

Studying the Experience of Mobile Applications Used in Different Contexts of Daily Life

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ABSTRACT

Mobile applications and services increasingly assist us in our daily life situations, fulfilling our needs for information, communication, entertainment or leisure. However, user acceptance of a mobile application depends on at least two conditions; the application's perceived Quality of Experience (QoE) and the appropriateness of the application to the user's situation and context. Yet, there is generally a weak understanding of a mobile user's QoE and the factors influencing it. The mobile user's experience is related to the Quality of Service (QoS) provided by the underlying service and network infrastructures, which provides a starting point for our work. We present "work-in-progress" results from an ongoing study of Android phone users. In this study, we aim to derive and improve understanding of their QoE in different situations and daily life environments. In particular, we evaluate the user's qualitative QoE for a set of widely used mobile applications in the users' natural environments and different contexts, and we analyze this experience and its relation to the underlying quantitative QoS. In our approach we collect both QoE and QoS measures through a combination of user, application and network input from mobile phones. We present initial data acquired in the study and derived from that, a set of preliminary implications for mobile applications design.

Categories and Subject Descriptors

H.m. [Information Systems]: Miscellaneous

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General Terms

Measurement, Performance, Human Factors.

Keywords

Quality of Experience, Quality of Service, subjective experience, network performance, mobile application.

1. INTRODUCTION

The growing availability of diverse interactive mobile applications, envisaged to assist us in different domains of our daily life, make their perceived QoE increasingly critical to their acceptance. Comments such as, "If it's slow, I won't give my credit card number" [1] indicates the QoE expectations of a typical commerce application user [2]. These expectations depend on the user's previous experiences with an application or an application's criticality to the user's task at hand. To date, evaluation of QoE has mainly been conducted with qualitative methods that focus on an applications' usability [3], where the studies are conducted for a limited time in very controlled laboratory environments, under conditions that do not resemble users' natural daily environments. The results of such evaluations help to discover a mobile application's serious and immediate usability design issues, but they are unlikely to help in recovering issues that are relevant to real-life situations outside the lab.

These real-life issues involve, amongst other things, a non-deterministic QoS and, in particular, the performance of the underlying networks' infrastructures that support the execution of an application and mobile service delivery as depicted in Fig. 1. This QoS is quantified by measuring delay, jitter and network throughput. It is usually provided at a 'best-effort' level; that is without any guarantees by a service provider that it will work at an optimum level. Yet, as we argue, this QoS can be critical to the mobile user's QoE, especially for highly interactive mobile applications, for which delivery depends on frequent data transfers over the underlying network infrastructures.

A common practice for QoE provisioning is that mobile application designers use their own judgment and perception of an application's ease of use as a bellwether to gauge

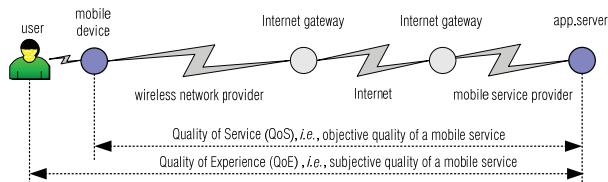


Figure 1: QoE and QoS in a mobile service delivery

an application’s perceived experience [3]. The overall effect of this situation is that users whose QoE expectations are not satisfied, simply stop using the applications or switch to another provider. For example, it is estimated that there are, on average, 200 new applications available daily in the online store for Apple’s iPhone platform [4]. However, due to numerous reasons including inappropriate content or inadequate user experience, more than half of these applications do not achieve a critical mass of user acceptance and are withdrawn from the store’s list of offerings within months of the launch.

The challenge for designers and researchers studying these technologies and new applications is that no rigorous and robust scientific methods, tools, and systems exist for evaluating an application’s perceived QoE in the user’s natural environment(s) [5]. Rather, there are separate methods for usability evaluation in the Human Computer Interaction (HCI) community [3], [5] [6] and separate methods for the evaluation of the QoS and performance of an application’s underlying network infrastructures in the data networking community [7] [8] [9]. The former methods are largely qualitative, while the latter are largely quantitative. Both types of methods enable an acquisition of quality results in their dedicated areas of applicability. However, due to the dichotomy between these two scientific communities, there are no scientifically proven methodologies that combine both types of methods. In general, the community understanding of QoE for mobile applications is weaker than it should be. Our approach is to measure QoE and QoS through a combination of methods with a goal of improving our understanding of variables influencing QoE, and enabling us to derive implications for mobile application design.

