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Center for Quality, Faculty of Engineering, University of Kragujevac

Andreja Samčović

Faculty of Transport and Traffic Engineering, University of Belgrade, Serbia
andrej@sf.bg.ac.rs

ASSURANCE OF QUALITY OF EXPERIENCE AS A FRAMEWORK TOWARD NEXT-GENERATION NETWORKS

Abstract: *This article aims to invoke assurance of Quality of Experience (QoE) as a framework toward next-generation networks. QoE can be viewed as the end-user's perception of the quality. The goal of this paper is to present some major problems of the today's telecommunications networks and how they can be solved by the techniques related to QoE.*
Keywords: *Telecommunications networks, Quality of Service (QoS), Quality of Experience (QoE), Video*

1. INTRODUCTION

Assurance of quality of experience (QoE), that is, service quality as subjectively perceived by the user, is an important challenge facing network operators and service providers in current telecommunication networks. Convergence between fixed and wireless networks as well as within wireless systems using different technologies makes it possible to use a large variety of applications that include surfing the web, sending emails, listening to music, watching movies, playing games, or GPS (Global Positioning System) navigation, on a variety of terminals located in different geographical environments. Customers require high quality telecommunication services regardless of localization and time constrains. In other words, they want to receive any service, anytime, anywhere, and on any device.

In general, these four user requirements motivate the need for convergence from the user point of view. From the network point of view, the situation is more complex. The user perception of the quality is influenced by several elements associated with end-to-end service delivery, namely: network, equipment, data encoding, protocols, terminals, etc. Each of the end-user requirements translates to various technological and business challenges. Accordingly, services must be provided over any medium and networking technology, and by any operator.

It is expected that a variety of services, from low demanding to real-time broadband, will be delivered to the end-user regardless of the type of access network, or end user device. Services must be provided in a multi-domain and multi-operator environment. As a result, various technological challenges must be faced. Moreover, users expect to be able to use a given service continuously while on the move without a noticeable deterioration of service quality.

This paper is organized in the following way: in Section 2 the major problems of today's networks are given, in Section 3 several definitions of QoE are presented, in Section 4 some techniques related to QoE are selected. Section 5 presents QoE with respect to convergence requirements, while conclusions are presented in Section 6.

2. MAJOR PROBLEMS OF TODAY'S NETWORKS

Network operators are confronted with massive network traffic increases while seeking to reduce investment and operating costs for their networks. New service offerings such as video streaming and personalized services led to a steep increase of network traffic [1]. Five main trends can be identified that require more intelligent, adaptive network management mechanisms [2]:

1. *Rich media consumption*. The increasing availability of IPTV (Internet Protocol TeleVision), leads to surges in network traffic. Especially in the early evening hours high network traffic peaks can be observed.

2. Service personalization. Besides traffic neutral service personalization, e.g. personal settings in web platforms, other personalization can induce changes in the network. The latter is valid for Video-on-Demand (VoD) platforms such as Google's YouTube. Instead of broadcasting linear television without responses from users, VoD services require dedicated connections – unicasts – to each user.

3. Time, place and device sovereignty. Smartphones and tablet computers pave the way for independent media offerings of the future. These will allow watching any video content at any time on any different devices. To realize such services, content needs to be streamed over unicasts in fixed and mobile networks.

4. Quality expectations. After years of low-quality video offerings in the web – mostly due to poor Internet connections – end users are becoming increasingly sensible to quality issues. Especially IPTV offerings need to maintain a perceived quality level similar to that of other television transmission technologies to succeed.

5. *Efficiency increases.* The network operators' wish to decrease the degree of overprovisioning, i.e. increase network efficiency. Currently, stable services are assured due to greatly overdimensioned networks. These networks operate at their capacity limit in peak times only. Most of the times resources are unused which is cost intensive and leads to unnecessary high environmental load.

