# QoE Dimensions and QoE Measurement of NGN Services

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***Abstract* — In varying environment such as nowadays packet-based communications, providing NGN (*Next Generation Network*) services with quality as in traditional voice communications to users with high expectations is a great challenge. Therefore, the following aspects of QoE (*Quality of Experience*) should be taken into the consideration: technical parameters, usability, subjective evaluation, expectations, and context. The ability to measure QoE is crucial, because it gathers the contribution of all QoE aspects to the overall level of user experience. Thus, a comprehensive palette of available techniques and approaches for measuring QoE is outlined. This paper seeks to raise questions related to all these aspects in order to reach conclusions about the prospects for development going forward and corresponding implications for QoE.**

***Keywords* — NGN services, QoE dimensions, QoE measurement.**

## I. Introduction

Currently, leading trend and future aim in telecommunications world is seamless integration of existing and new wireless networks, thereby providing mobile users an access to any service, along with reliable and cost effective communication, anytime and anywhere, via any media and access network [1]-[3]. The NGNs (*Next Generation Networks*) are envisioned as platform for realizing the paradigm of providing services with quality as in traditional voice communications, such as ongoing users' session continuity, no service disruption and higher level of users' satisfaction with service quality. Delivering such a paradigm is a challenging task, especially when we consider users' predefined requirements and high expectations. For the user to be satisfied with the experience, expectations must be met.

Given that the user is the one who experiences the resulting performances of networks or services, special attention must be given to QoE (*Quality of Experience*) of the user. There are many definitions of QoE. One of them defines QoE as: "A measure of user performance based on both objective and subjective psychological measures of using an ICT service or product." [4]. Users experience sensations, opinions and perceptions, while interacting with the environment. The characteristics of these experiences determine the overall quality of experience [5]. However, QoE is conceived as a multidimensional concept that consists of both objective (e.g., network-related parameters) and subjective (e.g., user-related parameters) aspects [6]. Therefore, apart from QoS (*Quality of Service*) which is a technical and objective concept, user-related factors, such as availability, cost, fidelity, reliability, usability, and utility have direct impact on users' satisfaction, i.e. QoE. It is often assumed that the growth and optimization of network-related parameters, i.e. QoS, will automatically result in swift adoption of products and services on the consumption side. However, QoS usually has a little influence on a user. It is only a subset of the overall QoE scope. Although higher QoS would result in higher QoE in many cases, fulfilling all traffic QoS parameters will not guarantee high users' QoE. Moreover, it is assumed that products and services that meet users' requirements and expectations and that allow them to have high QoE in their personal context will probably be more successful then products and services that have higher QoS, but failed to meet users' high demands and expectations.

QoE is important for network operators, product manufacturers and NGN service providers. Their ability to measure QoE and to use data about the QoE of nowadays packet-based communication networks is crucial, because it gathers the contribution of network performances and environmental parameters to the overall level of users' satisfaction. There is a need for them to understand the QoE, because products and services may be optimized [7]. Low QoE result in products and services rejection, therefore if QoE is improved, this problem, as well as customer churn could be prevented.

This paper seeks to raise questions related to all these aspects in order to reach conclusions about the prospects for development going forward and corresponding implications for QoE. It is organized as follows: Section II provides classification of wide range of technology-centric and user-centric aspects and metrics of QoE and considers their impact on it. Comprehensive palette of available techniques and approaches for measuring objective and subjective counterparts of QoE is outlined in Section III. Section IV concludes this paper.

## II. QoE Dimensions of NGN Services

QoE doesn't take into account only crucial component, a technology performance in terms of QoS, but also what people can do with that technology, what are their expectations form it, to what degree it meets their expectations, and in what context they use it or intend to. Fig. 1 illustrates multidimensional concept of QoE.

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### A. Technology performance

Technology performance, i.e. traditional QoS approach on QoE, considers factors, such as availability, reliability, quality, effectiveness, latency, etc. on four levels: application/service, server, network, and device. This paper puts an accent on delay caused by mobility and its management, since users' movement (horizontal handover) and migration of communications from one network to another (vertical handover) with session and connection continuity is important requirement in modern communications and it affects users' satisfaction.