In Section 2 of this paper we provide an overview of related work, and in Section 3, we present and discuss our combined method for understanding QoE and QoS. Section 4 presents preliminary results from using this method. We conclude in Section 5 with a discussion of future work.

2. RELATED WORK

There exists much related work in the area of evaluation of QoS and some related work for evaluation of QoE for mobile applications and services. Sousa et al. [16] emphasized the importance of understanding user’s QoS requirements in a wired networking environment and they proposed a framework for engineering software systems capable of adapting to resource variations, such that the QoS requirements for the given user’s task are met. Their main focus and evaluation criterion was usability of an interface for setting up the QoS requirements for an average user. Furthermore, Dinda et al. [15] postulate on involving users in experimental computer systems research and they give an example of evaluation of performance for a set of (fixed) client/server applica-

tions (e.g., office applications, web, gaming) that experience resource constraints, and the relationship between this performance and the comfort level expressed by the user. The comfort level is a metric of QoE for a user of these applications.

Putting focus onto wireless networking environments, we point to the work of Huang et al. [10], who evaluated a selected QoS metric, namely speed of download of a given website accessed from a set of mobile devices. They have identified how this speed is influenced by the speed of Domain Name Server (DNS) lookup, followed by the Transport Control Protocol (TCP) handshake, the download of the webpage and its objects via parallel connections, and the rendering and processing of the page. Those QoS evaluation results are important as web access is commonly used by an increasing number of mobile applications.

Buchinger et al., [13] focus on evaluating multimedia QoS for a mobile user, yet, they require a user to be instrumented with devices for environmental measurements (e.g., temperature, humidity), claiming that these environmental variables may influence the user QoS. MyExperience is an open-source framework of Froehlich et al. [12], running on Windows Mobile devices, that combines passive logging of contextual information and sensor readings (e.g., temperature), and, in principle, could serve as a basis for a QoS evaluation study.

In selected studies, researchers have focused on a particular QoS characteristic of a mobile device; e.g., Shye et al. [14] observed battery lifetime and power usage breakdown for a large group of Android users. Falaki et al. [11], provided phones with unlimited access to mobile applications to users. In this study, users interacted with their phones, on average, between 100-200 times a day, with each interaction lasting between 100-200 seconds. The authors state that the longer the user has not interacted with the phone, the less likely he/she will start interacting with it again.

According to Jaroucheh et al. [27], when modeling situations of pervasive technology usage and the resulting user experience, one should consider the historical as well as current user context, the combination of automated capture of situation and the flexibility of user behavior. Similarly, according to Hassenzahl and Tractinsky [25] user experience is influenced by user’s internal state, the characteristics of the designed system, the context within which the interaction occur and meaningfulness of the activity.

Reichl et al. [17] proposed the study with the aim most similar to ours. They attempt to evaluate QoE in real user environments by capturing user interaction with the mobile phone, as well as the user context using two different cameras mounted on a large female hat worn by the (female) user. The approach also includes the acquisition of QoS measures on the mobile phone and relating these to QoE. The authors indicate that the best QoE for mobile video streaming application is achieved with circuit-switched solutions, having minimal setup time (QoS). However, the study setting is very intrusive for the mobile user (i.e., user wearing the hat) and limited in scope, and therefore the results are hard to generalize.

The most important difference between the existing studies and our studies is that we are focused on measuring users’ perceived experience on users’ (personal) phones, based on the set of mobile applications they use in their natural daily environments, and we aim to increase the understanding of

factors influencing this experience, amongst others, related to network QoS.

3. METHODS

This section presents the design of our experiments aiming to understand users' perceived experience of using mobile applications and its relation to user context, including QoS.

3.1 Overview of the Approach

Measuring QoE for real application users in their real environments is the only chance to bridge the gap between lab studies and real measurements and implementation. To this end, our approach uses mixed methods, incorporating qualitative and quantitative methods in a four week-long user study embracing i) a continuous, automatic, unobtrusive context data collection (including QoS) on a user's mobile phone, ii) gathering user feedback on his/her perceived QoE via an experience sampling executed multiple times per day, and iii) a weekly interview with the user. In our approach, we focus on already implemented and operational interactive mobile applications, which are available on a typical mobile phone. We assume that these applications have undergone a cycle(s) of (re)design and usability tests in a laboratory environment, although we do not have access to the results of these.

