilising a different segment duration. As this work is part of a larger effort regarding MPEG-DASH, QoE and interactive digital broadcasting, we conducted our experiments over an interactive DVB-T testbed. The experimental results show a strong correlation between the video’s segment duration and the MPEG-DASH users QoE level: the user utilising a longer segment duration achieves a higher QoE level than the one utilising a shorter segment duration.

Index Terms—MPEG-DASH, QoE unfairness, QoE metric, Interactive Broadcasting.

I. INTRODUCTION

MPEG-DASH[1] is the first international standard in the area of Dynamic Adaptive Streaming over HTTP (DASH) and as its vendor counterparts [2], [3], [4] enables users to receive video services, over the Internet, at the best possible QoE level the network capacity and the users’ terminals capabilities allow. To achieve this, MPEG-DASH enables video Service Providers (SPs) to segment the video content and then offer it in several Quality Profiles(QPs), named Media Representations. Each Quality Profile utilises a different set of video encoding rate, resolution and codec attributes aiming to match a specific network rate and user’s terminal screen resolution, playout buffer capacity and processing power. On the other hand, MPEG-DASH users exploit "intelligent" applications that estimate, in a per segment basis, the available bandwidth and playout buffer’s size. Based on the estimation results, the users request segments from the best fitting Quality Profile and therefore achieve the best possible QoE level.

However, it has been reported [5], [6], [7] that when MPEG-DASH users, sharing the same access network, request, in parallel, the offered video content, QoE unfairness occurs: some users receive video content that corresponds to a high QoE level whereas all others do not. As possible explanations for this phenomenon, the authors at [6] suggest MPEG-DASH switching algorithm’s ON-OFF operational pattern, along with the parallel operation of TCP’s congestion avoidance mechanism.

In this paper, we aim to continue the efforts towards achieving a better understanding of this QoE impact.
unfairness issue. Our question is the following: Does segment duration have a positive or negative effect on the MPEG-DASH users’ QoE level—therefore contributing to the observed QoE unfairness? Towards getting an answer, we designed a number of experiments where two identical users request, concurrently, the same MPEG-DASH video service, but utilising a different segment duration. In the direction of evaluating QoE unfairness, we introduce a QoE index that derives each user’s achieved QoE level from their respective distribution of segments per Quality Profile—we assume that each Quality Profile corresponds to a certain QoE level. In this way QoE unfairness can be measured as the users’ QoE index difference.

Finally, it is noted here that as this work is part of a larger effort regarding MPEG-DASH, QoE and interactive digital broadcasting, we conducted our experiments over an Interactive DVB-T (IDVB-T) testbed [8], [9], [10]—terrestrial digital video broadcasting networks enable for the direct and robust transmission of IP video services to a massive number of users, dispersed in wide geographical areas with just one transmission point.

Following this introductory section, a brief presentation of IDVB-T systems is given. At section three, the evaluation testbed, MPEG-DASH’s video content & switching logic, experimental scenarios, evaluation metric and experimental results are presented. Finally, section four concludes the paper.

II. IDVB-T IN A NUTSHELL

During the last decade, two architectural designs regarding Interactive DVB-T networks emerged: centralised [11], [12], [13] and decentralised architectures [14], [15] with the decentralised predominating over the centralised ones when scalability issues come to the foreground. In our network deployments, we utilise decentralised IDVB-T since it is the latest outcome in the field of interactive Broadcasting and its capacity for triple play services provision has been proven [8].

In decentralised IDVB-T (see figure 1), intermediate distribution nodes, named Cell Main Nodes (CMNs), interconnect Service Providers (SPs) and End Users (EUs) via DVB-T’s virtual Ethernet backbone—realised from the UHF link (forward channel) and the CMNs’ return paths. In this configuration, SPs and EUs send, via their respective CMN, their services/requests to the DVB-T platform. There the DVB-T platform broadcasts, via the forward channel, all the received traffic. Finally, the receiving CMNs route, via their access networks, any traffic destined to their respective SPs/EUs.