When mobile user wants to use NGN service, it has to pass few following steps. Firstly, in order to be granted the access to the network, user has to wait for security procedures, such as authentication, to be performed. Therefore, whenever security implementation is considered, its impact on performance should be investigated, because it increases the time for the user to access the network and disruption of the session during handover. Thus, performing the security procedures especially affects the QoE of NGN services that have stringent requirements in terms of delay.

Then, user experiences additional waiting time while signaling procedures are completed in order to establish the session. Since they affect users' satisfaction directly, it is necessary to consider types of delays, or disruption factors which contribute to signaling delay, and consequently find space for its reduction.

Mobility affects session or connection quality due to disruption, and introduces additional delay due to renewal of security and signaling procedures, which have to be performed at every handover with the aim of continuing the session or communication. Thus, mobility procedures should be completed in order to support minimum handover delay. Namely, handover between nodes can disrupt multimedia communication if packet loss occurs or packet has a long delay. Packet losses, as well as their delays lead to loss of multimedia content and can make communication awkward [8]. By minimizing disruption time, i.e. handover delay, we can reduce users' dissatisfaction with products and services, and provide a communication which is expected to last as in traditional circuit-switched networks [9].

Mobility solutions are engineered differently in different network layers, so mobility management on network layer is performed using MIP (*Mobile Internet Protocol*) protocol [10], on transport layer using mSCTP (*Mobile Stream Control Transmission Protocol*) protocol [11], and on application layer using SIP (*Session Initiation Protocol*) protocol [12]. All these approaches have their advantages and disadvantages that need to be investigated in order to be improved and achieve the optimization of QoE.

### B. Usability

Usability is another key dimension integrated in many QoE definitions, besides QoS. It is approached in terms of users' behavior when using the device or technology, i.e. its efficiency, effectiveness and satisfaction with it. It refers on interaction between man and machine, ease of working, and user friendliness. Actually, it deals with how easy it is for the user to accomplish tasks. If product or service is complicated for use, users will not adopt it and evaluate it with high QoE, regardless that it could be the technology state of the art. Also, users' emotions and feelings when using the product or service are considerably important, but often neglected when usability is considered.

### C. Subjective evaluation

Since QoE has partly subjective character, it is very important to investigate is the technology working good enough in order for user to be satisfied. Therefore, user performs subjective evaluation of: device, network, and application/service. There are many different factors affecting perceived quality. For example, a screen size (mobile terminal vs. plasma TV screen), content (talking heads vs. an action movie), an application type (YouTube video vs. video for medical diagnose purposes), viewing distance (20 centimeters vs. several meters), a user profile (an amateur vs. professional), and many others affect users' subjective perception of certain service. However, certain type of interface can be very simple for one user, while it remains very complex for another. Also, in technical terms, although technology may be performing very well, sometimes that is not efficient enough to satisfy the user or meet users' expectations [13].

### D. Expectations

In order to perform subjective evaluation and to understand users' expectations seen in relation to the quality of the delivered service, we need to have an insight in the users' expectations. For example, with multiple choices of access network as well as choices of service provider, user may be happy with a low-quality voice service if the relative cost is also low. Only when users' expectations are known, technology can be estimated in terms of whether it is working well or sufficient enough for certain user. Therefore, subjective evaluation depends on the level up to which users' expectations are met.

### E. Context

Very imporatant components are contextual aspects that highly influence users' QoE. Context variables can be considered in environmental, personal/social, cultural, and technological context [13]. For example, features like seamless handover and mobility are very important for users' satisfaction in environmental context. Privacy is also important aspect in personal/social context, because users like to ensure that they are well preserved from being exposed or misused by unauthorised parties. Also, one of the major factors in determining users' satisfaction is price and billing. This technological context variable can negatively influence users' QoE if it is high for certain service.

