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THE METHOD FOR QUALITY OF EXPERIENCE EVALUATION OF IT SERVICES

Summary. Quality of Experience (QoE) is one of the major aspects that service providers focus on during development of their services. However QoE elements that are meant to increase user satisfaction are sometimes contradicting with Quality of Service (QoS) or Quality of Protection (QoP) factors. In order to balance the QoE to QoS or QoP values ratio we propose a method that takes into account various configurations of parameters and their relations and based on their state and values evaluates the QoE levels. The proposed method includes a model which describes the elements, their relations and the stages in which they are defined and used.

Keywords: Quality of Experience, QoE, Security and Usability, Security as a Quality of Service, QoS, Quality of Protection, QoP

METODA EWALUACJI JAKOŚCI DOŚWIADCZEŃ DLA USŁUG IT

Streszczenie. Jakość doświadczeń (QoE) jest jednym z najistotniejszych aspektów, nad którym usługodawcy powinni się skupić podczas budowy swoich usług. Często elementy QoE, które mają za zadanie zwiększyć satysfakcję użytkowników, niestety są sprzeczne z czynnikami jakości usług (QoS) oraz jakości ochrony (QoP). W celu zrównoważenia proporcji wartości QoE z QoS lub QoP proponujemy metodę, która wykorzystuje różne konfiguracje parametrów oraz ich relacje i bazując na ich stanie i wartościach, określa poziomy QoE. Metoda ta zawiera model, który opisuje elementy, ich relacje oraz etapy ich definiowania i wykorzystania.

Słowa kluczowe: jakość doświadczeń, QoE, bezpieczeństwo i użyteczność, bezpieczeństwo jako jakość doświadczeń, QoS, jakość ochrony, QoP

1. Introduction

Nowadays it is very important for a service to meet the QoE expectations of the users. This trend will continue to increase as the technological barriers that didn't allow for better user experience, decrease in popularity. With the emergence of multimedia services like IPTV that highly rely on quality and user satisfaction, new methods of measurement and adaptation are desired. Services like VoIP (Voice over IP), VoD (Video on Demand) that are highly dynamic require real-time adjustment of quality parameters. The main quality parameters that are relevant are those affecting the service and the satisfaction of the users that use them. The Quality of Service is a static and quantitative measure of overall performance of a service. It takes into account reliability, performance, availability, scalability, security and interoperability. QoS is not the best indicator for measuring the satisfaction of the users using the service. For this reason the concept of Quality of Experience is introduced [14]. In contrast to QoS, QoE is a subjective measure that is more user-centric and fully represents the satisfaction of service usage. In many cases QoE depends and is affected by QoS parameters like i.e. when considering a network service the latency of packet sending and receiving between data link connection endpoints. The relations that influence both measures and the mapping of causes to effects between them is not yet fully understood. There is research done on investigation of correlation between QoS and QoE [13]. Unfortunately no methods of QoE quantification were proposed.

In most cases QoE factors can be evaluated through subjective surveys that need to be carried out on users of the specific service. This allows to measure their satisfaction with a given service and produces a mean opinion score (MOS) indicator [1]. The MOS is a subjective coefficient of perceived quality initially used in telephony networks to measure the quality of the network. It is represented by a value from 1 to 5, where 1 means bad and 5 means excellent quality. When it comes to subjective grading of services every individual has his own set of QoE values for exactly the same service and usage conditions. To minimize the mentioned limitation one can categorize the users with similar characteristics (needs, values), as their measurements are relatively similar.

The main contribution of the paper is the creation of a holistic model that takes into account any service with any QoE and QoS factors that are present in order to provide results for balancing of the factor's values. Additionally we define factors and a transformation function that will make data eligible for producing the desired result. Finally, we propose a QoE measurement method with the intention to use the result as an indicator for balancing the levels of QoE, QoS and even QoP for a given service.

2. Related work

The literature provides only partial solutions to the subject of QoE factor definition. Most papers deal with a specific service and take under consideration solely the time (delay) factor as the major element that affects the QoE of the service. In Gómez Lorenzo et al. [8] the Android application that evaluates and analyses the perceived QoE for the YouTube service on wireless terminals are presented. The method involves mapping of objective QoS factor measurement to subjective QoE factor measurements achieved via MOS which is justified by the fact that it is a simple measurement of complex QoE elements. The main factor that is taken into account is time latency of the various connection types and the way it affects video buffering. The presented method works only for the specific described environment and is not general conception of QoE evaluation.