More specifically, our approach is based on our experience in research on measurement-based QoS, i.e., performance evaluation methods for interactive mobile applications [18]. We have successfully used this methodology in a healthcare domain, specifically in the creation of interactive applications for health telemonitoring and tele-treatment depending on delay and throughput (i.e., QoS metrics) of the underlying network infrastructures [7], [19].

3.2 Mobile Users and Data Collection

First Interview

To recruit the subjects for our study we conducted a survey asking mobile users for their socio-economic status (age, occupation, education level and family status), how long they have used mobile technologies (year started), type of and provider for their current phone, how they think they use their current phones for voice communication and data, which applications they use and with what frequency, general experience with their phone, and whether their expectations (and which ones) were being met, and to which extent. We used the responses to this survey to randomly select 30 subjects for our four-week long study.

Android Context Sensing Software (CSS) Application

There is a set of QoS parameters that influence the user's QoE, especially for highly interactive applications. We have developed the CSS application to unobtrusively collect the following information from Android phones: current time and user's geographical location; wireless access network technology (cellular or WLAN); cell-ID (for 2.5G, 3G or 4G) an Access Point name (for WLAN); wireless access signal strength (RSSI); current running applications with total amounts of application data throughput, (i.e., Bytes/second) sent and received; Bluetooth network status; screen brightness level; screen orientation and device's proximity status. We also logged the device acceleration, magnetometer and orientation to derive user activity level, as well as phone activity for interpersonal interaction in terms of number of

calls, SMS and MMS. While some of the data is collected at a constant frequency (e.g., every 3 minutes for user location), while other sensor data is collected only when the sensor changes its value.

As a network performance indicator we measured the median Round Trip Time (RTT) for an application-level control message of size 64 Bytes, sent every minute from the mobile device through the available wireless access network technology to a dedicated server deployed at our university.

The CSS sensor logs are written directly to the phone storage card each time the QoS changes. The aim is to minimize the memory allocation on the phone throughout the data collection process, as well as to minimize the risk of losing any data.

QoE Data Collection

We deployed another application on the users' mobile phones to gather their subjective perception of the QoE. For applications they just finished using. For this purpose we have used the Experience Sampling Method (ESM), [20], [26]. ESM is based on occasional user surveys, which can be administered over specific time intervals, after particular events, or at random. We implemented this in the form of a short, mobile-device based survey given to users after using an application. The survey posed questions about a) user experience for the application (poor (1) to excellent (5), based on the ITU recommendation [21]), b) location (choice of: home, office/school, street, other indoor or other outdoor); c) social context (alone, with a person, with a group) and d) mobility level (sitting, standing, walking, driving, etc.). The ESM method is designed and deployed such that it does not influence the experience and behavior of a mobile application user, but enables us to gather information that is relevant and (hopefully) predictive for this user's QoE. Therefore the survey does not appear after each application usage, but at random times after random application usage, with a maximum of 8 to 12 surveys per day. When rating the same application throughout the study or even for a given day, we requested that users do their best at providing independent QoE ratings. We instructed the user that her rating is aQoE purely subjective, episodic assessment provided on the basis of the given perception of the specific episode of application use.

We aimed to capture and attempt to understand QoE for a set of widely available mobile applications for leisure, entertainment, communication or information purposes, for e.g., YouTube, Internet-based radio, interactive Voice over IP (VoIP), instant messaging, web browsing, multiplayer on-line games, email and news.

Weekly Interview

To analyze possible relations and causality between variables, the methodology requires the occasional involvement of a mobile user in the data analysis process. Namely, a mobile user needs to be interviewed about his usage pattern of and experience with a particular mobile application. This data must then be matched to the data automatically logged in the application and service infrastructure. The interviews we conducted were based on the completion of a detailed diary of the previous 24-hour period, as suggested by the Day Reconstruction Method (DRM) [15]. This breaks the day into episodes described by activities, locations and time intervals, and the mobile application usage and expe-

periences during these times. During the interview, users can explain in detail their responses from the ESM, and these results are compared to the state of other data logged in the system. This way causalities and relations between QoE and its influencing factors, specific to this particular user can be identified, while any inconsistencies in measured data can be clarified. Based on the ESM and DRM we can derive new variables and factors influencing QoE for each user. These variables can be then 'grounded' [23], [24] and serve as a basis to derive application design implications.

