QoE: User Profile Analysis for Multimedia Services

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Abstract—In multimedia services, user’s perceived quality of service is very important as compared to other end-to-end network factors. With the growth of emerging technologies, it becomes necessary for network service providers (both in the wired and wireless domains) to consider all aspects of network elements, not only to offer a better Quality of Service (QoS) but also to achieve higher end-users satisfaction. The analysis of users’ profile provides vital information, which can help service providers in managing their resources efficiently, by analyzing users’ behavior and expectation. In this paper, we setup a testbed to investigate the various factors that contribute to the Quality of Experience (QoE), in the context of video streaming delivery over wireless and wired networks. The comprehensive study of users profile provides significant insights on all metrics that influence the QoE (network parameters and video characteristics). Wireless and wired networks have different infrastructure aspects (reliability, availability etc.) but the analysis and evaluations of users’ profile are equally important for both networks. Our analytical study gives an opportunity for network service providers to obtain high user satisfaction by providing a service level that matches customers’ usage patterns and expectations.

Keywords: Quality of Experience; Quality of Service; QoE; User Profile Analysis; Video; Multimedia Services; Wireless/Wired Network.

I. INTRODUCTION

The growth of online video services are expanding rapidly, which have prevailed in the global Internet traffic with a larger distinct share. According to Cisco forecast report, the total global consumer of Internet video traffic will be 69% (excluding Peer-to-Peer (P2P) video file sharing) of all consumer Internet traffic in 2017 [3]. The remarkable growth in video-enabled devices that ranges from smart mobile to Internet-enabled large screen Television have significantly changed the usage paradigm, and easily availability of wireless networks (WiFi/3G/4G), are main contributory factors of video popularity. The online video applications and services should have mechanism that facilitates the end users to get the desired video contents in quickly and effectively manner. To achieve this task, the user profiles are built in the central location of video streaming service providers to fulfill the Quality of Experience (QoE) requirement. The main objective of network service providers is to achieve a good user experience with the minimum utilization of network resources, as wireless mobile networks have limited radio resources.

The user’s profile plays a vital role in helping the network service providers for offering the better service in order to achieve the high user satisfaction. The different methods and techniques are used to build the user analysis based on log files that helps the service providers to generate the usage pattern of current service according to user profiles. Mostly, systems build the user profiles by monitoring the user activities in the form of log files. The analysis of log files helps the service providers to generate the usage pattern of current service accordingly the user behavior.

The user’s profile is a collection of user personal characteristic data, which represent the specific user personnel interest and preference. There are many important factors, which contribute in constructing the user profiles, that clearly illustrate the behavior and habits of the users, e.g. age, sex, etc.

The Quality of Experience (QoE) is defined as the measure of overall acceptability of an application or service perceived subjectively by the end user [5]. The user profiles are very important metrics that influence the QoE.

Mostly, users have the high expectation in the context of services offer by the network service providers in flexibility and reliable manner. As videos streaming have major share of internet traffic, it is necessary to analyze video streaming services carefully in order to find out the degree of influence of (measureable and non-measureable) parameters on users’ satisfaction. The measureable parameters are those which are related with technological characteristics of the services while the non-measureable parameters deal with the users behavior and perceptual of the services.

The researchers use the two methods to evaluate the quality of multimedia services: the subjective method and the objective method. The subjective method is proposed by the International Telecommunication Union (ITU) Rec. P.800 [4] and the Video Quality Expert Group (VQEG). It consists of a group of people watching distinct video sequences under a specific controlled environment, and rating their quality. The Mean Opinion Score (MOS) is an example of a subjective measurement method in which users rate the video quality by giving five different point score from 5 to 1, where 5 is the best and 1 is the worst quality. The second quality evaluation method is the objective method which uses different models of human expectations and tries to estimate the performance of video streaming service in an automated manner, without involving human.

