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# **The effect of mobile cellular network performance and contextual factors on smartphone users' satisfaction**

**A study on QoE evaluation for YouTube video  
streaming via CrowdSourcing**

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## Abstract

Mobile data traffic will continue to show rapid growth in the coming years; however the data revenue is not rising fast enough to ensure the operators' profitability. Therefore, mobile operators must seek new approaches to find out what service does the customers need and what quality makes the customers satisfied in order to keep their increasingly sophisticated customers satisfied at the same time minimizing their revenue gap. This paper investigate the effect of mobile cellular network performance and contextual factors on smartphone users' satisfaction, this was done via crowdsourcing through an experiment where an Android Application and a user Survey were included, which is able to evaluate and analyze the perceived quality of experience (QoE) for YouTube service for Android Smartphone users. To achieve this goal, the App NPT performs measurements of objective quality of service (QoS) parameters, whereas the survey carriers out collecting subjective user opinion. The result show that network performance parameters do impact the MOS (Mean Opinion Score) exponentially, either in a positively or negatively way, however, multiple parameters need to be considered together in order to draw a more accurate correlation with QoE. In addition, QoE are heavily affected by many other contextual factors, such as age and gender as well as users location. QoE are also impacted by several subjective factors, such as user expectation. Not always the highest throughput will lead to the best QoE, and not always the best technology (LTE) deserves the best MOS. Even though user received very high downlink throughput, their MOS value may still be low due to they might think the video were not fun to watch and the quality has not meet their expectation.

**Keywords:** Quality of experience; Mean opinion score; Smartphone; YouTube; Android.

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## 1. Introduction

With the growth of mobile networks, the number of mobile data users has increased dramatically; Mobile data traffic has grown 3.2 times faster than fixed data traffic and has grown 39 fold from 2009 to 2014 globally, especially driven by mobile video. [1]

The growth of mobile revenues is undoubted; however the data revenue is not growing fast enough to ensure the operators' profitability. Therefore, mobile operators must seek new opportunities and strategies in order to keep their increasingly sophisticated customers satisfied at the same time minimizing their revenue gap. The mobile operators have been trying different strategies in order to fill in this gap, by using, such as, network sharing, spectrum re-farming and offloading heavy data traffic to local networks, etc. [2] However, these approaches do not seem to stop the gap to grow. By only offering customers the best Quality of Services (QoS) does not make the situation better, even though the mobile operators believe that the one can provide the best QoS will gain brand loyalty. [3] Therefore, it is important to deliver appropriate user's Quality of Experiences (QoE) with the speed, capacity, coverage and availability demanded by mobile users. QoE is an individual perspective to the quality of a service. Therefore, the most significant approaches for the operators are not only to minimize the network resource cost, but at the same time to keep their customers still satisfied with the provided services. Therefore, it is crucial to identify the correlation between the customer satisfaction and the network Key Performance Indicators (KPIs) in terms of data rate, throughput, stability, retainability, as well as other contextual factors, so that mobile operators can generate new cost effective mechanisms to deploy the network resources meanwhile keep customer loyalty in order to maintain competitive among others.

This approach will be done by a subjective QoE assessment for YouTube Video Steaming on Android users smartphone via crowdsourcing [4] which is a low-cost, fast and flexible method of steering user experiments in a Living lab [5]. A Living Lab is a gathering of public-private partnerships in which businesses, researchers and citizens work together for the creation, validation, and test of new services, ideas, markets, and technologies in real-life contexts. The purpose of a Living Lab is to create a shared arena in which digital services, processes, and new ways of working can be developed and tested with user representatives and researchers [5].

**Thesis outline**, this thesis will be structured as following:

In the remaining part of chapter 1, detailed literature study will be presented, where previous research in this area will be discussed and compared; this is to find out their limitation as well as the research gap for this study. This chapter then leads to the problem and research questions that this thesis aims to investigate. Later, Scope and contribution of the thesis will also be discussed in this chapter.

Chapter 2 will discuss the methodology being used in this thesis together with the data collection methods in detail.

Chapter 3 contains the analyzed result for the data which has been collected through subjective and objective evaluation.

Chapter 4 concludes with discussion on the findings made from the results of the evaluation and link to the research question. This chapter will then ends with the limitations and recommendation for future works.

## **1.1 Related work and Research gap**

QoE Evaluation is not young, particularly in evaluating the quality of experience of video streaming services. In this chapter, some of the most similar previous research will be discussed.

There are several previous works that has been done to find out the relations between QoS and QoE, especially for the mapping between them in the video streaming field.

In [6] authors develop a QoS/QoE correlation model for IPTV QoE evaluation. Network providers can evaluate users' QoE using QoS parameters weight and some analyzed data which is from the proposed model, and control QoE as deduce QoS parameters (delay, loss, jitter etc) related with QoE. Through this model, network operator can predict users' QoE value in offered network environment and create the network environment which can meet an optimum QoE. However, this evaluation was performed in a lab environment, not in a living lab [5] environment, which also means the QoE evaluation is not based on field testing.

There are also different previous studies regarding video service quality measurement methods.

Quality evaluation method can be classified into two categories: subjective and objective ones. In [7] an acceptability-based QoE models, is proposed based on the results of user studies on subjective quality acceptance assessments. The models are able to predict users' acceptability and pleasantness in various mobile video usage scenarios. The model was built with a group of influencing factors as independent predictors, which including, bitrate, encoding parameters, video content characteristics, and mobile device display resolution. However, this model does not contain the measurements of objective QoS indicators which are important for QoE evaluation.

One of the previous works has been done at Telenor Research which is about 'YouTube Video Streaming: How Does the Traffic Look Like and what are the QoE Implications?' [8] This study explained how and why we need to evaluate QoE, by performing a Video Streaming experiments in the lab. Then it maps the QoS and QoE metrics to evaluate the user satisfaction. But this research has not been performed in a live environment and via the crowdsourcing way to collecting user data. The lab-based user studies could be time consuming and costly, therefore only a limited set of influence factors can be tested per test session.

A QoE framework for multimedia services, also called Quality of Multimedia, for run time quality evaluation of video streaming services is discussed in [9], this approach is based on the impact of different QoE factors and various network and application-level QoS parameters, however, the evaluation of the proposed QoS/QoE Model in a context of a real wireless network has not been performed in this study.

Another research study which is to quantification of YouTube QoE was performed via Crowdsourcing approach [10]. In this study, the authors present a dedicated QoE model for YouTube that takes into account the key influence factors (such as stalling) and they propose a subjective QoE assessment methodology that is based on crowdsourcing. However, they performed this study in a controlled environment and did not take other network parameters and other contextual factors (such as location, screen size, etc.) into consideration in order to identify the most important network parameters and contextual factors which might affect user experience the most.

None of the recent works so far has been done by combining both subjective and objective quality assessment methods to study the relation between QoE and QoS, and evaluate QoE in a with Crowdsourcing method [4]. With crowdsourcing, subjective user studies can be efficiently conducted at low costs with adequate user numbers for obtaining statistically significant QoE scores.

In addition, no previous works has performed a QoE Evaluation through real tests over different radio technologies. In this Study, the QoE evaluation will be performed by real experiment in a living lab [5] which will perform the measurements of objective QoS indicators connected to YouTube video streaming sessions. Then the users can qualify the session through a survey. These combination will not only capture the real live network parameters and other contextual factors such as Android Version, Phone Model and Location, which is powered by Network Performance Test tool (NPT) [11] but also based on user survey that can reflect the opinion of the user (powered by Qualtrics) [12]. These different indicators and factors are then mapped onto subjective QoE, in terms of MOS. Therefore, this study will clearly fill the research gap and offer the vision on how network performance affects user satisfaction and try to find out what could be the most important factors which mostly affect user satisfaction.

This research will only focus on evaluation the user satisfaction for YouTube Video Streaming under cellular networks, this is due to mobile voice has been replaced as a dominant service by mobile data, in particular by video and multimedia services which are predicted to account for more than 50% of data traffic by the end of 2019[13]. In addition, the reason why Wifi is not considered as part of the experiment is due to in most cases, Wifi is more stable and ideal compare with cellular, this is according to Network Performance Test statistics, therefore, Wifi users will have a higher satisfaction rate compare with 3G/4G users, by analyzing the ideal Wifi QoS parameters result will not add too much value for this study.

## **1.2 Problem Formulation**

In order to achieve sufficient user satisfaction level by offering appropriate smartphone users' Quality of Experiences (QoE), it is essential to understand customers' expectations and satisfaction on certain services or APP usage, such as one of the most dominating mobile video streaming services – YouTube. According to Ericsson Mobility Report, the total mobile video traffic of next six years will be around 17 times that of last six years, and one of the top services is YouTube [13]. It has arisen to be the largest single source of real-time internet traffic than any other service. YouTube accounts for 20% to 25% of total traffic in mobile networks. Additionally, 27.8% of all YouTube traffic (first half 2012) has been consumed on a smartphone or tablet [14]. It is therefore important for the operator to find out the relation between users' perceived network QoS and their subjective opinion on QoE, this is also to find a good balance between the QoS

based cost effectiveness of the network performance and the QoE based Android Smartphone user's satisfaction. In this way, the operators will be able to interpretation and interact with the network parameters as well as other contextual factors to make their business decisions which will ensure to deliver the user desired level of service quality and make sure the customer satisfaction at the same time keep the operator's cost in an ideally level. Therefore, it is very demand to understand how satisfied the Android Smartphone users are with the current YouTube services they have been given.

Thus, the **research question** arises: how does mobile cellular network performance affects the YouTube user satisfaction? And what are the key contextual factors which affect user satisfaction the most?