3.3 Subjects

We recruited 30 Android users with three types of phones (Motorola, HTC and Samsung) subscribed to four providers (Verizon (22 subjects), Sprint (3), T-Mobile (2) and AT&T (1)). The number of participants dropped to 28 in the third week of the study due to battery issues that occurred particularly for the users of older phones. Of these 28 users, there were 18 male participants and 10 female of which 95 had ages in the range of 25 to 30 years. None of the participants had accessibility problems related to their phone use and, when asked, none of them admitted that they are adversely affected by the rumors regarding electromagnetic radiation Electron Magnetic Resonance (EMR) health issues for mobile phone usage.

4. PRELIMINARY RESULTS

By the end of the study, we collected a total of 15 GB of data from all users. The largest sized log files belonged to the accelerometer, magnetometer and orientation CSS modules. The most energy consuming modules were the location log module (including Global Positioning System (GPS) sensor), WLAN sensor and accelerometer, magnetometer, orientation, illumination and proximity modules.

4.1 QoE Ratings

In total we have received around 7500 QoE ratings from all users. In the first week we collected around 1300 ratings from our users, in the second 1700, in the third 2500, while in the last week there were 2000 ratings. The high ratings (4 and 5) are much frequent than low ratings (1, 2, 3) for all the users as depicted in Fig. 2. We conclude that in general, people seem to find their QoE to be acceptable in most cases. We expect such results since if the user was not happy with an application, she will likely not continue using it.

4.2 Role of QoS

Choice of the wireless access technology, i.e., WLAN, 2.5G, 3G or 4G, influences the resulting QoS; therefore we expect that such a choice also influences QoE. We observed that our users either did not use WLAN at all (having unlimited 3G unlimited data) or left WLAN always on to connect to predefined networks such as in their home or office. Nine participants did not turn on their WLAN interfaces at all within our study, while six participants never turned them off, allowing the device to connect to any available network automatically. Moreover, 4G was rarely used because of unavailability, as one user claimed: *"unfortunately, I don't get 4G in (A). And when I'm in (B), the 4G connection keeps switching on and off, and the notifications (which are similar to the notification for Wireless Fidelity (WiFi) connections) are just annoying. So I keep 4G switched off"* (S18). Another (S20) said: *"My phone can operate on a 4G network,*

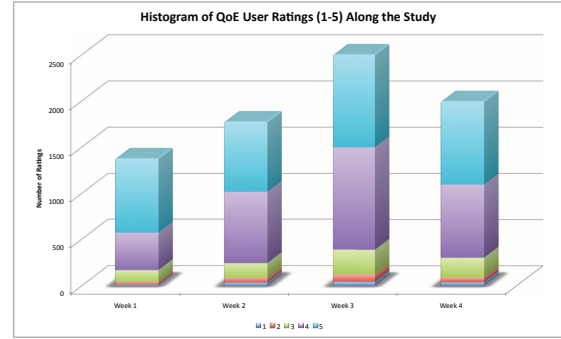


Figure 2: QoE Ratings Distribution Over 4 Weeks

but I usually keep it set to 3G because in my experience, the 4G is not considerably faster and just eats up my battery. [â&Ae]. Generally I keep 4G turned off unless I am doing something network intensive and I know it is available".

We were surprised to hear that, because according to the results of performance measurements we conducted for the 3G and 4G networks, use of the 4G network results in better QoS parameters than 3G. We presume that the applications used by this particular user worked sufficiently well on 3G (e.g., these are non-real time applications), and they did not need network (QoS) improvement. It seems to contradict with our initial hypothesis that a mobile user always wishes to have the best possible and fastest service. Our future work includes analysis of the data to support or refute this hypothesis.

Additionally, using our DRM, we discovered clusters of users, for which network selection and the resulting QoS depended directly on their phone charging behaviors. Namely, users who were able and willing to charge their phones often preferred the access technologies in the order *WiFi - 4G - 3G*, whilst this changes to *3G - WiFi - 4G* for the ones who charge their phone less often. A common feeling among our users was that 4G was as good as WLAN but drained too much battery. In addition, 4G coverage is a problem, thus users who are subscribed to providers with 4G support are not necessarily always within the 4G coverage, which leads to the connectivity oscillations between 3G and 4G, resulting in draining extra battery and putting users at risk of instant disconnections.