A notable method of combining both quantitative and qualitative QoE metrics is presented in the work of Skorin-Kapov et al. [10]. It incorporates an Application-Resource-Context-User (ARCU) model which categorizes the influence factors into four multi-dimensional spaces. The combination of the QoE factors is then mapped to a multi-dimensional QoE space. The main limitation of this method is that the evaluation do not refer to the user profiles and preferences which further influence the QoE measurement.

Another existing methodology is proposed by Moldovan et al. which automatically assesses and quantifies the impact of the aspects that contribute to a user's QoE for a given service [11]. This methodology requires a consumer-grade electroencephalography system (Emotiv EPOC) to measure the user's frustration level which then is used for the QoE evaluation. According to our new method, the QoE evaluation takes into account not only measurements achieved through EEG but also MOS.

In the paper [17] a method for selecting reliable relay nodes for data transmission in Intermittently Connected Wireless Networks (ICWN) is proposed. The main contributions of the article are that relationship strength between neighboring nodes is estimated according to previous encounters and that it evaluates process-based and relationship-based credibility. According to the authors those features greatly improve the forwarding decisions in such a network which ultimately lead to improvement of QoP and user QoE as well.

In [12] a study is done to investigate metrics such as PSNR (Peak Signal to Noise Ratio), MPQM (Moving Pictures Quality Metric) and VQM (Video Quality Metric) and correlates them with MOS. The QoS/QoE correlation model allows network providers to predict subscriber's QoE for video services. The authors state that the correlation coefficient for those metrics are good enough to be used as a way to measure QoE using only QoS parameters. However the tests were conducted only for video streaming services.

Another article [18] proposes a data search scheme for balancing the QoP and QoE parameters of a mobile cloud computing applications. The technique that is used utilizes the secure k-nearest neighbor (kNN) technique. The article points out some open research issues like i.e. the need of a unified model for qualifying the QoE and QoP for different mobile services. In [19] a systematic method for augmenting smart space design which among other things takes into account QoS and QoE. The authors claim that it enables a near optimization of various QoE criteria by means of a top-down refinement.

3. The model

The proposed method of QoE evaluation of IT services includes three steps: IT system definition, user and service configuration and QoE evaluation. The final result is a value representing the overall QoE of a service according to a specific user. Depending on the threshold that is set for QoE acceptance rates, an optimization process selects the best possible QoS, QoP and QoE level ratio.

3.1. Step 1 - IT system definition

The initial step of the model specifies the service providers and the user which take part in the IT system. Service providers are the companies that provide the service and have responsibilities towards its proper functioning. They are also responsible for the definition of QoS and QoP factors that affect them. We usually deal with only one service provider who has to define the elements of the next steps. However for cases that require additional service providers we can form a set: $\{SP_1, \dots , SP_n\}$. The set possess only names and definitions that are used to categorize underlying elements.

This step also requires the definition of Services which are described as a set of operations which are realized through interaction with certain applications. By IT services we understand the ones defined by the ISO/IEC 20,000 standard. The entity that is responsible for supplying the factors is the previously mentioned service provider. The next steps will elaborate on every type of factors that are present. For enumeration purposes we introduce a set of services: $\{S_1, \dots , S_n\}$. For every service provider there is a corresponding set of services, which provide only names and definitions that are used to categorize underlying elements.

The User is a person that makes use of the service. This is also the same entity that is surveyed in order to generate the MOS which is used to calculate the QoE level of some of the QoE factors. Users possess characteristics which differ for every individual. For enumeration purposes we denote a set of users *U* consisting of individual users: $\{U_1, \dots, U_n\}$. Users also provide only names and definitions for the categorization purpose of the underlying elements.

3.2. Step 2 - user and service configuration

The next step involves the selection of QoS Factors that are present during the operation of a given service *S*. The QoS Factors are related to the quality of a given service. This includes: maintainability, availability, interoperability, reliability, scalability, security and usability. It has to be noted that not all of them are always taken into consideration in every case of a service. The entity responsible for their selection is the Service Provider. The QoS Factors of a given service can be calculated by different tools mechanisms (i.e. SMETool [15] or AQoPA [16]). This is also the time to provide the influences *INF* that certain QoS factors impose on some of the QoE factors and denoted as a set: $INF_{S_i} = \{INF_1, \dots, INF_2\}$. *INF* is a value from the range of 0 to 1 and is provided by the Service Provider. A service includes a set of QoS Factors which represent a value within the (0-1) interval and denoted by the set: $QoS_{S_i} = \{QoS_{F_1}, \dots, QoS_{F_n}\}$.