## 2. Methodology

This research proposes the method to quantitatively measure the QoS network performance parameters and contextual parameters via Crowdsourcing method [4] in the living lab [5] on Android Smartphone users' device for YouTube Video Streaming with the help of Network Performance Test tool (NPT) [11], at the same time evaluate the user opinion for the video streaming session via a survey which is conducted by Qualtrics[12] that can reflect the opinion of the user satisfaction to find out the correlation results among QoE, QoS and other factors. Through this proposed model, network operators can predict users' QoE in provided network environment and deliver services in a cost effective and optimize way. Furthermore, the evaluation of QoE will give the operators some opinion of the contribution of the network's performance to the overall level of user satisfaction. In addition, by identifying the key network parameters and other key factors which might impact the most on YouTube user's experiences and satisfaction, the network operator will have the possibility to minimize the network resources by allocating only the necessary resources that are adequate to maintain a certain level of user satisfaction. The purpose of this section is to describe and explain what and why the following data parameters has been chosen for this research, it also give an introduction on the Network Performance Test tool that has been used for the test and give a detailed explanation on how exactly the experiment has been performed as well as how QoE has been measured.

## **2.1. Network Performance Test (NPT) tool**

In order to collect the objective QoS network parameters and the subjective user QoE as well as other contextual factors, so that a deeper study about the relationship between QoS and QoE can be made, a real QoS/QoE evaluation experiment has been performed. This is done via an Android Smartphone APP called Network Performance Test (NPT) [11], this tool is an extended version of Ericsson APPs (EA) [15] which is an app recommendation engine for Android Smartphones. EA will capture the APP usage and data consumption that are used in the foreground, the data will be collected once user open the app, i.e. open up YouTube video clip in Chrome browser and display it on the screen, and the data collection will be finished when user close the browser. EA also measure the network performance data. This is done by sampling the network performance parameters such as downlink bitrate and TCP timeout 4 times every second for only the first 2.5 minutes after starting the App, then report the consumption into the database every second hour on cellular networks, this is to reduce the EA consumption for user smartphone.

For legal reason, NPT has been decided to be used within Ericsson and KTH internally; this will unfortunately limited the number of sampling for the experiment of this study. In addition, after installing NPT App on Android smartphone, it will require an activation code to be able to use it; this will for sure require more detailed explanation and also lead to lower user motivation. An App that can follow 'click, install and run' will be much easier and handy for the user to participate and use.

In addition, due to some technical limitation of NPT, there are certain parameters that cannot be captured by EA which are also critical for Video Streaming, since the sampling time for EA is 250 ms, which is very large since the length of one LTE radio frame is 10 ms. This will lead to one sample contains 25 LTE frames. Therefore it is impossible to calculate parameters such as jitter and latency which are crucial for TCP. The impacts for this study are large, since some of the key factors above will have to be ignored for this study. All available and useful parameters that can be found in NPT database will be discussed further in the next section.

## **2.2. Data Parameters**

A deeper data analysis for the Network Performance Test (NPT) Database has been performed; first, this is to find out the available network QoS parameters that collected by NPT which will be used in designing the QoE evaluation

experiment that will be mentioned in the next step. Second, this is also help to identify the key network parameters which might have the most impact on YouTube users' experiences and satisfaction.

For this study, NPT tool use only EA's background probes to capture network performance parameters and a few other parameters that are listed in Table 1 below:

TCP Time Out
Network Type
RSRP(Reference Signal Received Power)
RSRQ(Reference Signal Received Quality)
Downlink Throughput
Uplink Throughput
Android Version
Phone Model
Location

Table 1: Parameters can be collected by NPT

However, not all above parameters can be used to evaluate and calculate QoE directly, they need to be further analyzed and processed. This is can either because of the special characteristics of Video Streaming, or due to the limitation of the NPT itself. NPT are not measure the QoS that the network offers, instead, it collecting the real time network performance that the users actually received, which is even better for measuring QoE, since the QoS that the users actual receiving will have directly impact on users QoE.

### **Uplink throughput**

Uplink throughput is not important since video streaming is a download intensive service. [16] Therefore, in this study, uplink throughput will not be used to measure the user QoE.

## **Downlink throughput**

One of the important factors, the median value of downlink throughput will be used for this study that is due to the mean value for downlink throughput samples are quite sensitive and highly depends on every sample values, since there are a lot of 0 values in the downlink, the mean value will become less robust and accurate. Therefore the median value of Downlink throughput has been chosen as the average for “skewed” datasets in this measurement study.

## **RSRP & RSRQ**

Reference Signal Received Power (RSRP), is defined as the linear average over the power contributions of the resource elements that carry cell-specific reference signals within the considered measurement frequency bandwidth. Reference Signal Received Quality (RSRQ) is defined as the ratio  $N \times \text{RSRP} / (\text{E-UTRA carrier RSSI})$ , where N is the number of RB's of the E-UTRA carrier RSSI (Receive Strength Signal Indicator) measurement bandwidth. [17]

Both RSRP and RSRQ can directly reflect the network's signal strength as well as network coverage, however, the measurement for RSRP and RSRQ does not distinguish the other parameters such as, noise, serving cell power, interference and serving cell load, etc. Therefore, the values that collected for these 2 parameters cannot be used for QoE measurements since they are inaccurate.

## **Location**

In this experiment, user location factors were divided into home, office and “on the move”, this is due to time and sample limitation, in addition, network performance comparison between operators are also out of the scope of this thesis. However, in the future, the location factor can be improved with the integration of cell-id logging and GPS data.

## **Network types**

Network types should have strong relation with network performance; NPT can capture all types of networks in live environment, but only 2G (EDGE), 3G (including UMTS, HSPA, HSDPA and HSPAP) and 4G (LTE) have been chosen as general network performance parameters.

## **Android Version and Phone model**

These parameters are all UE related factors, but by knowing the phone model, it is possible to retrieve the screen size which will have a direct impact on user QoE.

Therefore, the actual parameters that can be suitable used to do a proper measurement and evaluation for YouTube Streaming QoE can be translated into table 2 below:

TCP Timeout
Network Type (2G,3G or LTE)
Downlink Median Throughput
Android Version
Screen Size
Location (Work, Home or On the Move)

Table 2: Parameters that are used for QoE Evaluation

### 2.3. Introduction for YouTube Video Streaming

YouTube service uses progressive download technique, which enables the video playback at the same time downloading new content [18] for both Smartphones and PCs, the video download via Hyper Text Transfer Protocol (HTTP) over Transmission Control Protocol (TCP), which is the preferred transport protocol for YouTube and other video streaming servers since the majority of video content delivery over the Internet is not live.

In our experiment, user click on the web link to the video clip, then the download process starts and it sent to the YouTube web server. The client then clicks on the play button after they receive the YouTube web page on their screen. The YouTube Media server then starts sending the streaming data over HTTP response. The streaming data start to be stored in the buffer on the client side before displaying to the client. (See Figure 1 below)

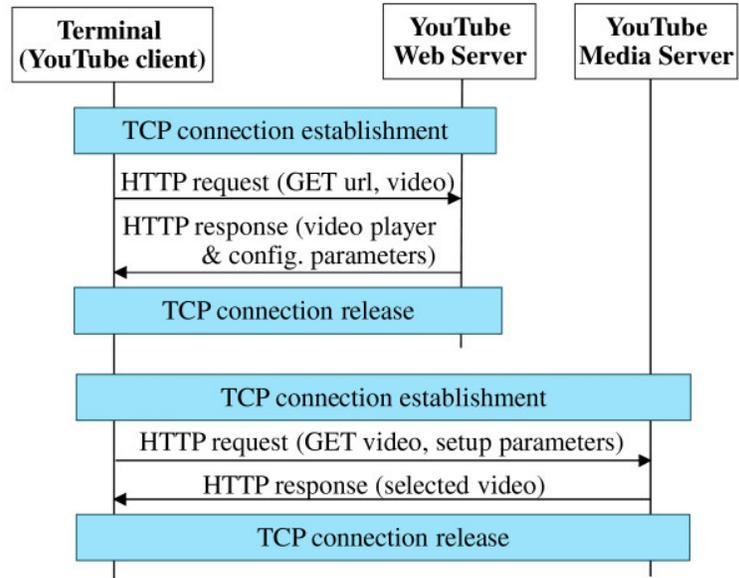


Figure 1: Flow chart for YouTube Video Streaming via Chrome browser

Similar to other network services in general, YouTube Video Streaming quality is largely depending on throughput, especially in Downlink. However, unlike the other internet services such as, web browsing and messaging, video streaming are having more requirements which are stream-specific, for example, if an initial buffer occurred due to low downlink throughput, which could possibly cause a re-buffering, in this case the user client satisfaction will drop down quickly. Therefore, it is important to not only measure the downlink throughput for YouTube Streaming, but also to collect the information such as Jitter and buffer. However, due to NPT limitation, these parameters are impossible to be captured; fortunately, we can acquire these info from the user Survey that based on their observations during the streaming sessions.

**2.4. YouTube Video Streaming Experiment Design (Test Setup)**

As mentioned in previous sections, an experiment for collecting YouTube user’s satisfaction (QoE) and network performance (QoS) as well as other contextual factors has been performed through Network Performance Test.

The purposes for the experiment are:

- To explore how the network performance looks like while smartphone users using YouTube Streaming over different cellular network technologies (2G/3G/4G).

- To evaluate what are the key factors that could impact user satisfaction with the services they have been provided.
- To identify how QoE is related to QoS in video streaming.

## Experiment Plan

(Step-by-Step details, refer to **Appendix A** for Experiment Instruction)

- The experiments have been performed on a group of volunteers' Android smartphone which has Network Performance Test installed and provide user-side measurements of QoS and QoE.
- Three YouTube video clips with the length of less than 2.5 minutes have been watched by the users. These 3 videos have been classified with different video content, such as, live sports, news and movie, which will provide a more valuable QoE measurement result. In addition, these 3 video clips are having the same video resolution (1080p), which is to obtain fair comparison.
- Each video clip together with the evaluation form which is powered by a Mobile polling app 'Qualtrics' has been sent out to the users, the 2nd and 3rd video links are being sent after the user is finishing with watching the 1st video.
- The users perform the test by clicking the video link in their email, and then it will open in a web browser, in most case google Chrome. Once the page is displayed, the users then need to play the video as soon as they can, the test starts when the user clicks the play icon on the video, and this is the requirement from Network Performance Test that the data sample will start to collect at this point.
- After the users have viewed the video clip, they will immediately be asked for rating their test experience about the MOS value and answer the short survey to provide their user experiences. The survey contains 15 questions and it takes less than 2minutes to complete. The survey is anonymous and the collected data are only be used by the researcher which means no personal info for the participant will be exposed. The participants are always feeling free to express their experiences by given different feedback based on their user experiences.
- The users can perform the test by watching the videos and answering the survey at anytime and anywhere under a cellular network, however, not watching all these 3 videos in a raw, it is recommended to perform the three tests in different location and occasion.

