

Some Musings on QoE Definitions

Philosophy and Practice

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1 Motivation

Interest in Quality of Experience (QoE) has spiked over the last five years or so. Several large-scale research initiatives have been undertaken under a “QoE flag”, with interesting and useful technical results coming out of them.

Despite all this, a suitable definition for QoE is still lacking. Everyone agrees on some aspects of QoE, such as its subjective nature, but yet a clearly satisfactory definition is missing.

The most commonly used definition as of this writing is probably the one given by the ITU-T SG12¹, which defines it as:

the overall acceptability of an application or service, as perceived subjectively by the end user.

This definition is arguably correct (as in, not wrong), but it does not provide any meaningful insight into what makes QoE interesting, or how it

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¹ITU-T SG 12: Definition of Quality-of-Experience. COM12 - LS 62 - E, TD 109rev2 (PLEN/12), Geneva, Switzerland, 16-25 January 2007.

can be understood, measured, or reasoned about².

Another, better definition was produced in a 2009 Dagstuhl Seminar³, and it states that QoE:

...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.

This definition, while significantly better than the SG12 one, does not for example consider the temporal aspects of QoE (which can be both short- and long-term). It also has a purely hedonistic focus (*degree of delight*), hence not considering utility-related aspects of the experience.

1.1 What is the Problem?

In my opinion, the problem with the current definitions is that they are better suited for philosophers than for practitioners of the art, whereas most of the people involved in QoE research are in fact practitioners, who need workable definitions in order to do their work.

Working “on QoE”, for the most part, refers in practice to devising tools and techniques for measuring QoE, improving QoE, and charging for QoE. This, however, is hard to do without a clear understanding of what QoE *means* for each user (or user group), concrete application and usage context.

Until very recently, most research on QoE has had a very clear focus on media-oriented applications. While QoE has been studied in other domains, such as web browsing, the core of the currently available knowledge in the domain is focused on audio, voice, image and video quality assessment. These applications have nice features from a QoE research point of view. Namely, it is possible to *see* or *hear* the quality level of a given service, and the QoE tends to be defined around this *perceptual quality*, which we

²And given the nature of SG12, the definition itself is geared towards audio-visual services.

³Dagstuhl Seminar - Quality of Experience: From User Perception to Instrumental Metrics, 1-5 May 2009

can't properly define, yet we can measure⁴. Furthermore, the perceptual quality is dependent on a few factors (such as encoding, error concealment, and network QoS) that are very well understood. This allows for relatively simple assessment of the perceived quality, and hence good estimations of QoE⁵.

We should note, however, that the definitions needed are not specific to media services. Indeed, a plethora of other services exist, for which QoE measurements, improvements and pricing schemes are needed. With the continuing growth of Cloud-based services, the issue becomes even more pressing.

2 Towards Workable QoE Definitions

It is widely agreed on that QoE is specific to the user and to the service or application under consideration, among other things. To some extent, the existing definitions (in particular the Dagstuhl one) consider this. For a given user, in a given context, the experience of using two different applications may vary wildly (a trivial example of this would be instant messaging vs. video streaming on a mobile connection). Likewise, for a given application in a given usage context, the quality will vary for different users or user groups. This pattern repeats itself, likely with different levels of impact, each time that services, users, context, intent of use, and other factors are considered in isolation.

This tells us that any definition of QoE will have to deal with all those factors in order to be complete. It also hints at the possible variation of each of those factors' impact on the QoE for each of their possible combinations.

For example, if we were to compare the quality experienced by an over-worked office clerk using a badly-designed Cloud-based ERP⁶ system over

⁴Or more correctly, which we define by its own measure. What is good voice quality, you ask? Why, it's that which scores above 3 in a 5-point MOS scale, of course! And no, saying that toll quality corresponds to the quality in a POTS system is not a good definition, as it is still circular.

⁵This doesn't hold up so well when the influence of the media content on the QoE is considered, though.

⁶Enterprise Resource Planning

a congested Internet connection with that of a teenager on holidays, watching his favorite show streamed in HD over a fast connection with no impairments, we would probably have to say that the problem is ill-defined. Yet, we are talking about QoE in both cases, as if it were a single concept. The currently available definitions, however, fail to capture what quality actually *means* for those users in such different contexts.

To me, at least, this suggests the need for domain- and context-specific definitions of what quality means. Do we need a generic definition of QoE? We certainly do. Is it enough? It most certainly is not. A generic definition of QoE should act as a template, or meta-definition of what QoE is, which should then be specialized to specific application domains, usage contexts, usage intents, user profiles, and societal contexts in order to create concrete definitions of what QoE means in the case being considered.