3.3. Step 3 - QoE evaluation

The final step of the proposed method is to let the Service Provider define all the QoE factors that are related to a given service. Also in this step we define the user profiles *UP* consisting of the weights *QFW* that users place on the factors. Lastly we can proceed with the calculation of the individual QoE Factors acceptance *QFA* modified by the weights that we previously obtained and the other factors that might influence them *QFI*. *QFW*, *QFA* and *QFI* are vectors consisting of values from the range of 0 to 1 and represent the weights, acceptance and influence for a given QoE factor respectively.

In the model we introduce the following possible QoE factors: $QoEF = \{QoEF_1, \dots, QoEF_n\}$ which are also enumerated in the list below. The items below represent the acceptance level *QFA* for a specific QoE factor.

a) Cost: determines the user's acceptance towards the price of the service.
   - aP – actual price for a service (or its component),
   - pP – price that the user is willing to pay for a service (or its component).

b) Reliability: determines the feeling of the user towards the level of assurance of a given service to perform as intended under stated conditions.
   - rS – success rate for the operation of a service (or its component),
   - rF – failure rate for the operation of a service (or its component).

c) Interface user-friendliness: denotes the feeling of the user towards the user-friendliness of the interface.
   - gV – graphical element visibility. It is affected by: size of the graphical element, colour of the graphical element, position of the graphical element.
   - gU – graphical element operation understanding by the user. (How intuitive it is).

d) Security: describes the user's acceptance of the security methods that protect the services resources.
   - sM – used security methods affecting: integrity – assurance of data consistency, availability – assurance of data being available when they are needed, confidentiality – assurance of restricted access to data.

e) Privacy: determines the user's acceptance of the privacy that the service offers.
   - anonymity – user's data access and public visibility,
   - dhM – data handling methods,
   - deM – data encryption methods.

User profiles are predefined sets consisting of weights/importance of factors for groups or individual types of Users. The weights *QFW* are denoted as a value from the range of 0 to 1, which corresponds to the default five levels of importance: 0 – none, 0.25 – Vague, 0.5 – Casual, 0.75 – High and 1 – Severe. The amount of levels and the corresponding values however can be redefined for the specific requirements of a given service.

The weights are used to mitigate or enhance the importance of every QoE factor that a service *S* holds in accordance to a given user *U*. Every user profile *UP* corresponds to an individual user. It denotes his preferences. Therefore we denote the set of user profiles: $\{UP_1, \dots , UP_n\}$ for which $UP_i = \{QFW_1, \dots , QFW_n\}$, where UP_i is a user profile corresponding to a particular user and *QFW* are the weights (level of significance) that are associated to each QoE Factor.

Additionally we need to calculate the dependencies modifiers *QFI* for the applicable QoE factors *QoEF*. This is done by use of the equation (1). *QFI* is a value from the range of 0 to 1. When a QoE factor has no QoS factors that influence it in any way, the default *QFI* value for this particular QoE factor is 1.

$$QFI_{QoEF_i} = \sum_{y=1}^{n} \frac{QoS_y \times INF_{QoS_y}}{n} \quad (1)$$

where:

QoS_y – specific QoS factor,

$QoEF_i$ – specific QoE factor,

n – sum of all *QoS* related to the specific *QoEF*,

INF_{QoS_y} – QoS factor influence.

QoE for a given user *U* is the result of a function of the factors which is denoted as a number within the (0-1) interval.

Individual QoE for a user *U* and a given service *S* is measured as follows:

$$QoE_U^S = \sum_{i=1}^{m} \frac{QFA_i \times QFW_i \times QFI_i}{m} \quad (2)$$

where:

i – QoE factor for a service,

m – sum of all QoE factors,

QFA_i – the user's acceptance/feeling towards a level of a QoE factor (E) for a service (S),

QFW_i – the user's level of importance towards the QoE factor for a service,

QFI_i – influence of a QoP factor towards the QoE factor of a given service.

Overall QoE for the service *S* is measured as follows:

$$QoE^S = \sum_{j=1}^{k} \frac{QoE_{U_j}^S}{k} \quad (3)$$

where:

j – the number of user,

k – sum of all users,

QoE_U^S – the QoE for a user *U* and for the service *S*.