This paper investigates the analysis of users profiles, which are built through the influence of different QoS and other parameters on the QoE of video streaming services. The evaluation of users’ profile are very important for any wired and wireless networks. For subjective measurements, we implemented a testbed to collect QoE datasets in the form of a MOS score and evaluate the influence of each parameter (delay, packet loss, video types, and users profile) on perceived video
quality. Based on these datasets, we analyze the users profile in the perception of different other parameters; which can help the network service providers to get high user satisfaction by providing the services according to user’s satisfaction.

The remaining paper is structured as follows: we discuss related works in Section II. Section III contains discussion about metrics affecting the QoE. Section IV is dealing with the environmental approaches for assessing video QoE. Section V focuses on the testbed experimental setup and discusses experimental details. We present our results in Section VI, and conclude the paper in Section VII.

II. RELATED WORK

The large research works have carried out in order to provide the application services with acceptable quality. The researchers study the different techniques to correlate the networks QoS with end user perceived QoE. Some other methods are also developed to provide the better QoS for evaluating and predicting the user’s QoE. Generally, the developed methods are studied and examined in the form of experiments by setting up the testbed, which consists of different equipments, methods and tools. The datasets, collect in the end of testbeds experiment, are analyzed by observing the impact of different factors subjectively perceived by end users. The user’s profile is also built-up as an outcome of this testbed.

In [11], a testbed experiment is implemented to assess the QoE model for video streaming service using the QoS parameters in the wired-wireless network. In this paper, the authors just consider the QoS parameter to estimate the perceived QoE of end-users and do not consider the important information relating to users profile. Similarly, a testbed experiment is done in [13] which also simply consider the QoS parameter and investigate to show that how network QoS affects the QoE of HTTP video streaming. In [10], the authors propose the objective method for measuring the QoE by using the QoS parameters. In this paper, the QoS and QoE correlation model is proposed and the QoE evaluation method using the QoS parameter in the converged network environment. A lot of research works are done to predict the QoE based on the QoS parameters. The correlation between QoE-QoS is studied in [15], where authors investigate that how the controlling QoS parameters (packet loss, jitter, delay) of networks influence the QoE. In [2], authors highlight the problem with existing QoE model, which do not take into account the historical experience of user satisfaction while using the certain service. This important psychological influence factor is called memory effect, which plays a vital role to meet the expectation of end-users for better QoE.

A lot of studies are done on user’s profile, but mostly investigations are relating with World Wide Web (WWW). In that circumstance, it is very important for the service provider to find out the pattern that clearly pointed out the utilization of information at the end system. In [1], authors use the fuzzy clustering algorithm to analyze the e-learning behavior of the user. The analysis of cluster helps the teacher to understand the students in a better way by considering their interest, personality and other informations. In [14], authors describe a method which presents the information to the end user by considering users profile. The user’s profile is a key factor which can be very helpful for the network service providers to offer the service that is acceptable for end users. In our work, we intend to investigate the statistical analysis of QoS parameters and their impact on end users. It helps the network service provider to utilize its resources efficiently and get high user satisfaction by maintaining the certain threshold of QoE parameters.

III. METRICS AFFECTING THE QoE

QoE is very subjective by nature, because of its relationship with users point of view and its own concept of a good quality. The ability to measure QoE would give network operators some sense of the contribution of the networks performance to the overall customer satisfaction, in terms of reliability, availability, scalability, speed, accuracy and efficiency. As a starting point, it is necessary to identify precisely the factors that affect QoE, and then try to develop methods to measure these factors. We categorize these factors in three types, as follows.

A. Network Parameters

QoE is influenced by QoS parameters, which highly depend on network elements. Key factors are packet loss rate, jitter and delay. The impact of each individual or combined factors lead to blocking, blurriness or even blackouts with different levels of quality degradation of video streaming.

1) Packet Loss: Packet losses have a direct effect on the quality of video presented to end users. Packets losses are occurring due to the congestion in the networks and late arrival of packets at application buffers. If packet loss is occurring, then it becomes difficult for the video decoder to decode properly the video streaming. This results in the degradation of video quality.