- GooglePlay email address for the users will be needed, this is used as the identifier when query data from the Network Performance Test Database. The purpose of the usage for the email is clearly addressed to the user and the privacy of the personal information is also secured.
- Before doing the real experiment, a small pre-trail test has been performed in a small-scale; this is to verify if the QoE related questions are correctly placed and to validate whether the data that has been collected during the pre-trail are really useful or not.

Detailed Experiment setup can be illustrated in Figure 2 below:

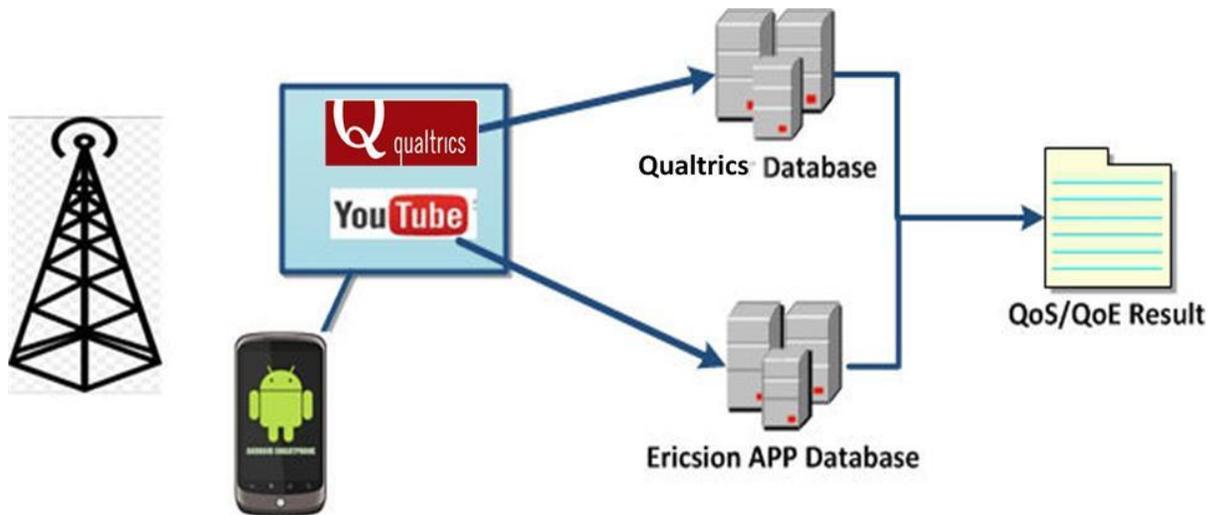


Figure 2, Experiment setup

## 2.5. YouTube Video Streaming QoE Evaluation Survey

For this research, a comprehensive survey has been conducted in order to collect the subjective user opinion on the YouTube Streaming session the user has watched. In the study, the network performance (QoS) has been measured by Network Performance Test automatically, whereas, QoE has been measured by using the short survey where the Mean opinion score (MOS) [19] from 1 (bad) to 5 (excellent), shown in table 3, will be asked together with few questions to evaluate the customer satisfaction.

MOS	Quality	Impairment
5	Excellent	Imperceptible
4	Good	Perceptible but not annoying
3	Fair	Slightly annoying
2	Poor	Annoying
1	Bad	Very annoying

Table 3: Mean opinion score (MOS)

### 2.5.1. QoE Conceptual Model

The QoE-concept has been defined to have multidimensional character [20], even though the overall user perceived quality (often in terms of MOS) [19] are the key aspect for the characterization of Quality of Experience, therefore, to be able to perform a more accurate QoE measurement, more important QoE factors need to be considered, such as Conceptual factors. There are several key contextual factors and application related factors have been collected by the survey of this study. This is to gain a better understanding on how does different contextual factors could impact QoE differently and how Application factors would affect user QoE. Measuring only 1 or 2 dimensions for QoE is not sufficient, in addition, 'quality of human's experiences changes over time because different contextual factors influence on it' [21]. Figure 3 below shows how the QoE is a non-linear function of QoS and influenced by many factors

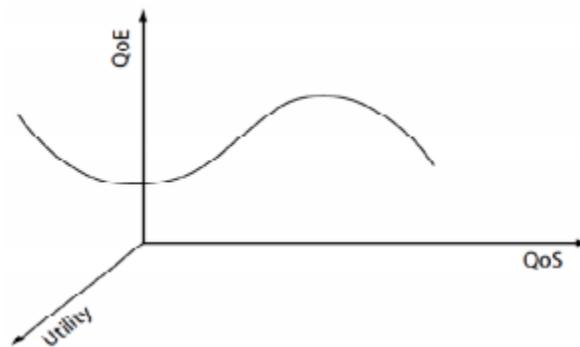


Figure 3: QoE is a non-linear function of QoS and many factors [22]

Therefore, QoE shall be measured in multiple dimensions. Consequently, several questions need to be addressed for the Survey in order to obtain user experience.

There are many previous studies discuss the method or model for QoE measurement. In [10] the authors present a dedicated QoE model for YouTube that takes into account the stalling factors and propose a subjective QoE assessment methodology based on crowdsourcing. However, it does not cover the full aspect of QoE measurement, which is, the contextual part. Therefore, a model that covers the method for both network performance and contextual part is considerable needed. In [20], there are 5 building blocks have been defined to measure the QoE, they are: Quality of Effectiveness, Usability, Quality of Efficiency, Expectations and Context. (See Figure 4 below), which is comprehensive to be used for this research study, therefore, this 5 building blocks conceptual model has been chosen to design the questions for the Survey.

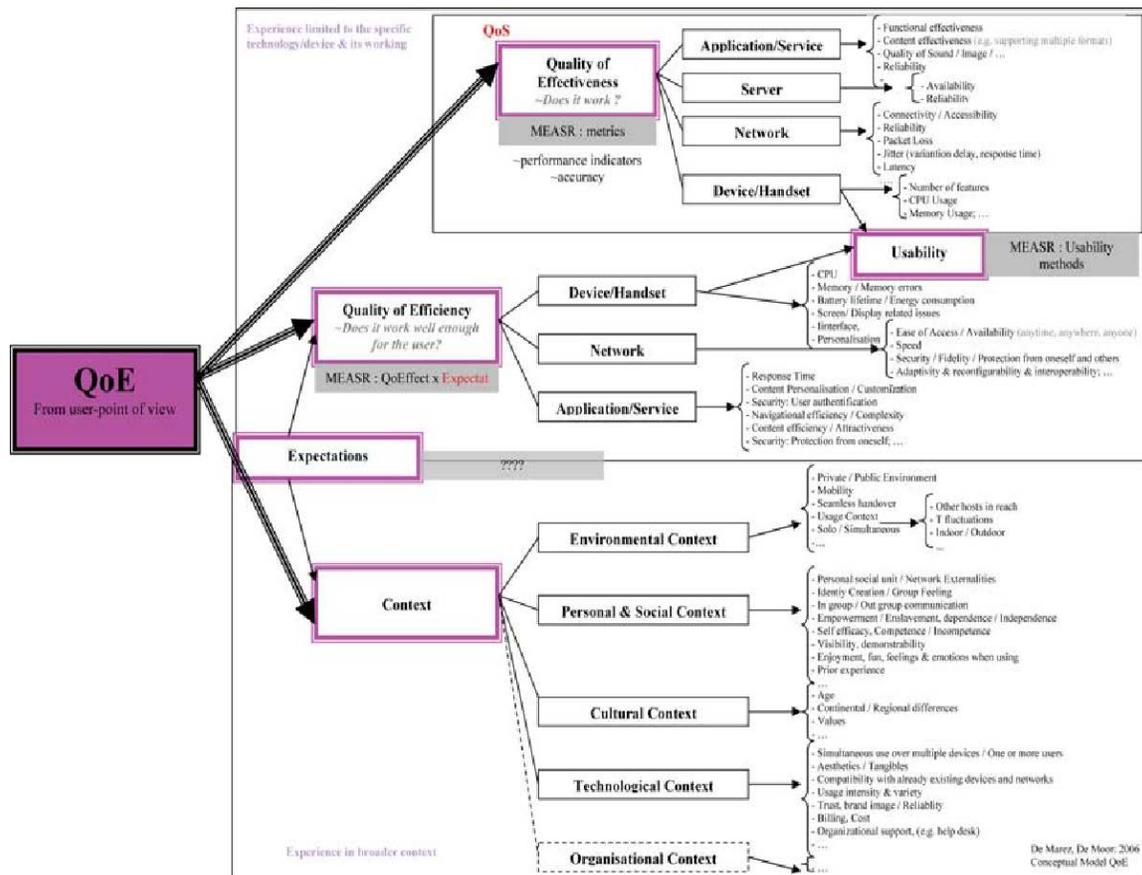


Figure 2: QoE 5 building blocks.

Source: [20 Lieven De Marez and Katrien De Moor, 2007]

### **Quality of Effectiveness:**

This dimension represents the traditional 'Quality of Service' approach on QoE, therefore, it's all about the accuracy and technological performance for the certain services.

### **Usability:**

This often implies the emotions and feelings of the user when using the device or technology, i.e. is this user friendly enough for the user to have a good feeling.

### **Quality of Efficiency:**

This dimension cover the subjective character of QoE, often refers to, 'is the technology working well enough for the user?'

### **Expectations:**

Whether or not the expectations are met, will determine the Quality of Efficiency.

### **Context:**

This could include different types of context, such as, environmental, personal, cultural, technological and organizational.