Fibre-to-the-Home (FTTH) or Fibre-to-the-Cabinet (FTTCab) roll-outs will increase network capacity greatly. However, these networks require massive capital expenditures into the infrastructure while postponing the impending problem only. Additionally, fibre networks do not lead to efficiency increases. To the contrary, at the beginning the degree of overprovisioning will increase significantly instead of being reduced [3]. Thus, other possible solutions for these challenges such as Quality of Service (QoS) and Quality of Experience (QoE) are currently subject to research.

3. DEFINITIONS OF QUALITY OF EXPERIENCE

Especially quality sensible services require high-speed broadband Internet connections with real-time, interactivity, security and reliability capabilities. Whereas the term Quality-of-Service is not used consistently in the literature, it usually implies the possibility to differentiate individual services and the possibility to allocate different quality parameters to services [4]. Technically, usually four parameters are used to determine the quality of a data connection: the available bandwidth, delay time, jitter and packet loss. With these parameters, different service classes or priority levels can be created, ranging from level 0 called "*best-effort*", to level 7 called "*layer 2 network control reserved traffic*", with latency and jitter less than 10 ms. However, QoS does not address the subjective end user perception of quality that is harder to measure [5].

The notion of Quality-of-Experience (QoE) is more user-centered than QoS. It aims at linking together the technical parameters described above and the users' perception of quality. Several definitions of QoE exist:

• Mostly used is the definition of ITU-T (International Telecommunication Union) SG12 that describes QoE as "*overall acceptability of an application or service, as perceived subjectively by the end user*" that "*may be influenced by user expectations and context*" [6].

• Lopez et al. describe QoE as "*extension of the traditional QoS in the sense that QoE provides information regarding the delivered services from an end-user point of view*" [7].

• Soldani et al. define QoE as "*how a user perceives the usability of a service when in use – how satisfied he/she is with a service in terms of, e.g., usability, accessibility, retainability and integrity*"[8].

• And rather recently Fiedler et al. defined QoE as a concept that describes "*the degree of delight of the user of a service, influenced by content, network, device, application, user expectations and goals, and context of use*" [9].

All definitions except for the very broad one by Lopez et al. have in common that quality levels are defined by the user's *perception* in addition to measurable network parameters. The user's perception may be influenced by the *network*, the *context* and his/her *expectations*. The extended set of influencing factors can be addressed on very different levels. In the context of QoS, network improvements were mostly developed on the lower OSI (Open Systems Interconnection) levels to improve and control the QoS service parameters. When taking into account user perceptions, improvements need to be realized on higher levels as well, i.e. optimizations up to OSI layer 7 – the service layer – need to be addressed. Table 1 summarizes the three concepts.

4. TECHNIQUES RELATED TO QUALITY OF EXPERIENCE

Several research projects address QoE, ranging from systematic QoE measurements to the development of a set of technologies that aim to improve different aspects from the network to the service layer. The latter found a multitude of possibilities to improve the perceived quality. The following six selected techniques show the range of possibilities that exist exemplarily:

1. *Monitoring and traffic estimation mechanisms*. Allow forecasts of congestion situations and triggering adequate reactions to congestion problems at occurrence.
2. *Scalable video*. Can be used in at least two cases. First, the variety of end user devices can be served with the correct resolution, minimizing CPU load on the devices. Second, downscaling of video in case of traffic peaks allows continuation of streaming instead of complete failures.
3. *Routing, notification and admission control mechanisms*. Increase network efficiency by optimizing link usage, provide technical solutions to trigger reactions in case of service failure, allow notifying end users about current and estimated problems.
4. *Caching*. Caching within the access network, often referred to as microcaching, allows answering similar requests fast and without causing traffic in higher network aggregation levels.
5. *Video streaming based on Mean Opinion Scores* (MOS). Studies found that the Mean Opinion Score fluctuates depending on the kind of the movie despite of the same bit rate, resolution, etc. By implication this means that the perceived quality on a certain level can be achieved with different video parameters, potentially allowing either improving or economizing video streaming services.