III. EVALUATION

Towards being able to study the effect of MPEG-DASH segment duration on users’ QoE, and therefore assess its contribution on the QoE unfairness, we designed the following experiment: two equivalent users, residing in the same access network, request, concurrently, from the same HTTP server, MPEG-DASH video content that differs only in the segment duration. The subsequent sections describe in more detail the used Testbed, MPEG-DASH Video content, MPEG-DASH client switching logic, evaluation metric and experimental results.

A. Testbed

Figure 2 depicts the Testbed that was used for studying the effect of MPEG-DASH segment duration on end users’ QoE. More specifically the Testbed was realising an Interactive Digital Video Broadcasting Terrestrial (IDVB-T) network consisting of:

1) The DVB-T platform broadcasting at UHF channel 40 (622-630 MHz), using 8k transmission mode, 16QAM modulation scheme, 7/8 code rate, 1/32 guard interval and the MPE (Multi-Protocol Encapsulation) protocol for encapsulating the IP packets.

2) An edge router (CMN 1 in Fig.2) interconnecting the HTTP server, hosting the MPEG-DASH content, with the IDVB-T network. The communication between CMN 1 and the DVB-T platform was established using a wireless (IEEE 802.11g-54Mbps) dedicated link (Uplink 1), whereas the interconnection between the HTTP server and CMN 1 was realised with a WiFi (IEEE 802.11g-54Mbps) hotspot.

3) An edge router (CMN 2 in Fig.2) interconnecting the HTTP server and the DVB-T network. The communication between CMN 2 and the DVB-T platform was achieved via a
wireless (IEEE 802.11g-54Mbps) dedicated link (Uplink 2), whereas the interconnection between the MPEG-DASH users Emulator node and CMN 2 was implemented using another WiFi (IEEE 802.11g-54Mbps) access hotspot.

Finally, from the UHF downlink’s total available bandwidth (20.5 Mbps), 10 Mbps were reserved for the MPEG-DASH services.

**B. MPEG-DASH Video Content**

We used "Big Buck Bunny" [16] movie, because it has no copyright constraints, it is provided in several High Definition (HD) formats and it contains both low and high action rate scenes. Using the 1920x1080, H.264 HD format (9:56 minutes duration) as a source media file and exploiting ffmpeg [17] tool, we created five Quality Profiles (QPs) with encoding rates of 6133(Quality 5-Q5), 4134(Quality 4-Q4), 2135(Quality 3-Q3), 1135(Quality 2-Q2) and 634(Quality 1-Q1) Kbps respectively. It is noted that Q5 is the highest QP and Q1 the lowest. Each of these 5 Quality Profiles, was segmented, using the MP4Box [18] MPEG-DASH segmenting tool, having a duration of 2, 5, 10, 15 and 30 seconds. Lastly, we created the proper manifest files and uploaded both manifests and segments to the HTTP Server of the testbed.

**C. MPEG-DASH client switching logic**

Both MPEG-DASH Users in this paper exploit the logic depicted in the following figure. We note here that we have developed our own MPEG-DASH client module and whenever a new user is needed the MPEG-DASH users emulator (see Figure 2) loads an instance of our software module.

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**TABLE I**

MPEG-DASH SEGMENT DURATION IN EACH EXPERIMENTAL ROUND

<table>
<thead>
<tr>
<th>Round</th>
<th>Duration 1 (sec)</th>
<th>Duration 2 (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>15</td>
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<td>4</td>
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</tr>
<tr>
<td>9</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
<td>30</td>
</tr>
</tbody>
</table>

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1. Manifests are media presentation description files, providing information to MPEG-DASH clients about the available Quality Profiles and where to get the corresponding video content segments.
E. Evaluation metric

We evaluate QoE unfairness as the difference of the users’ achieved QoE levels. This assumes that there is a metric that can measure the QoE level of each user. The challenge is that QoE is dependent on a number of objective and subjective factors: Objective like the video resolution, available network bandwidth, terminal capabilities, and subjective like the end user’s emotional status, interaction with the surrounding environment and perception of the world. Following this segregation, the literature suggests several subjective (e.g. Mean Opinion Score-MOS) and objective (e.g. Video Quality Metric-VQM) QoE metrics each one taking into account some of the factors that play a role towards forming the user’s QoE level.