These 5 blocks illustrate the different aspect that constitutes the subjective QoE experienced by the user which are also shed some light on what the user thinks and feels related to each block. The aggregated answers are then used to create a complete picture for QoE measurement. See below for the example questions that were asked during the survey:

<b>General Question Examples</b>	
What is your age?	
Are you male or female?	
Are you watching this video at (home, work or On the Move)?	
<b>QoE Elements</b>	<b>Survey Question Examples</b>
Service in General	Q: How do you rate this video session in general? A: (MOS 1-5)
Service availability	Q: Can this video be played once you clicked the play icon? A: YES/NO (If No, is there a long delay before the video can be started?)
Quality of Efficiency	Q: Have you experience any delay or buffering during the session? A: YES/NO (If Yes, how many times)

User expectation	Q: Do you think this video quality meet your expectation? A: YES/NO (If No, why? Leave user comments)
Context	Q: Do you think the video is fun to watch? A: YES/NO

Table 4: QoE Elements VS Survey Questions

## 2.6. Data Collection Method and Sampling

For this study, a survey which is based on Qualtrics[12] has been chosen as one of the best methods to collecting the user experiences, since surveys are particularly good when looking for patterns of activity within groups or categories of people, They are very useful for linking findings with specific social classes, age-groups, sexes, ethnic backgrounds, etc. [22, p.12].

The survey will be well designed and clearly carry out through internet browser on user's smartphone, the question will be prepared and designed via <http://www.qualtrics.com>. All the questions will be coded and categorized in advance and the answers can also be accessed via Qualtrics's database.

The goal of QoS is to deliver a high QoE or user experience, QoS is what the operator can objectively measure in the networks but QoE is what the operator are really interested in, the subjective method which is based on user survey can reflect the experience of user more directly and match well with their feelings about a certain service. However, as far as survey or measurements are concerned, these might lead to an unhappy user since it is not always easy to motivate users to share their experiences, even though the service quality itself was good enough. In this case, the outcome from the survey may tell the operator very few about the real level of customer satisfaction, this is also one of the drawbacks of crowdsourcing.

Furthermore, in order to make appropriate conclusions from the feedback, the number of surveyed users should be relatively high, and that can be highly depending on the way the survey is executed. Therefore, the survey will be designed in a most user friendly way by using gamification, which is to use of game thinking or mechanics in non-game contexts to increase user engagement in solving problems [23]. This is to collect the most valuable and sufficient user experiences on YouTube Video Streaming. There are several approaches can be reach in order to make the survey questions more gamified, for example, experimenters will be reward according to their feedback, in this case, 30% of the participants who have finished watching all 3 video clips and provided their

feedback will have the chance to win a cinema ticket, this is done by random selection of 30% of the total participants from the valid poll database.

In addition, cheat protection has been introduced for designing the survey for this study. This was done by repeating similar question at different occasion and in a different way. For example: Have you experienced any delay or buffering during the session? (A: Yes/No). How many times have you experienced buffer during the session? (A: 0, 1, 2 or more). If the user first answered yes, then in the later question choose '0' which will lead to a result of cheating. Therefore, the result for this user is not considered for final data analysis.

For this study, convenience sampling has been chosen as the suitable method for data collection. The reason was that "Convenience sampling is built upon selections which suit the convenience of the researcher and which are 'first to hand'" [22, p. 37]., which suits best the research needs, although this is not the best solution to do research, it will affect the outcome for this study as according to [22, p. 38]. 'Choosing things on the basis of convenience run counter to the rigour of scientific research. It suggests a lazy approach to the work'. However, due to time limitation for this study, convenience sampling has to be considered as the main approach for this study. One of the approaches was to involve as many volunteers as possible to explore their satisfaction behind YouTube streaming experiences. Since convenience sampling doesn't seek to choose specific respondents. In this study, the selection of the participants in the survey was made through the KTH QoE project team members as well as the researcher's social network via crowdsourcing approach.

In crowdsourced experiments, participants may view media content under various conditions [10]. This means our crowdsourced experimenters are difficult to control, in terms of user behavior, test condition and the way of performing the test. Regarding the method of performing the experiment, a clear test instruction will be delivered to every experimenter in order to make sure the users perform the test in a slandered way. However, there are certain conditions that we cannot control, such as different network conditions. Fortunately, our purpose of experiments is not to measure the quality of video content in a specific condition, it is to measure the network performance just the users received, crowdsourcing allows us to assess how YouTube users actual experience in their real-life.

## **2.7. Data Analysis**

The data analysis will be performed by using machine learning and statistical analysis to analyze both the QoS and QoE data from Network Performance Test

database. This is due to machine learning is the algorithm that can build the model from example inputs and using that to make predictions or decisions [24]

The purpose of analyzing something is to gain a better understanding of it [22, p. 235]. That's why the first stage in the analysis of quantitative data is to organize the raw data in a way that makes them more easily understood [22, p. 246]. Therefore, for this research study, the raw QoS data which is also the user received network parameters will first be categorized, and then analysis their different relation against the QoE feedback.

Quantitative data will be analyzed using a quantitative method for this study that is because this method had a subfield of mathematics devoted to it - statistics. This will help the researcher to get a direct impression of Customer satisfaction. Randolph [25, p. 83].

## **2.8. Research Ethics**

The participants were motivated to answer all questions by having the chance to win a cinema ticket; however, the participation was voluntary and could be withdrawn at any time abandoning the site. Answers may also be skipped in case that participant wished not to answer. The participants of the survey were asked to answer the survey after reading the disclaimer. The participants that contribute to the research had to be 18 years of age or older. The responses were kept completely confidential and anonymous. No personal information or data will be logged or disclosed. The participants' e-mail list was electronically protected in order to avoid any disclosure. The data collected was stored on Google Drive and Excel file with strong password protected, then, at the end of the study, they will be deleted.

## **3. Results**

### **3.1. Data collection and analysis**

The questionnaire was designed using the website 'Qualtrics.com'. The selection of the participants in the Experiment was made through the researcher's social network. The web link was sent via E-mail to the selected participants. They were also informed about the content, purpose and contact details for the researcher. This survey was sent out in end-April 2015 and answers were received within 4 weeks. There were 15 participants between age of 18 and 60 years have participated in this QoE evaluation Experiment, most people finished watching

with 3 video clips, therefore, in total 38 samples have been collected. However, there were a few incomplete responses which lead to inaccurate result, hence, those data has been excluded from the final data analysis. In total there were 28 valid samples used for this research study.

The data samples were automatically collected and stored in ‘Qualtrics’ and the NPT data was retrieved via Python scripts from the NPT databases. The raw data has been sorted out and stored in Microsoft Excel. The statistics are being analyzed by Excel and Matlab. The final results are then presented with table, charts and diagrams that are shown in the next section. Since producing a table or chart is to convey information in a succinct manner and use visual impact to best effect. Denscombe [22, p.242].

### 3.2. Results

The first part of the analyzing result is to show the effect of network performance parameters on user satisfaction. The second part of the result will explain how contextual factors impact the Quality of Experience of the users.

#### 3.2.1. Network Performance vs MOS

##### 3.2.1.1. Hypothesis

One hypothesis for this study is to perform QoS/QoE Mapping in order to evaluate subjective and objective metrics and create the QoE/QoS metrics, depending on the collected data; the mapping then can be done between MOS and different network performance parameters. See example below in Figure 5, the x-axis again denotes the TCP timeout, whereas the y-axis denotes the MOS rating.

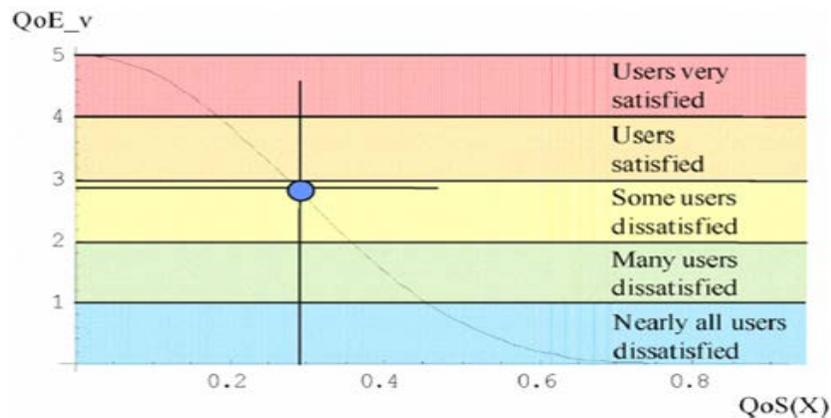


Figure 5: QoE Mapping Example (Hypothesis)

### 3.2.1.2. Generic MOS calculation method

In [26] introduces a generic MOS calculation method, which encapsulates the effect of diverse parameters in difference services. It also introduces the concept of increasing and decreasing parameters when measuring QoE. For example throughput, affect the QoE positively, therefore referred to as increasing parameter in this work. On the other hand, parameters such as delay or TCP timeout affect negatively the QoE while increasing. Those parameters termed decreasing parameters. As shown in figure below. 'm' is the influence factor of a parameter, such as DL throughput. The influence factor represents how fast the fluctuation of the DL affects the MOS. Below figure 6 demonstrate the MOS of increasing and decreasing parameter respectively, and the two different influence factors  $m = 1$  and  $m = 3$  show that the higher the influence factor  $m$  is, the larger the MOS variation will be for a given fluctuation of the DL throughput. This generic method is used in this study to illustrate the correlation between different network parameters and MOS value.