6. *Policy-based EPGs*. Electronic Program Guides (EPG) can be improved based on manually or automatically generated user policies. These can be created based on previous user behavior, manually selected preferences etc.

Summarized, QoE improvements are technically possible. It also shows that most QoE improving technologies need to be implemented or supported by the network. Thus, the network operators need to adapt their network accordingly. Whereas the different approaches promise to increase customer satisfaction and increase network efficiency these benefits cannot be expected to cover capital expenditures and operating costs for the network operator. Thus, new revenue streams are necessary to incentivize the adoption of QoE technologies by network operators.

5. QoE WITH RESPECT TO CONVERGENCE REQUIREMENTS

QoS, GoS (Grade of Service) and QoR (Quality of Resilience) describe various intrinsic characteristics of a network while customers' satisfaction with using services is commonly described as QoE. It strongly depends on intrinsic network features and performance, although this relation is not always straightforward. There is no simple mapping between QoS/GoS/QoR parameters and QoE. These relations can be better understood only in the context of particular applications. However, efforts are ongoing towards finding mathematical relationships between QoS parameters and QoE, expressed quantitatively by the mean opinion score (MOS) value. It must be noted that such formulas are derived for a particular application under several assumptions. Provisioning of QoS, GoS and QoR at an appropriate level is crucial for achieving high QoE, however, QoE also depends on many orthogonal factors, as the end-user's device, the environment in which the service is received, and the type of service, which is shown in Figure 1. The orthogonal factors are especially important for voice and video services. For instance, voice quality assessment may be affected by background noise, type of equipment (headphones, speakers), and type of content (music, news, telephone conversation). The rating of video quality is influenced by screen llumination and size (e.g., mobile phone or PDA (Personal Digital Assistant) screen outdoor vs. large LCD (Liquid Cristal Display) TV at home), viewing distance, and content (video call, action movie, ‘‘talking heads’’). User evaluation of a service is also affected by subjective factors including psychological and sociological aspects such as emotions, expectations and experience with similar services, opinions of others, etc. In general, a service with the same network-level QoS/GoS/QoR support might be experienced differently by a user depending on several factors [10].

The above mentioned components influencing QoE, except for the psychological and sociological ones are more or less related to network convergence.

To ensure that customers receive a service with a high QoE – that is they are satisfied with the service – all factors influencing QoE must be taken into account. QoE expectations related to different applications and services translate into differentiated QoS, GoS, and QoR performance offered by the network. There are no mechanisms in place provisioning QoE directly. Instead, in order to achieve a desired QoE level, QoS/GoS/QoR provisioning mechanisms must be selected and designed appropriately. The complete set of solutions necessary to meet various QoE requirements in converged networks should also address issues related to several orthogonal factors, e.g., capabilities of user terminals.

6. CONCLUSION

In this paper, assurance of Quality of Experience (QoE) as a framework toward next-generation networks is studied. In today's ICT-environment, it is no longer sufficient to measure only 'technological' performance or Quality of Service (QoS) since it is not the final goal anymore. The central goal should be to deliver high Quality of Experience (QoE) to the user. During the development of new systems and applications, it will be crucial to gain adequate insight in the user's expectations regarding Quality of Experience, its different components and its relation with technical performance metrics.

In order to achieve this, a multidisciplinary approach is called for, including both technical and user aspects. Those two domains need to be brought together, and concepts as well as methods need to be combined in order to fully understand and improve a product's Quality of Experience. The integrated framework presented in this paper provides a detailed look at the different techniques related to the QoE, from both technical as well as user perspectives.

Growing user expectations related to perceived quality of services accessible anywhere, anytime, on any user device and on any media are setting new challenges for technology developers and service providers. These expectations can only be fulfilled if an appropriate set of metrics reflecting quality of experience is defined and interoperability between different converging networks is assured.