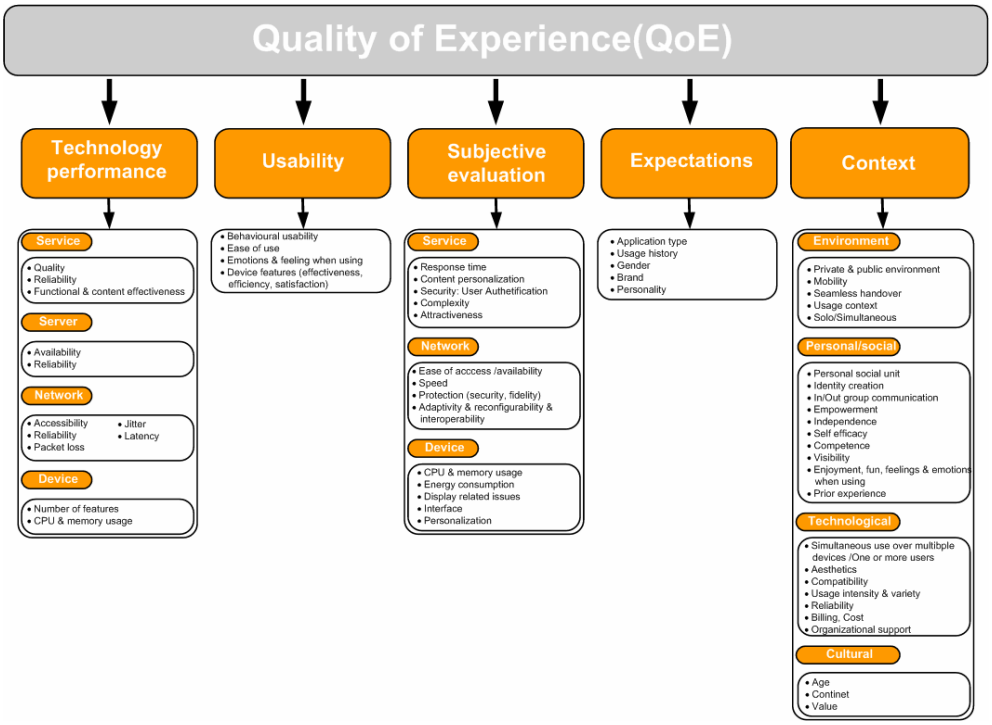


Fig. 1 Multidimensional concept of QoE

## III. QoE Measurement of NGN Services

As shown in previous section, QoE is a multidimensional concept, which is difficult to be defined or measured in a simple unified manner because there are many factors affecting it. For accurate QoE measurement, considering only one or two dimensions is not sufficient. Consequently, QoE should be measured in all its dimensions taking into account as many factors as possible. Since this results in complex QoE metrics for practical use, most of current QoE research activities have focused on specific applications, such as stream audio, video or IPTV (*IP Television*) [14][15]. As QoE gets often technical and QoS-alike interpretation, it is mainly measured in terms of technical metrics. Many authors criticize this approach when stressing the multidimensional character of the concept of users' experience [13]. Measuring the subjective dimensions of experience is often skipped or neglected because of the shorter product/service life cycles, time pressure, budgetary reasons, or simply because of ignorance. This leads to the problem regarding today's QoE measurement practices: no consensus about the methods to measure QoE and a lack of knowledge of the existing methods. For the dimensions that are not measured in the current approach, an overview of existing methods and methodological renewal is required.

There exist subjective and objective assessment methods. Subjective assessment methods are expected to allow researchers to gain the deeper understanding of the subjective dimensions of QoE. Although MOS (*Mean Opinion Score*) is used as a subjective performance measure, it draws on the conversion of the objective quantities into subjective scores. It is an approach that is used for the evaluation of quality parameters by users and by means of standardized scales. For a number of reasons, the use of MOS has been criticized and extended to other subjective measures, such as acceptability measures and (semi-) automated subjective measures [6]. However, considering the complexity and costs associated with subjective performance measures, objective assessment methods are preferred in general.