2) Jitter: Jitter is another important QoS parameter, which has a great impact on video quality. It is defined as the variance of packet arrival times at the end-user buffer. It occurs when packets travel on different network paths to reach the same destination. It causes jerkiness and frozen video screens.

However, the effects of jitter can be nullified or reduced, to some extent, by adding a large receiving buffer at the end user and delay the play out time of the video. Nevertheless, when packets arrive out of order, after the expiration of a buffering time this packet is discarded by the application. In this context, jitter has the same influence as packet loss [16].

3) Delay: Delay is defined as the amount of time taken by the packet to travel from its source until its reception at the destination. Delay has a direct influence on user perception while watching the video. If the delay exceeds a certain threshold, then its effect is a freeze and lost blocks of video. The threshold of delay values varies according to the nature of the multimedia service.
B. Video Characteristics

The characteristics of video are defined in terms of frame and resolution rate, codec and types of content. The impact on the users satisfaction by reducing bit rate of video streaming services according to the available bandwidth is presented in [8]. The video content types can also influence users opinions. In case of interesting video contents, a user will be more tolerant, and low quality will not influence users experience as much as in case of a boring content. In [12], authors found that if users show enough interests in the video content, then they can accept even an extremely low frame rate.

Generally, the real network considers the user’s interest as the access’s frequency of a specific video. However, this approach is unsuitable to represent the users’ interest and preference for the video content. The optimize method to measure the user’s interest for a specific video is to record the number of clicks and stays in time. The total time that the user spends in watching the video, provides the significance information about the user’s interest.

C. Terminal Types

The consumers’ electronic devices expand largely with the rapid growth of new advancement in telecommunication industries, and they have a large number of products available for modern multimedia services. These new-generation devices are present in different sizes, processing powers, advanced functionality, usage and so many other aspects. We can classify these devices into three categories: Personal Computers, Mobile devices, and Television (TV). All these terminal devices influence user satisfaction while using video streaming services. For example, it is pointless to send HD terminal devices influence user satisfaction while using video streaming services. If you send HD terminal devices to users who watch videos on a small screen.

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IV. EXPERIMENTAL ENVIRONMENT FOR QoE ASSESSMENT

Mostly, the QoE assessment is done by using the subjective method, because it tries to match the real perception of users while using a service. Generally, there are two distinct approaches use to collect QoE datasets: a crowd-sourced, and a controlled environment approach. In crowd-sourcing, one assigns the video testing task to a large number of anonymous users who can participate from different regions of the world. In parallel to the crowd-source approach, there is an orthogonal approach in which the experiment environment is totally controlled. The ITU has provided guidelines to conduct such subjective tests in a controlled environment, including the selection of participants who represent the users of a service [6]. In order to analyze the impact of distinct parameters on users perceived quality in video streaming, a subjective test is carried out with the participation of 45 persons. The participants watch the video streaming and rate the quality of the different videos.

In this testbed experiment, the QoS parameters (packet loss, jitter and delay) are varied in a fully controlled manner. Further, their influence on user perception is recorded in the form of a MOS. In addition, another parameter is taken under observation, the conditional loss. The conditional loss reflects the loss probability of the next packet, given that the current packet has already been lost. As most real-time applications exhibit a certain tolerance against infrequent packet losses, this metric helps in concentrating losses on a single part of the sequence, which makes the losses occasional. For our experiment, the relevant parameters and their selected values are given in Table I.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay</td>
<td>0ms, 30ms, 60ms, 100ms 120ms</td>
</tr>
<tr>
<td>Jitter</td>
<td>0ms, 4ms, 8ms, 16ms, 32ms</td>
</tr>
<tr>
<td>Packet Loss</td>
<td>0% to 5% with a step of 0.5%</td>
</tr>
<tr>
<td>Conditional Loss</td>
<td>0%, 30%, 60%, 90%</td>
</tr>
</tbody>
</table>