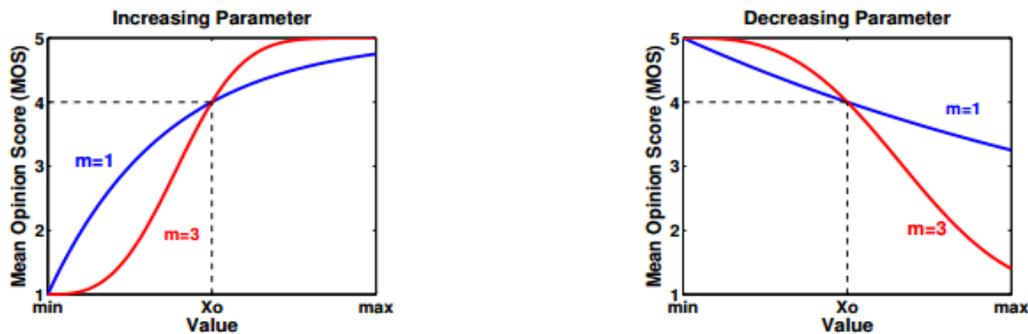


Figure 6: MOS for increasing & decreasing Parameters for Two Different Influence Factors [16]

### 3.2.1.3. DL Median Throughput vs MOS

In the figure below, exponential fit was used for curve fitting. Exponential fit algorithm is chosen since it is assumed that the rate of MOS change varies for different DL median throughput, just similar as the hypothesis QoS/QoE Mapping curve, but in an increasing direction. Plus, it is obvious that the MOS cannot keep growing exponentially at some point, since it is bounded. Therefore, two exponential components are used, one representing the exponential growth and the other representing exponential decay. The growing component is the second term in the formula with  $c=4.404$ ,  $d=0.02205$ , whereas the decaying component is the first term with  $a=-0.02754$ ,  $b=-3.856$ .

The curve shows that in the region of relatively low DL median throughput, which is an increasing parameter for MOS, the MOS increases exponentially as the throughput which is understandable since low throughput typically would lead to significant packet delay causing unsatisfactory user experience. However, on the other hand, the curve more or less saturates after reaching 0.5 megabytes per second. This means that to achieve optimal user experience, it is not necessary to have very high throughput. There might exist other factors supplementing the throughput.

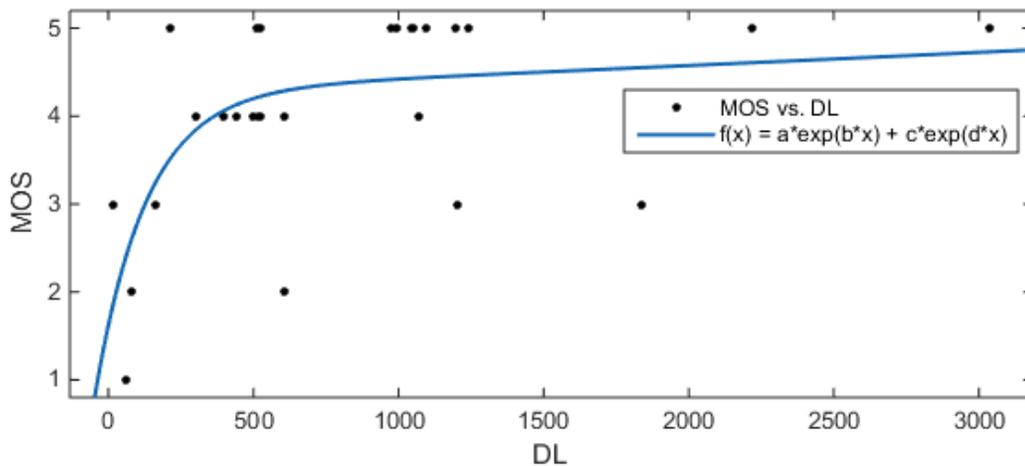


Figure 7: DL Median Throughput vs MOS

As discussed above, we can see that MOS value are exponentially affected by DL throughput, higher throughput is necessary to sustain high definition video streaming therefore lead to higher MOS, while reducing throughput quickly decreases the MOS due to lack of bandwidth, however, if throughput are up to certain level, in this case 500 kbps, increasing throughput further will only slowly improves QoE because the region of MOS plateau has been reached where network performance has almost no dependency with MOS. See figure 8 below. This phenomenon can also be explained by another recent research done by Markus Örbloom, who has done an analyzed on the network performance on user behavior [26]. From his statistics it can be clearly seen in figure 9 below, most of the YouTube users in Sweden are having their DL Median throughput between 500 kbps and 2 Mbps, which is also most of the samples that this research have. If the sample group has reached a certain level within the MOS plateau, then it became harder to investigate further on the correlation between DL throughput and MOS with the current data samples since the differences between data are rather minor.

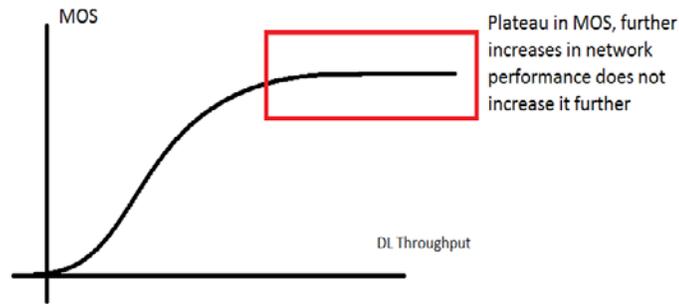


Figure 8: Plateau in MOS has been reached

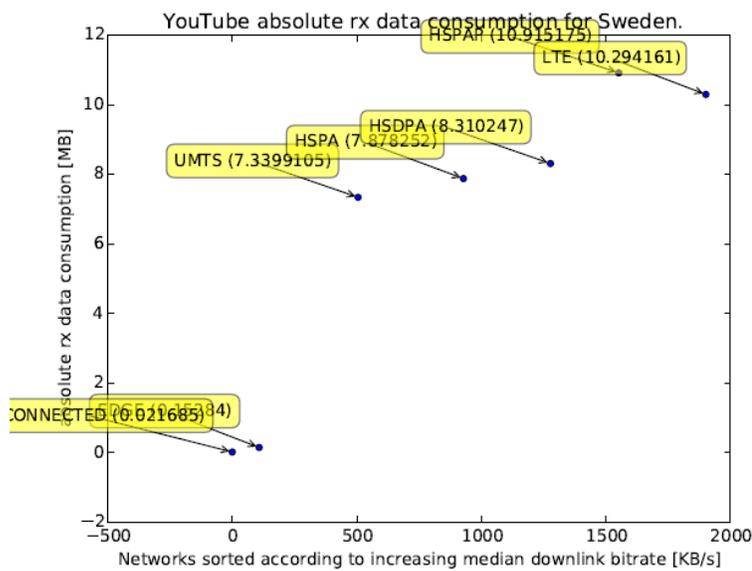


Figure 9: YouTube absolute rx\_data consumption for Sweden [26]

### 3.2.1.4. TCP Timeout vs MOS

Similar to the method used in analyzing the relationship between DL throughput and MOS, the impact of TCP timeout (decreasing parameter) on MOS is studied by exponential curve fitting algorithm. It is clear that low TCP timeout will lead to high MOS as it reduces the probability of TCP retransmission which is undesired for a smooth video streaming experience. This curve is almost following the hypothesis for this research study, and the result shows that with less than 10ms timeout in TCP will contribute a MOS scale of 4 or above.

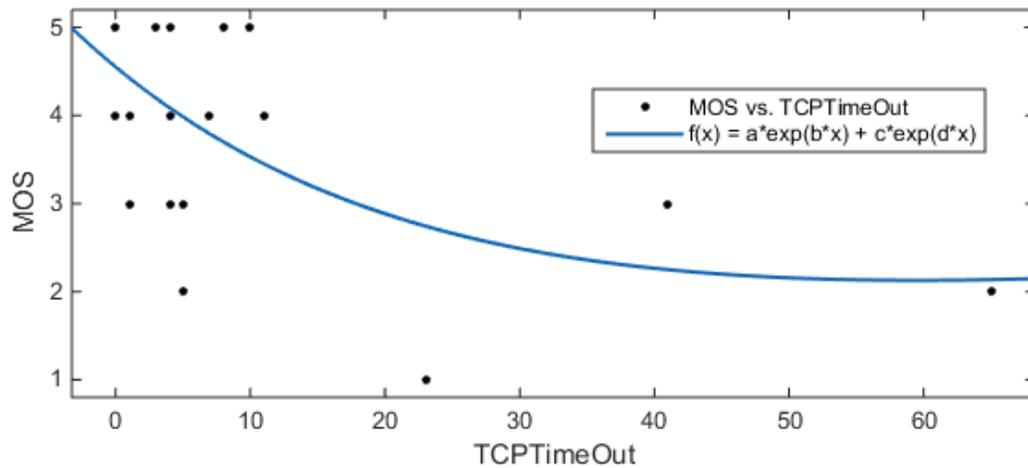


Figure 10: TCP Timeout vs MOS

### 3.2.1.5. Multiple Parameters vs MOS

Since focusing on one parameter while analyzing QoE might generate a misleading expectation, therefore, it is essential to consider multiple parameters together when calculating the MOS for a specific service such as YouTube Video Streaming. This is also according to the Generic MOS calculation method [16].

Therefore, MOS could be modelled by increasing parameters and decreasing parameters together. In this case, the increasing parameter is the DL median throughput and the decreasing parameter is the TCP timeout. From this plot, a few observations can be made. Firstly, given a low DL throughput, TCP timeout has an exponential impact on MOS whereas with a high DL throughput, TCP timeout does not seem to contribute much to MOS. Secondly, given a certain TCP timeout, more or less the same exponential curve as shown in below figure 11 can be observed.

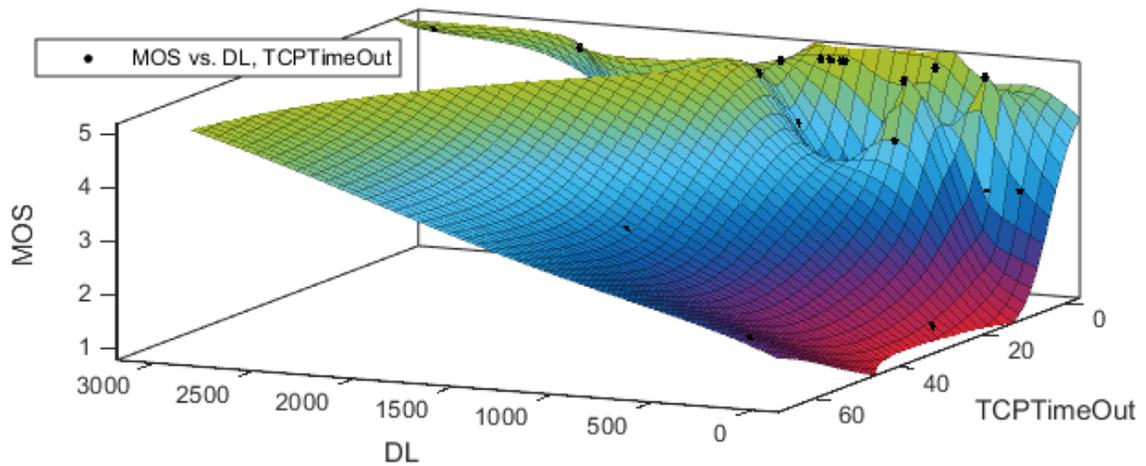


Figure 11: Multiple parameters correlation

### 3.2.1.6. Network Types vs MOS

Even though 4G (LTE) technology has the highest Median Downlink throughput (see table 5), it however does not receive the highest average MOS value. On the contrary, 3G technology has comparably lower Median downlink throughput, but it has the highest MOS 4.5 (shown in Figure 12). This explains that not always the newest radio access technology, such as LTE, will deserve the highest user satisfaction. QoE are also affected by many other factors, such as contextual ones, which are discussed below.