Objective assessment methods are expected to provide an indication that approximates the rating that would be obtained from subjective assessment methods. The objective measurements can be performed using one of the following models [16]: (1) no-reference model; (2) reduced-reference model; and (3) full-reference model. The most prominent example of a no-reference model is the E-model (ITU-T Rec. G.107), which is used to predict the quality users experience during a voice conversation based on the end-device characteristics and the transport parameters. While the listening quality for speech can be objectively measured by PESQ (*Perceptual Evaluation of Speech Quality*) model (ITU-T Rec. P.862), the standard for objectively measuring audio QoE is PEAQ (*Perceptual Evaluation of Audio Quality*) model (ITU-R BS.1387). Both models are examples of a full-reference model. Like the E-model for speech, a G-model is developed for the QoE prediction of FPS (*First Person Shooter*) games, which are the most investigated ones since they pose the strictest requirements with respect to quality. The standard for video quality measurements covers full-reference (ITU-T Rec. J.144 and ITU-R BT.1683) and reduced-reference (ITU-T Rec. J.249) methods for standard definition TV (*Television*), as well as a full-reference (ITU-T Rec. J.247) and reduced-reference (ITU-T Rec. J.146) for multimedia. However, there are currently no standards covering no-reference methods.

Since the objective assessment methods tend to disregard the subjective character of QoE, several studies, like [6] and [17], have focused on the relation between objective, technical QoE parameters and subjective, user-centric

indicators of QoE from a more holistic and interdisciplinary perspective. Although these studies have tried to relate technical parameters to the concept of perceived QoE, they have been criticized from a more user-oriented perspective for various reasons, such as under-evaluation of the subjective character of QoE [6]. To gain insights into the more subjective dimensions of QoE identified in previous section, the combination of state-of-the-art technical measures and user-oriented measurement techniques should be used. This also implies that the evaluation of QoE should be embedded in an interdisciplinary approach, which refers to multidimensional conceptualization of QoE [13]. The interdisciplinary approach proposed in [6] contains the following steps: (1) preusage user research based on a combination of qualitative and quantitative methods in order to detect the most relevant QoE dimensions and users; (2) preusage translation to find an optimal match between user-indicated QoE dimensions and objective QoE parameters in order to bridge the gap between user/social and technical perspective; (3) monitoring QoS parameters during usage in order to collect the relevant data; (4) postusage questions on the device served as an evaluation of QoE by the test users; (5) postusage comparison of expectations versus the quality of the experience in order to identify and explain differences between expectations and actual experiences. Partitioning QoE measurement approach to these steps enables interdisciplinary collaboration among experts with different backgrounds, such as social researchers, usability experts, and researchers in the field of information and communication technologies.

As can be seen, users are involved throughout the whole QoE measurement process (not only in the evaluation steps), and insight in the users' expectations and requirements serve as a starting point of the measurement process. However, the user involvement must be simple not to disturb users' evaluation. To get the accurate user test measures, the users' time is needed, resulting in a low participation rate. Therefore, balancing between a participation rate and accuracy of the user test measures is one of the open issues in user-centric approach of QoE measurement [18]. Since technology and users' expectation evolve continuously, QoE measurement process should also be flexible and evolve together to encompass the changes. In other words, there is a need for simple and sustainable QoE measurement framework that may be applied to any type of NGN service.

## IV. Conclusion

Rapid growth of NGN service portfolio introduces much wider scope of choice for the end-users. The freedom of choice opens up for a much more complex management of QoE. A significant challenge related to management of QoE is the requirement of multidimensional and interdisciplinary insight into QoE aspects of NGN services. With five dimensions identified in this paper, the intention was to provide a conceptual overview of QoE aspects of NGN services, which cannot be considered as exhaustive on the level of sub-dimensions. Referring to the fact that QoE is subjective matter, not only technology-centric, but also user-centric aspects that may impact the quality of users' experience when using any NGN service are covered. Approaching these QoE aspects from a wide interdisciplinary perspective, this paper provides better understanding of user requirements and expectations needed for management of QoE. Moreover, having these QoE aspects as a starting point for improved QoE measurement, this paper hopefully makes the reality of QoE clearer and provides some new perspectives on QoE.

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