In this experiment, we consider the users participation according to ITU-R Rec. BT.500-11 [7]. Indeed, to obtain a subjective notation according to this recommendation, participants should be non-experts, in the sense that they should not be directly concerned with image or video quality as part of their normal work. User characteristics are also stored for analysis purposes, which include users participant profile like age, gender, familiarity with video streaming, and interest in video content as presented in Table II. End-user devices are Mobile, Tablet, Notebook, Samsung HD Screen, Dell desktops with Intel core duo processor, and a display size set to 1024 \( \times \) 740. Mozilla Firefox is used as the Web navigator.

<table>
<thead>
<tr>
<th>Users Profiles</th>
<th>Values</th>
</tr>
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<tbody>
<tr>
<td>Age</td>
<td>18 to 30 years</td>
</tr>
<tr>
<td>Gender</td>
<td>Male, Female</td>
</tr>
<tr>
<td>Familiarity with the video streaming</td>
<td>Rarely, Weekly, Daily</td>
</tr>
<tr>
<td>Interest in the content</td>
<td>Interested, Not Interested</td>
</tr>
</tbody>
</table>

There are 25 HD and Non-HD video streams selected for this experiment, with different motion complexities (high, alternating, and low) but with same frame rate (25 frames per second) and video codec (H.264). These videos are related to different fields of interests (e.g. politics, sports, news, social life, commercial ads, and animated cartoons). In our experimental analysis, we used NetEm as a network emulator to control QoS parameters. This tool can emulate the properties of Wide Area Networks (WAN), and its functionalities is evaluated in [9].

V. EXPERIMENTAL SETUP

Generally, the laboratory experimental setup consists of three important elements: a video streaming server, a video client, and the Network Emulator (NetEm), which emulates
a core and cloud network. The example of this basis experimental setup is shown in Figure 1. The traffic flows between the server, and the client is forwarded via the network emulator. The emulator introduces artificial delay, jitter and packet loss within a dedicated connection. In testbed example, the client sends the requested message to the video server and in response, the requested video sends to the client via NetEm. In the end of video, the client provides its feedback as the perceived video quality in the form of MOS score, which is stored in the database.

Our experimental setup is shown in Figure 2. We have stored 25 videos at the server side, and the client can reach them through a private Web site. The client device, either wireless or wired connects to the Web site to read the description of the experiment and provide the personal information (age, gender, etc.). Users are unaware of the QoS parameters’ settings on the videos, and they are asked to rate the perceived quality (in form of MOS score) after watching each video. The client side consists of different devices which are; desktop devices, Tablet, and Mobile; while the streaming server and the shaper (NetEm) are configured on a Linux OS. The resultant QoE of each video is stored in the database, as a MOS score.

In this experiment, there are total 45 users are participating in which 20 are female and 25 are male participants. Most of them belong to the age group ranging from 18 to be 30 years old. We collected $25 \times 45 = 1125$ samples in our database, which means that we have 1125 different combinations of all settled parameters, associated with a MOS value for each combination. However, we reduced this number after a deeper look over on the dataset, to average repeated lines and try to eliminate parasite ones.

The laboratory-based test is a time consuming study, but it is easy to investigate the influence of each factor on desired service. In our experiment, we have collected the good dataset in order to investigate the impact of different factors on QoE, as users’ profile. The number of participants and video contents in our testbed is good enough as compare to [13], where only one video clip and ten participants conduct the laboratory test.

VI. RESULTS

The resulting datasets from the controlled experiment were processed and cleaned from any parasite information. Therefore, we have dataset that is ready to apply for classical statistical analysis. The statistical analysis applies on the user profile, and we observe the parameters that more influence the user experience as compare to other parameters. We are presenting the results based on user’s profile and other parameters.