Network Types	Median DL	Number of Samples
4G	790 kbps	16
3G	512 kbps	11

Table 5: DL throughput 3G vs 4G

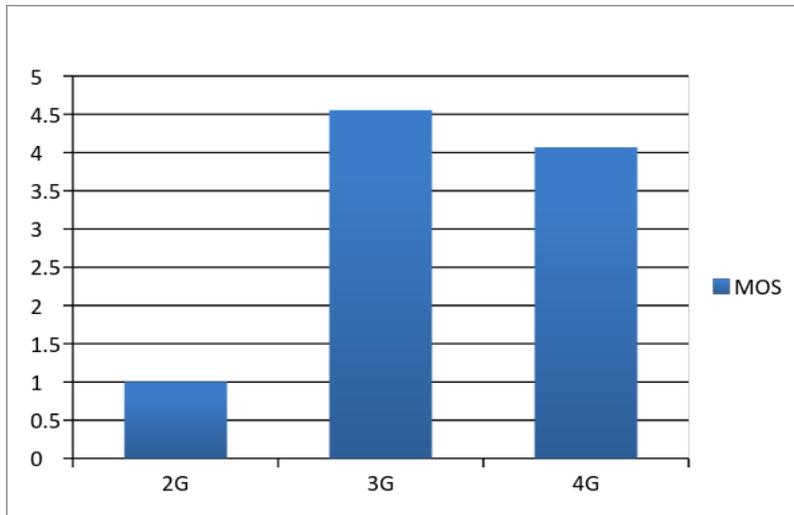


Figure 12: Network Types vs MOS

### 3.2.2. Contextual Factors vs MOS

Contextual Factors in general can cover many different aspects, which are all important for QoE measurement. In this study, the following factors have been included for evaluation of MOS value.

#### 3.2.2.1. AGE vs MOS

As shown in the result below that younger people are more optimized on providing higher MOS value on an average of 4.4. The participants with the age over 40 years old are pickier and hard to be pleased with the offered QoS, they only provided with an average MOS value of 3.

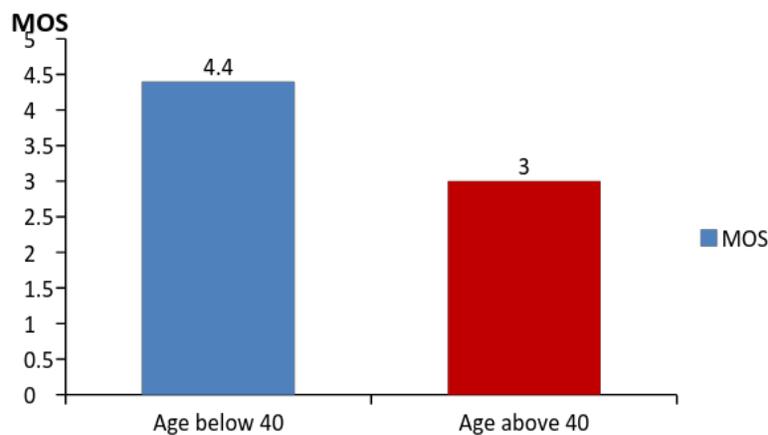


Figure 13. AGE VS Average MOS Value

### 3.2.2.2. Gender vs MOS

The below diagram shows Males have an average MOS of 4.5, whereas Females only provided an average MOS value of 3.5. These could be because Females are normally more sensitive on providing feedback, on the other hand, males are often giving judgment easier and without too much cautious.

However, this result could also be due to the video content are not favor of female. Therefore, it is recommended to consider the gender equality when selecting the videos in the future studies.

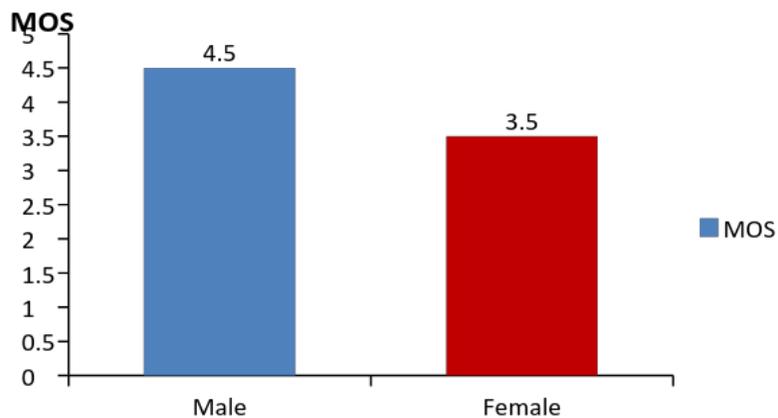


Figure 14: Gender VS Average MOS values

### 3.2.2.3. Video Content VS Average MOS value

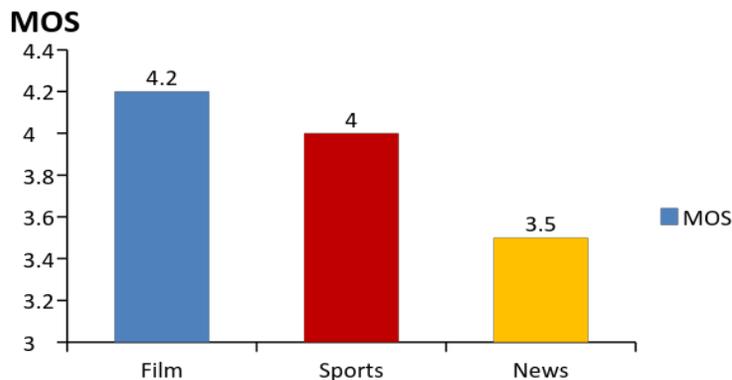


Figure 15: Video Content VS Average MOS

Users' demand for quality of streaming service is very much content dependent. [27] Therefore, it is important to determine the relationship between the users' perception of quality to the actual content of the video, since video content has a significant effect on user QoE in the following aspects. For example, the main influencing factor for a slow moving video clip, such as news, was packet loss alone, while for a fast moving football match clip, video bit rate as well as packet loss were both highly important. This is according to the previous study in [28]. Therefore, this research also introduces 3 different types of video clips, which are: Fast and Furious 7 trailer which is in the category of film, Champions League Final 2015 AD (Juventus vs FC Barcelona) which representing sports, and one BBC NEWS clip 'comet 67p contains heavy water'. The results clearly show the various MOS values for different video contents, most users are in a favor of latest and attractive movies therefore provide highest MOS; On the contrary, football game might be bias for those who does not like these two teams, so does the content of News, people might not interested in the news that they does not be fond of, therefore received comparably lower MOS score.

#### 3.2.2.4. User Expectation VS Average MOS value

User Expectation is one of the most important factors that need to considered while measure QoE, it is also one of the most important block in the QoE contextual Model [16], without knowing specific user expectation, MOS can be hardly mapped accurately, thus, this research take user expectation into careful consideration, and ask the users to provide whether or not the video clips meet their expectation from the survey, if the answer is negative, then the users are free to leave their comments which can be found in the survey, refer to Appendix [B]. The result shows that the MOS is in the value of 4.4 if the user expectation has been met, whereas the value will drop down deeply to 2.7 if the user expectation has not been met.

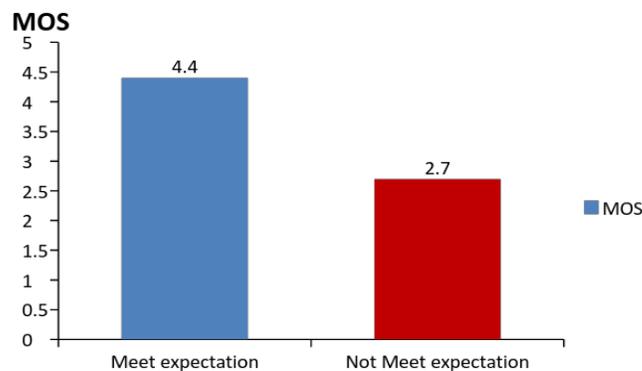


Figure 16: User Expectation vs MOS

### 3.2.2.5. Fun/Not Fun VS Average MOS Value

Similar to user expectation above, if the user think the video content are fun to watch, the MOS value will never below 4, on the contrary, if the user does not like the video content and think it is no fun, then the MOS value can never reach 3. Please refer to figure 17 below.