In this paper, we avoid the ‘vagueness’ and complexity of the subjective approach and introduce a simple objective metric that is based on the following observation: each Quality Profile in MPEG-DASH can be associated to a specific QoE level. In other words, higher Quality Profiles (QPs) correspond to a better QoE level than the lower ones. Based on this observation, our metric derives the users’ QoE level from their distribution of segments per Quality Profile as follows:

$$QoE_{index} = \sum_{i=1}^{n} w_i \times q_i \quad (1)$$

$$w_i = \frac{\text{count}(QP_1, \ldots, QP_i)}{n} \quad (2)$$

where $n$ is the number of QPs, $w_i$ is the weight of the $i_{th}$ QP and $q_i$ is the ratio of received segments in the $i_{th}$ Quality Profile. It noted here that for the weight derivation the Quality Profiles must be sorted with $QP_1$ being the lowest and $QP_n$ being the highest.

F. Results

As figure 4 depicts, QoE unfairness is present for all experimental rounds. Furthermore, Table II shows a clear correlation amongst the segment duration and the achieved QoE level: the user utilizing the longer segment duration achieves always a better QoE level. We explain, the experimental outcome as follows: a) the shorter duration segments have smaller sizes; b) smaller segments are downloaded in a shorter time; c) shorter times prohibit the send window$^2$ of TCP’s sliding window mechanism to reach a high value and this results to smaller sending (download) rates; and d) smaller sending rates lead the corresponding

\[\text{TCP’s send window represents the maximum number of unacknowledged bytes a host can have outstanding at anytime. High values of it indicate high sending rates.}\]

<table>
<thead>
<tr>
<th>Round</th>
<th>Segment Duration (sec)</th>
<th>QoE Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>0.56</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0.54</td>
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<tr>
<td>10</td>
<td>10</td>
<td>0.72</td>
</tr>
</tbody>
</table>

\[\text{MPEG-DASH clients’ switching logic to conclude that the available bandwidth is not enough for requesting segments from the higher Quality Profiles.}\]
IV. Conclusions

In this paper, motivated from the MPEG-DASH QoE unfairness issue—rising when two or more MPEG-DASH users, sharing the same access network, request video content—we investigated if the video content’s segment duration has a positive or negative effect on the MPEG-DASH users’ QoE level, thus contributing to the QoE unfairness phenomenon. In this direction, we designed a set of experiments consisting in two identical MPEG-DASH users, residing in the same access network, requesting concurrently the same video content, but utilising different segment durations in each experimental round. Towards being able to measure QoE unfairness as the difference between the users’ QoE level, we introduced a simple objective QoE metric that derives each user’s achieved QoE level from the distribution of their segments per Quality Profile. As this work is part of a larger effort in the area of MPEG-DASH, QoE and interactive broadcasting, we conducted our experiments over an interactive broadcasting (IDVB-T) testbed. The results verified not only the existence of QoE unfairness but also revealed a correlation between the segment duration and the users’ QoE level: amongst the two users the one utilising the shorter segment duration was achieving always the lower QoE level.

For the future, we will focus our efforts on three areas: a) investigate QoE unfairness when users utilise different switching algorithms; b) establish a standard process for associating Quality Profiles to QoE levels; and c) enhance our QoE metric with weights that take into account aspects like the playout buffer’s drain events, the amount of switches among the Quality Profiles and the QoE level distance between the Quality Profiles.

V. Acknowledgment

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References

[12] ETS 300 801 Digital Video Broadcasting (DVB), Interaction channel through Public Switched Telecommunications Network (PSTN) / Integrated Services Digital Networks, (ISDN)