REFERENCES:

[1] Casier, K. et al., "Adoption and pricing: the underestimated elements of a realistic IPTV business case", *IEEE Communications Magazine*, Vol.46, No.8 (2008) 112-118.

[2] Latre, S. et al, "Online estimation of the QoE of progressive download services in multimedia access networks", *Proceedings of the International Conference on Internet Computing*, 2008.

[3] Degrande, N., "Increasing the user perceived quality for IPTV services", *IEEE Communications Magazine*, Vol.46, No.2 (2008) 94-100.

[4] International Telecommunication Union, *ITU-T Recommendation G.1000*, Communications quality of service: a framework and definitions, 2001.

[5] Meddeb, A., "Internet QoS: pieces of the puzzle", *IEEE Communications Magazine*, Vol.48, No.2 (2010) 86-94.

[6] International Telecommunication Union, *ITU-T Recommendation G.1081*, 2007.

[7] Lopez, D. et al, "Adaptive multimedia streaming over IP based on customer oriented metrics", *International Symposium on Computer Networks*, 2006.

[8] Soldani, D., Li, M., Cuny, R., *QoS and QoE Management in UMTS Cellular Systems*, Wiley, 2006.

[9] Fiedler, M., Kilkki K., Reichl, P., *From Quality of Service to Quality of Experience*, Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik, Germany, 2009.

[10] Scholda, P. et al., "Quality of resilience as a network reliability characterization tool", *IEEE Network*, Vol.23, No.2 (2009) 11-19.

Table 1 – Quality concepts, potential improvements and measures

Concept	Description	**Realized on OSI Layers**	Measures
QoE	Extension of QoS understanding with user perceptions, quality optimization up to the service level	Layer 1-7	Network Context Usability User expectations
QoS	Classification into quality classes based on measurable parameters, pricing according to quality classes, quality optimizations on the network level	Layer 1-4	Bandwidth Delay Jitter Packet loss
Best effort Internet	Basic availability of Internet connectivity and services	Layer 1-7	Bandwidth (no assurances)

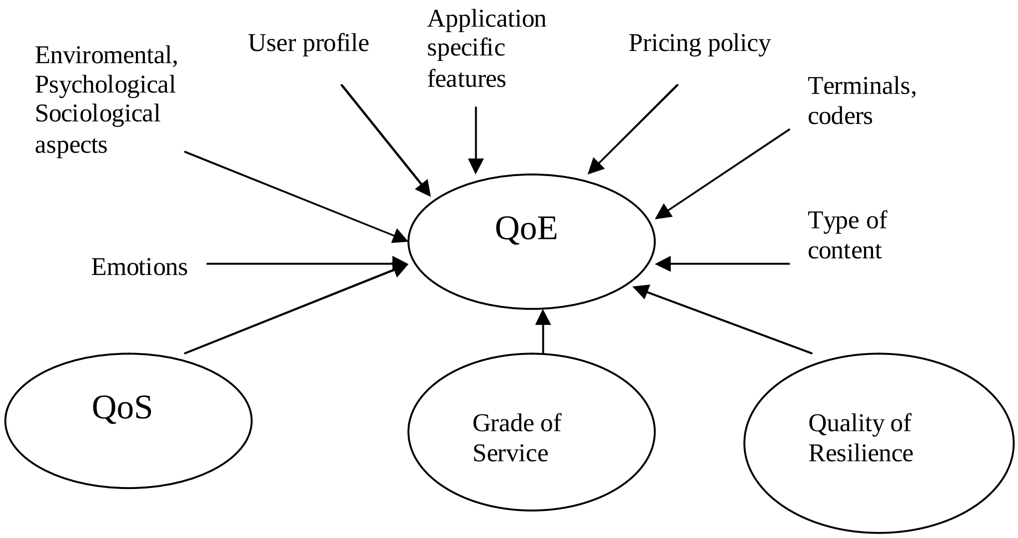

Figure 1. Different factors influencing QoE