A. Case 1. Interesting and Non-Interesting Video Content

In the first case, we consider the videos’ content that relate the user’s interest and non-interest. By considering the user’s interest, we observe that how the QoS parameters influence the user’s interest. In this scenario, we only consider the dataset which has the MOS score equal or more than 3 because users are quite satisfied on these scores. Figure 3a, compares the impact of delay on interesting and non-interesting video contents. It can be seen clearly that when delay is very low (0 ms) then a large number of users show high interest in the video content with high MOS score. When the value of delay is increased (more than 30 ms) then number of user to watch the video’s content are starting to decrease quickly. It is necessary for the network service provider to keep delay less than 30 ms for video streaming. By considering this delay threshold the network service provider still gets the high user’s satisfaction with efficient utilization of network resources. Figure 3b, represents the influence of packet loss rate on interesting and non-interesting video content. It is important to notice that the number of dataset recorded in non-interesting videos content are not as much than compared to interesting video content results. The results show that when the network operators require high user satisfaction than they must provide the low packet loss rate which is less than at least 1%.

B. Case 2. Frequency, HD and Non-HD Video Content

In this case, we are considering the three important parameters that represent the behaviour and expectation of end users while watching the video streaming. We are analyzing the datasets that relating to the frequency of watching HD and Non-HD video content; and also have MOS score equal or greater than 3. These datasets are examined with the QoS parameters of delay and packet loss rate.
users weekly watch the Non-HD and HD video content. The Non-HD videos’ content have the largest number of viewer’s record, whereas HD video’s content has the smaller number of viewers. In case of Non-HD videos, when packet loss rate is less than 0.5% then a large number of users watch videos’ content, but it is decreased when packet loss increased more than 1%. On the other hand, the weekly videos’ watchers of HD videos are sensitive to packet loss rate. The results indicate that network service provider must optimize its network in order to keep the packet loss rate equal or less than 1%, for getting higher users’ satisfaction.

Figure 4a, compares the impact of delay when users rarely watch the Non-HD and HD video content. In case of Non-HD video content, Figure 4a, illustrates that the rarely watcher of video streaming are less sensitive for delay but in case of HD video streaming, the users are more conscious about delay. There are a small number of viewers are recorded for HD videos against the rarely video viewers. It is necessary for a network service provider that HD video streaming should have the low delay to achieve the better user satisfaction.

Figure 5: User Weekly Watch the HD and Non-HD Video Content

Figure 6a, compares the impact of delay when users daily watch the Non-HD and HD video content. It is noticeable that a large number of user’s record fall within this category. In both cases of Non-HD and HD videos, the results clearly show that the daily videos’ watchers to some extent are less sensitive to delay as compare to those users who watch the video streaming on rarely and weekly basis. Figure 6b, depicts the impact of packet loss rate when users daily watch the Non-HD and HD videos’ content. A good number of viewer’s record falls within this category of results. The results clearly show that users have more tolerance levels against packet loss rate as compare to users of rarely and weekly videos’ watchers. By contrast, HD video’s viewers have less tolerance for packet loss rate, and the small numbers of records are found in results as like the videos’ watchers on the weekly basis.

VII. CONCLUSION

In this paper, we implement the real-time testbed experiment in order to collect the datasets and evaluate the QoE in mobile wireless and wired networks. Based on real datasets, we investigate the impact of different QoS parameters on user’s profile for achieving better QoE by using the multimedia video streaming services. The comprehensive study of users profile in the perspective of QoS parameters, give the significant information for network service providers to understand the behaviour and expectation of end users. The analysis shows that interesting videos’ content have more tolerance than non-interesting videos’ content. Similarly, the users for HD videos’ content are more sensitive in the delay and packet loss, while
for Non-HD videos’ content the users have more tolerance levels. Based on users profile analysis, the network service provider can efficiently utilize their resources to get the high user satisfaction. In the future work, we shall analysis the users’ profile with the influence of different parameters e.g. terminal types (HD TV, 10” tablets, smart mobile device, LCD screen) and we also apply the statistical analysis techniques.

REFERENCES