4.3 Some Factors Influencing QoE

For most of our users, it was not natural to talk about their QoE experiences; they implicitly assumed that with the study instruments being used, we could measure and understand all the factors influencing it. We observed that user's QoE is influenced by application designs such as web-browser page scrolling capabilities, or a specification of the built-in dictionary for messaging. This is one of the biggest problems that we will face in our final data analysis: a user scores an application with a particular QoE value due to any subjective reason, including an interface-related reason. For example, if a person uses an application, in which a slider is too small for her fingers, and she constantly has trouble

interacting with it, her subjective experience will be low, despite having an excellent QoS. These factors, however, are difficult to evaluate automatically.

We are still analyzing the data using an affinity clustering of user's subjective responses. Some preliminary factors influencing the experience, identified as common in our population, are as follows. Firstly, the routine of the user influenced the use of applications in given locations and times, e.g., different sets of applications were used in the morning, in the evening before going to sleep, in the car, outside of the office, etc. The user rating is influenced by user environment, the primary activity being performed, as well as the importance of the mobile application to this primary activity.

Secondly, the user rating was influenced to a large extent by a user's previous experience with the application. We observed that a user's expectations towards mobile applications are based on their experience on a PC-based platform, e.g., users claimed that the Facebook application is not functioning properly on Android, because it is running with much higher performance on a PC. Generally speaking, for mobile applications that users previously experienced on a fixed PC, the expectations are high. Therefore, for these applications we expect lower ratings, especially for situations where we observe that QoS was also low.

Similarly, as the third factor influencing the user experience, is whether the user has a choice of using a PC-instead of his mobile phone for particular application usage. If user has a PC available in his surroundings as an alternative device, e.g., to receive and send emails, user experience will be limited to reception of emails on the mobile device, while he will send them from the fixed PC. It may be because typing on a real keyboard of the PC provides a better user experience, especially for long messages.

The fourth identified factor influencing the user experience, relates to the situation where a user prefers mobile use only for a given application or for any application, i.e., overall for all her computing and communication needs. We observe that some users do not use a fixed PC, just their phone for all application needs. We conclude that for these users, mobile applications achieved enough usability to enable them not to use a larger and potentially more comfortable PC. Of course this is true only for some selected users, and, in our future research, we are interested in better understanding the characteristics of these users and the applications they use, as well as for those that prefer to use a PC.

The fifth identified factor relates to the social context in which the user finds herself, when using the application. The observation is that the ratings are influenced by disturbances from other surrounding people, i.e., a higher user rating is observed if a user is alone and can better focus on the application being used.

The sixth factor we have identified as influencing users' application usage and experience is related to the use of a mobile phone to support their lifestyle or hobby. There exist highly personalized applications for sports, lifestyle, nutrition and leisure, and these are highly ranked. They are used on a mobile platform due to their convenience of assisting the user when, e.g., in the gym (enabling the logging of calories expended), in the cafeteria (enabling the logging of nutrition and caloric intake), or on the street when trying find a suitable restaurant. Some participants indicated that they are using their phone to check their horoscope first thing in the morning, or to stay informed about celebrity gossip.

5. CONCLUSIVE REMARKS

In this paper we have presented our work-in-progress research and user study towards understanding a mobile user's experience (QoE) in their natural daily environments and relating this experience to the performance (QoS) of the underlying service and network infrastructures. Our approach is a blend of both quantitative and qualitative procedures, where the user becomes an active participant in the research. First, it requires gathering in-situ spontaneous information about the user's mobile experience for a set of widely used mobile applications, by employing the ESM for interaction with the user directly after each mobile application usage. Second, it requires a retrospective analysis of the user's experience and of the state of factors influencing it, by employing the DRM to assist with the recollection of the past 24 hours. We have presented a preliminary analysis of the collected data, highlighting some factors that impact a user's experience. Our future work includes analysis of other factors and user context influencing this experience. The implications for design based on these factors are numerous and our future work includes further analysis of the collected data and identification of these implications for design.

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