4. Case study

To visualize and explain the presented model and process of customization, a case study will be described. The case study acts as a form of real life use example as well. Because the QoE factors of an undefined service are very generic and usually can't be quantified, this use case will serve as a demonstration of the proposed model on a concrete service that includes quantifiable factors. For this purpose we define an e-learning platform.

4.1. E-learning platform

The E-learning platform consists of a client and server side. The client side is an Android application with the following functional requirements for the user: login into his account, register, view and edit his account data, view the list of available courses, sign up for a course, view and complete a course, view and submit results for a course's test, view and submit results for a course's task and view his results.

The main functionality of the application is to allow users to participate in on-line courses. These on-line courses are usually mobile aware, meaning that they possess elements that can be interacted with via mobile devices. Such an example are the various tasks that correspond to specific courses and ask the participators to perform actions in the physical worlds, like i.e.: walking a certain path and allowing the GPS coordinates to be tracked by the application, taking pictures of specific objects or finding and scanning QR codes.

The services that are used within the platform are the following: course provider, task provider, test provider, monitoring, registration and login. The client application has to query the web-service running on the server and request content in a RESTful manner. For the case study we will particularly focus on the Tasks service.

4.2. Step 1 - IT system definition

Following our model and its step order, firstly we need to define the Service Provider, the Service itself as well as the Users of the service. The Service Provider of this platform is denoted as SP_1 and the online service, provided by SP_1, as S_1. Let U_1, U_2, U_3 be the users that are using the service S_1.

4.3. Step 2 - User and service configuration

According to the model in the next step we need to define the QoP/QoS factors. Many of those factors are based on percentages of the current maximum that is acceptable for operation. The QoS and QoP factors for service S_1 which are described in the list below, belong to the set: $QoS_{S_1} = \{ER_{S_1}, EU_{S_1}, T_{S_1}, A_{S_1}\}$.

- error rate: $ER_{S_1} = 0.1$ – obtained through tests that check for conflicts during the same predefined task completion (i.e. 1 in 10 cases/iterations produced some sort of conflict),
- energy usage: $EU_{S_1} = 0.3$ – acquired through tests that control the energy usage of the tasks (i.e. the service uses more energy than 30% of current maximum),
- transmission delay: $T_{S_1} = 0.4$ – acquired through tests that control the time delay during task data sending and receiving (i.e. the delay in time is longer than 40% of current maximum),
- availability: $A_{S_1} = 0.2$ – obtained through tests that monitor the availability of the service in a period of time (i.e during 24 hours, the service was available and operating for more than 20% of the time).

At this point we also need to define the impact levels and dependencies between those factors and the QoE factors. Because of the fact that every factor has different dependencies which are also influenced by context we assume the Service Provider provides this information. For our case study we defined the following influences INF_{S_1}.

- error rate influences reliability by 0.8 (INF_1),
- error rate influences efficiency by 0.4 (INF_2),

- energy usage influences reliability by 0.3 (INF_3),
- energy usage influences efficiency by 0.2 (INF_4),
- transmission delay influences reliability by 0.9 (INF_5),
- transmission delay influences efficiency by 0.9 (INF_6),
- availability influences reliability by 0.6 (INF_7).

Having these information we can then proceed to calculate the overall influence of QoS and QoP influence towards specific QoE factors seen in step 3.

4.4. Step 3 - QoE evaluation

In this last phase we need to define the QoE factors of the service S_1. The QoE are:

- *pP* – obtained through MOS and divided by 5. The users were asked if they are willing to pay 10 PLN monthly subscription for using the service,
- *rS* – obtained through tests that check for conflicts during task completion by the users. The users had to complete 10 iterations of tasks,
- *time* – measures the time between requesting and receiving a task, acquired through MOS and divided by 5,
- *gV* – acquired by MOS and divided by 5. The users were asked if the GUI elements are visible enough,
- *gU* – obtained by MOS and divided by 5. The users were asked whether the GUI elements are understandable as to what is their purpose,
- *sM* – acquired through MOS and divided by 5. The question was regarding the security method (SSL 3.0) and how do they feel about it,
- *integrity* – acquired by testing the data consistency on the server and client side in 10 iterations,
- *dhM* – same as security method, the question was regarding data handling methods. The service stores private information about the user on an external server (i.e. location),
- *deM* – same as security method, the question was regarding data encryption methods. The data stored by the service are not encrypted.