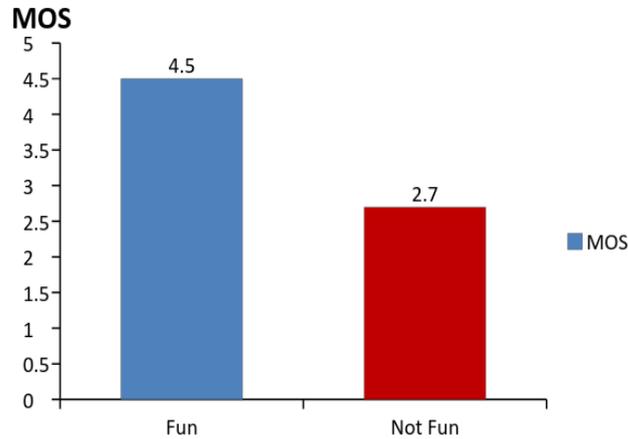


Figure 17: Fun/No Fun vs MOS

### 3.2.2.6. Location VS MOS

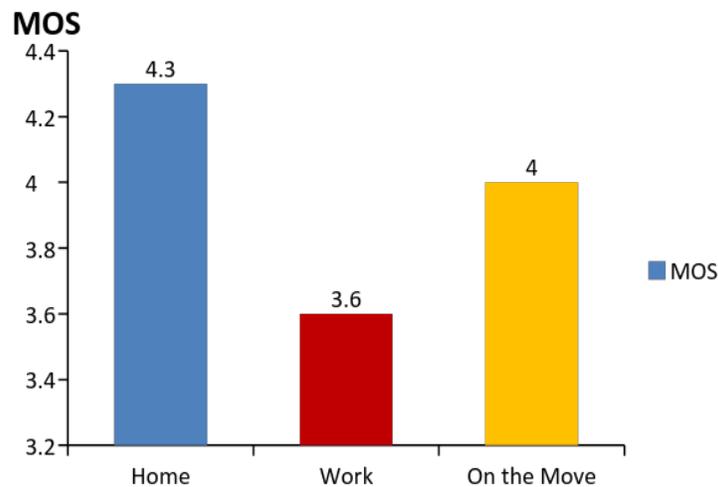


Figure 18: User Expectation vs MOS

The location factors show (in figure 18 above) that users who watched video clips at home have the highest MOS (4.3), whereas users watched video at work have the lowest MOS (3.6), the third type of users who watched during the move are having the median value of MOS (4). These can be easily explained that users are more relax and casual to watch videos at home compare with watching videos in the public, especially at work. Even though the average throughput are better at work than ‘on the move’, the users watching YouTube at work could still be stressed by the atmosphere which leads to lower user satisfaction. This could illuminate that user Experiences various based on different location and occasion.

One of the previous studies has been done by Aalto University in Finland, it explored the usage of Contextual patterns in mobile service [29]. From that study it shows that on average users use their smartphones the most at home. See figure 19 below. Surprisingly, we can see that these two figures are occasionally matched, wherever use smartphone the most, the highest MOS is. Perhaps in other locations than home there is less time available for casual video streaming.

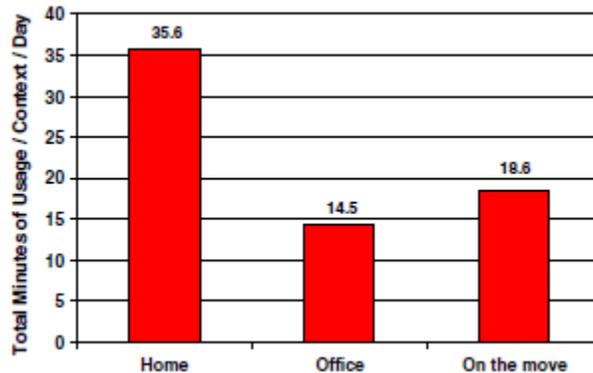


Figure 19: Contextual smartphone usage minutes [29]

### 3.2.2.7. Buffer times VS MOS (Including Initial Buffer)

For YouTube video streaming, network performance and other impairments result into related buffering event, also called stalling patterns. For this study, buffer times are calculated by the users themselves via the survey. Therefore, only the times of the buffers (including the startup buffer) has been counted, but not the duration for each buffer.

As shown from below figure 20, users experienced 0 buffer do have the highest average MOS (4.2), even by introducing only 1 buffer(including the startup buffer) does not seem to affect user experience that bad, which still achieve a MOS value of 3.9, However, if the user have experienced 2 times or more buffer, their experience will drop rapidly.

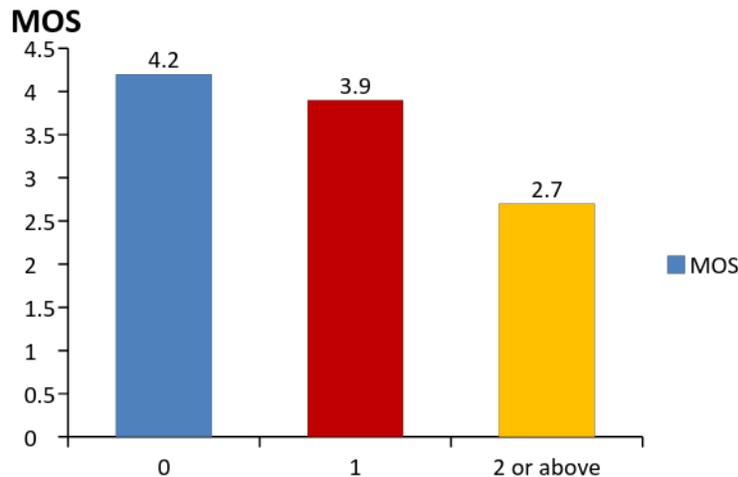


Figure 20: Buffer times vs MOS

This above result is perfectly in line with the previous research in [4] where it quantified YouTube users' QoE of YouTube with the frequency and duration of stalling events. As shown in figure below, the x-axis means the number of buffer events, whereas the y-axis indicates the MOS scale. The results show that users tend to be highly dissatisfied with two or more stalling events per video clip.

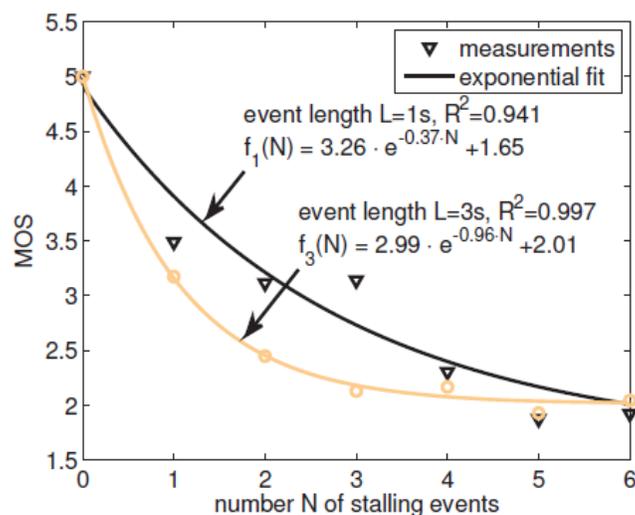


Figure 21: Mapping functions of stalling parameters to mean opinion scores [4]

### 3.2.3. Other Factors vs MOS

Other factors such as application factors also have great impact on user satisfaction, for example Android version and Smartphone screen size, the result show that users with an Android version more than 5.0 have slightly higher MOS value compare with the ones have Android version below 5.0, see figure 22 below, this is not surprising, since compare with Android older version, a more elegant and colorful look as well as modern feel has been introduced in Android 5.0, which of course increase the user experience when watching YouTube video clips for example.

However, the result of this study show that screen size does not play a big role in affecting user QoE. Refer to figure 23. This could because the bigger screen the user has, the higher expectation they will have and therefore more picky. On the other hand, user with smaller screen might hard to notice any video quality issue that appeared on the screen during the playback, therefore leads to a positive feedback.

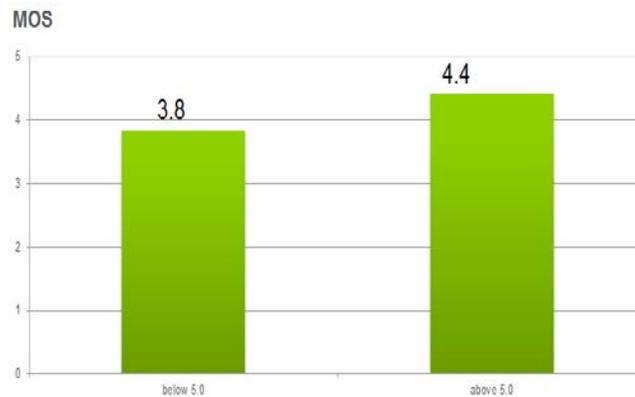


Figure 22: Android Version vs MOS



Figure 23: Screen Size vs MOS

#### 4. Discussion:

This research showed a brief view of the effect of network performance and contextual factors on user satisfaction for YouTube video streaming. The collected data has been validated by interview with several participants, interviews are ideal for collecting deep knowledge over a limited area [25], in this case, it confirmed the answers collected via the survey are in line with the participants' real opinion, which increased the accuracy for this study.

Quality of Experience is highly dependent on different factors and therefore should be measured in different dimensions. Network performance factors (QoS) are deciding the quality of the network that is offered to the end users, therefore they have a direct impact on user Quality of Experience. However, among different QoS parameters, there are many kinds of parameters that affect QoE in different ways. Downlink median throughput, for example, has been considered as one of the increasing parameters in this study, as can be seen from figure 7 above, it affects the MOS value positively, the higher the throughput the user receives, the higher the MOS value the user will provide. Nevertheless, this is not always the case, in this study, it has been identified that if the DL throughput reaches about 0.5 Mbps, most of the users will be fairly satisfied with the YouTube clip they have watched, no matter what mobile networks they were on, this finding is different from the prior research which was done by Hulu who recommends a downstream throughput of at least 1.5 Mbps for smooth video playback [30]. Further increasing throughput will only slowly improve QoE because the region of MOS plateau has been reached (refer to figure 8) where network performance has almost no dependency with MOS. Therefore, operators should not only focus on increasing the speed, instead, analyzing and understanding what the customer needs is crucial.

Unlike the DL throughput, TCP timeout has been considered as one of the decreasing parameters for MOS in this study. The more TCP timeout, the more TCP retransmission will occur which will lead to bad QoE. On the contrary, if the TCP timeout during video streaming playback session is less than 10 ms, the contribution for the MOS scale will be 4 or above.

This study has also found out that different network types do play a role in QoE, even though the 4G (LTE) technology has the highest Median Downlink throughput which in average is about 790 kbps for this study, it however does not receive the highest average MOS value. On the contrary, 3G technology has a comparably lower Median downlink throughput which is 512 kbps, however, it has the highest MOS of 4.5. This can also explain that operators or network providers shall not only focus on launching the newest technology, but also need

to pay attention to the usability of the network which could lead to better user satisfaction.