And the corresponding user acceptance levels towards those QoE factors are provided in the form of vectors in (5-7).

$$QFA = [QFA_{pP}, QFA_{rS}, QFA_{time}, QFA_{gV}, QFA_{gU}, QFA_{sM}, QFA_{integrity}, QFA_{dhM}, QFA_{deM}] \quad (4)$$

$$QFA_{U_1} = [0.6, 0.4, 0.3, 0.7, 1, 0.1, 0.2, 0.7, 0.8] \quad (5)$$

$$QFA_{U_2} = [0.8, 0.9, 0.5, 0.2, 0.3, 0.6, 0.1, 0.4, 0.3] \quad (6)$$

$$QFA_{U_3} = [0.6, 0.2, 0.3, 0.7, 0.4, 0.3, 0.2, 0.7, 0.6] \quad (7)$$

At this point we should also consider the QoS and QoP influence. Which is:

$$QFI^S = [QFI_{pP}, QFI_{rS}, QFI_{time}, QFI_{gV}, QFI_{gU}, QFI_{sM}, QFI_{integrity}, QFI_{dhM}, QFI_{deM}] \quad (8)$$

$$QFI^S = [1, 0.16, 0.15, 1, 1, 1, 1, 1, 1] \quad (9)$$

Note that for calculation in (9) we have to set the QoS and QoP influence value that corresponds to a specific QoE factor to 1 whenever there are no predefined influence definitions. For the rest we sum the multiplication products of QoS/QoP factors with their corresponding impact levels and then divide by their number.

Lastly during this step we need to create the User Profiles of the Users. The users set their own preferences.

$$QFW = [QFW_{pP}, QFW_{rS}, QFW_{time}, QFW_{gV}, QFW_{gU}, QFW_{sM}, QFW_{integrity}, QFW_{dhM}, QFW_{deM}] \quad (10)$$

$$QFW_{U_1} = [0.3, 0.5, 1, 0.1, 0.6, 0.5, 0.4, 0.7, 0.4] \quad (11)$$

$$QFW_{U_2} = [0.5, 0.3, 0.1, 1, 0.5, 0.4, 0.4, 0.3, 0.7] \quad (12)$$

$$QFW_{U_3} = [0.2, 0.4, 0.6, 0.1, 1, 0.5, 1, 0.1, 0.9] \quad (13)$$

Each of the vectors in (11-13) represent the weight values for the corresponding QoE acceptance vectors described in this step.

Finally, we have gathered every parameter that is needed to proceed to the last step of the whole methodology, calculation of the overall QoE level of the service S_1. By means of the formulae (3) we obtain the QoE_{S_1} which is 0.19.

5. Conclusions

QoE is one of the critical components of today's services, especially those with low entropy like video and audio related. In the paper we proposed a new method that allows QoE measurement of a service based on its underlying structure, their influences by QoS and QoP factors [20] and the subjective preferences of the user described through user profiles containing weighs for each factor. We also illustrated the method in practice via a case study describing the measurement process of QoE for an on-line educational platform service. In the future we intend to conduct an experiment which will act as a proof of concept for the proposed method. The presented approach allows to prepare QoE evaluation of IT services in a holistic manner, which is a novel idea in this area.

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Omówienie

Jakość doświadczenia jest jednym z kluczowych komponentów nowoczesnych usług, szczególnie tych, które posiadają niską entropię, jak np. te związane z wideo i audio. W artykule została przedstawiona metoda, umożliwiająca mierzenie poziomu QoE danej usługi, bazująca na: strukturze usługi, oddziaływaniu na czynniki QoS oraz QoP i subiektywnej preferencji użytkownika. Preferencje te są zapisane w profilu użytkowników przez wykorzystanie wag dla każdego z poszczególnych czynników. Wzór (3) przedstawia sposób obliczenia ogólnego poziomu QoE usługi. Dodatkowo działanie metody zostało zilustrowane w praktyce przez opisaną analizę przypadku, która pokazuje proces mierzenia poziomu QoE dla usługi on-line typu platforma edukacyjna. W przyszłości zamierzamy wykonać eksperyment, który będzie stanowił dowód działania metody. Zaprezentowana metoda pozwala na dokonanie ewaluacji poziomu QoE w sposób holistyczny, co stanowi nowe podejście do tego problemu.

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