It has been concluded that not only the network performance affect QoE, also contextual factors do, such as different user profiles, i.e. age, gender and location. From the analysis of the Experiment result it is clear that the male users do have much higher MOS value compare with female, and the younger users have much higher MOS compare with the elders, which shed some light on female users are harder to be satisfied with the same quality of service provided compare with male, so does the elders. The operator or service provider should pay more attention to the female users and the elder users in order to please them in a better approach, i.e. Advertisement.

The results also show that the smartphone users are most positive while watching the YouTube clips at home but much less pleased at work. The commuters' feedback lays on a median MOS value of 4. This can be easily explained that users are more relax and casual to watch videos at home compare with watching videos in the public, especially at work. Even though the average throughput are better at work than 'on the move', the workers watching YouTube at job could still be stressed by the atmosphere which leads to lower satisfaction.

Below chart summarize most of the objective factors VS MOS value.

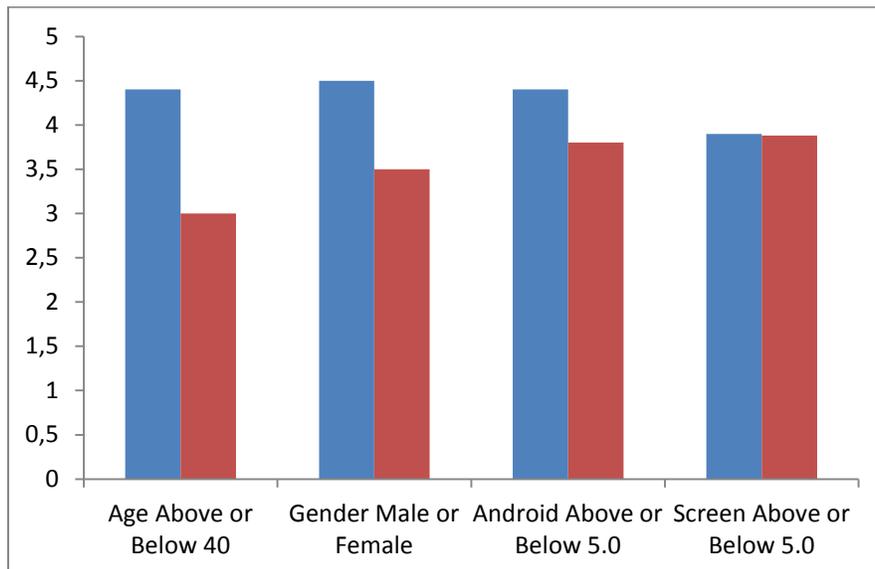


Figure 24: Different Objective factors vs MOS

Additionally, Quality of experience also strongly relies on many subjective factors, such as user experience, user interest and expectation. Several survey questions have been introduced to evaluate the subjective user opinion, the outcome indicate the human subjective judgment play a key role in determining the QoE metrics. (Refer to figure 25 below). The users might receive very high QoS from the network provider, however, they could still possible be less satisfied due to their expectation has not been made due to bad video quality, or they do not like the video content. Thus, operators or content providers should not only focus on capturing the attention of new customers, but also try to guarantee the content and quality for the service can meet customer satisfaction.

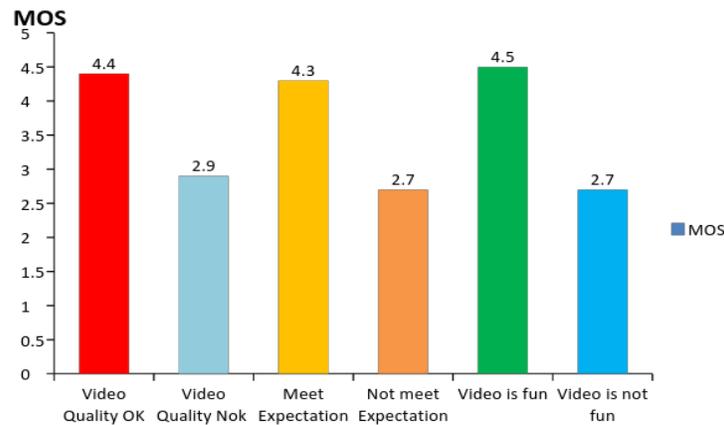


Figure 25: Different Subjective factors vs MOS

All of above, as according to the findings from this research by far, a lot more interesting results can be extracted in the future, therefore, man can say that this is just the starting point, further investigation on the impact of contextual factors and network performance on QoE evaluation could start from this research study.

#### 4.1. Conclusion

This paper investigate the effect of mobile cellular network performance and contextual factors on smartphone users' satisfaction, this was done via crowdsourcing method through an experiment where NPT [11] and a Survey were included, to evaluate Android Smartphone users' QoE for YouTube Video Streaming. The result show that network performance parameters do have the exponential relation with MOS, either impact MOS positively or negatively, however, multiple parameters shall be considered together in order to draw a more accurate correlation with QoE. In addition, QoE are heavily affected by many other contextual factors, such as age and gender as well as users location.

QoE are also impacted by several subjective factors, such as user expectation. Not always the highest throughput will lead to the best QoE, and not always the best technology (LTE) deserves the best MOS. Even though user received very high downlink throughput, their MOS value may still be low due to they do not like the video content. 100% of users who has a MOS value of 5 think the video are fun to watch and the quality meet their expectation.

Therefore, operators do not always need to spend too much money on focusing on developing the newest the technology and trying to provide the customers with highest throughput, instead, it shall concentrate more on using limited network resource that mention above in this study, and try to cooperate well with service providers and content providers in order to reach the maximum customer satisfaction, by doing so, they can generate more margin and save the cost in order to reduce the revenue gap.

## **4.2. Limitation and future work**

Firstly, this study mainly focuses on the effect of single parameter's on MOS scale, further investigation can be done to combine various parameters and investigate their combined correlation with QOE.

Secondly, the sample groups for this study are not big enough to draw a general conclusion, and the selection of the sample are also biased, this is due to the experimenters are mainly come from the researcher's social network, who are having similar background. Therefore, a larger amount of experimenters with less bias sample groups shall be targeted for the future.

Thirdly, the experiment select 3 different types of video, however, these videos' resolution are all in 1080p full HD. Three different video with different resolutions (1080p, 480p, 360p) shall be used instead of the same resolution. Since different video resolutions require different codecs which is necessary for QoE measurement. In addition, the video should be selected from the 'QoE certified database', where all video clips have been tested. By doing so, the result for this study can be used to compare with the previous work on the same video clip, so that the findings can be easily verified by prior art.

Fourthly, a more comprehensive Android APP could be developed to measure QoS and QoE at the same time, this can avoid users jumping between different Apps during the evaluation.

Finally, if the advanced tool will be available in the future, 3 different videos with different resolution will be chosen from the certified database and larger unbiased sample group can be target, a more comprehensive further study can be possibly done based on this research to find similarities and extrapolate the results with the Network Performance Test database to find a larger QoE-QoS mapping scale. This is trying to use limited amounts of sample data to make general conclusions on user satisfaction.

One says: 'QoE is a journey rather than a destination' [31]

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## Appendix

### Appendix A - Experiment Instruction

Dear Recipient,

You receive this email since you have recently participate the pre-test for the research study on "QoE Evaluation for YouTube Video Streaming" which is to provide user-side measurements on Quality of Service (QoS) and Quality of Experiences (QoE) for Android Phone users. Here comes the official test instruction. All participants will watch 3 video clips, anyone who has finished all 3 videos will have 30% of the chance to win a cinema tickets!

It is highly recommended to perform the test in a "complex" location, e.g., when in the subway or with bad coverage, of course under a Cellular network. (NO WIFI)

Thank you very much for your participant and effort!

#### Test Instruction:

1. Download and install **Network Performance Test (NPT)** on your Android Smartphone from link below

<https://play.google.com/store/apps/details?id=com.ericsson.mbbmeasurement&hl=en>

2. Use the activation code KTH\_XXXXX to activate NPT and click on Start button then accept the term of use.

3. Turn OFF your Wi-Fi connection on your phone.

4. Open the following link in google Chrome and watch the video immediately. <https://www.youtube.com/watch?v=Skpu5HaVkOc>

5. After finishing the video, please come back and open the Survey below to leave your feedback: [https://qtrial2014az1.az1.qualtrics.com/SE/?SID=SV\\_0uIBtp0BVeRUs5v](https://qtrial2014az1.az1.qualtrics.com/SE/?SID=SV_0uIBtp0BVeRUs5v)

6. Please make sure to fill in your correct Google Play email address at the end of the Survey.

Thanks again for your support!

## Appendix - B YouTube Streaming User Experience Survey

Q5 How do you rate this video session in general?

\_\_\_\_\_ 1 worst, 5 best.

Q6 What is your age?

- 18-25
- 26-40
- 41-60
- 61 or older

Q7 What is your gender?

- Male
- Female

Q8 Are you watching this video at...?

- Home
- Work
- On the Move

Q9 Are you watching this video alone or together with others?

- Alone
- With others

Q10 Can this video be played right after you press the PLAY icon?

- Yes
- No

Q11 If No, is there a long delay before the video can be started?

- Yes
- No

Q1 Have you experienced any delay or buffering during this video session?

- Yes
- No

Q4 If Yes, How many times do you experience delay or buffering?

- 0
- 1
- 2
- More

Q12 Have you experience asynchronous audio and video during the session?

- Yes
- No

Q13 If Yes, have you thought about stop watching the video?

- Yes
- No

Q14 Do you think this video quality meet your expectation?

- Yes
- No

Q15 If the video quality did not meet your expectation, why?

- Start-up Delay
- To many Re-buffering
- Asynchronous Audio and Video
- Video Quality was bad
- Others, please type below \_\_\_\_\_

Q3 Do you think the video is fun to watch?

- Yes
- No

Q16 Please enter your GooglePlay email address below! You will have 30% of the chance to win a cinema ticket. And the result for this research will share with you once the analysis is done!  
Thank you!

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