Such a meta-definition could stay at a high level of abstraction, but define all the aspects that concrete definitions of QoE need to consider in order to be workable. As an example of a high-level QoE definition, we could say that QoE is

the user's subjective assessment, be it qualitative or quantitative, of the degree of fulfillment of his or her expectations with respect to the utility and / or enjoyment derived from the use of a certain service or application, over a given period of time, for well-defined usage intent and context, and considering the user's own psychological and socio-economic context.

From this high-level meta-definition, a concrete definition could then be narrowed by application domain, by user profiles, by usage context, and so on.

2.1 Components of QoE

Let us look at the different components of the meta-definition given above (and let us remember that there are probably more that I failed to consider!).

2.1.1 Subjectivity

We consider the user's own perception of the fulfillment of *his* or *her* expectations. These expectations, subjective by definition, are heavily influenced by previous instances of use of a given service or type of service⁷, and any promises, either implicit or explicit made about the service and its performance, be this due to marketing efforts by the service provider or by second-hand experiences and opinions referred to by other users, or society at large. The user's own state of mind, as well as the context in which the service is used also contribute to the definition of the user's expectations.

2.1.2 Expectations

As mentioned above, the user's expectations about the performance of a service can be influenced, or even defined, by his or her previous interactions with it, by third-party opinions and tales of previous interactions, and the intended usage of the service, as well as by societal factors both cultural and socio-economic.

2.1.3 Assessment

A key component of QoE is the actual evaluation of the service by the user. It is likely that this evaluation is mostly subconscious and both qualitative and quantitative in nature. The qualitative component of the assessment is probably stronger than the quantitative one⁸. However, it is the case that a user can compare his or her experiences and provide an (at least partial) ordering for their quality; hence there is also a quantitative component inherent to QoE.

2.1.4 Utility and Enjoyment

It is the case that most (if not all) services exist for a concrete purpose (or possibly several). Users use the service purposefully, and derive enjoyment

⁷We'll henceforth refer to services and applications interchangeably, unless noted.

⁸Cf. T. Ebrahimi, "Quality of Multimedia Experience: Past, Present and Future", in Proceedings of ACM MM'09.

from them, or use them to satisfy certain needs. Services provide, therefore, both utility and enjoyment (which are orthogonal, and measured in scales that can include negative values in either dimension). Users assess these factors, and compare them to their expectations regarding the service.

2.1.5 Service or Application

Probably the largest single factor defining QoE will be the service in question. All the technical aspects of the service performance might contribute to the quality experienced by the user. The type of service itself will also greatly contribute to QoE, as will other factors such as content (where applicable), intended use, etc.

There are certain characteristics of a service which contribute to QoE but are not applicable to all services, and hence cannot be properly considered in a high-level meta-definition of QoE. A clear example of this is the case of content when considering media services. Some users might be provided with a high-definition, 3D, carefully encoded and flawlessly streamed football match, played out on a 60-inch AMOLED display and still be bored to tears (hence, deriving no enjoyment), whereas they might have an excellent experience watching cat videos on YouTube on a mobile phone. In this case, the content will have considerable weight on QoE, and yet in other services, it does not even make sense to speak of content (e.g. a code-hosting service, where there are many issues relating to QoE, but no actual content dependencies).

2.1.6 Usage Context

Context is a tricky term to use, as it can encompass basically everything related to the user's use of the service but, alas, there seems to be no way of escaping it. Examples of context can be whether the service is used at home or at work, or in emergency situations as opposed to in a relaxed setting. The devices used to access the service are also part of the context. The cost of using the service is another significant component of the context. Whether the service is free or paid (and in this case, how much it costs) has a strong

impact on the user's expectations about it, and what quality levels he or she will find satisfactory.

Several very good results have been obtained concerning the impact of usage context for media services QoE (e.g. lab vs. real-life settings^{9, 10}), but they still need to use a rather restricted definition of context, as it is probably not feasible to consider all possible context-related factors.

The following three points (about intent, the user's psychology and socio-economic aspects) deserve their own treatment, but they remain parts of the usage context.

- Intent

The intended use of the service has an impact on the users' expectations and requirements about its performance and quality. A service, such as casual gaming, which is used to spend idle time will not be assessed in the same way as a high-end tele-presence service used to finalize a large deal with a business partner overseas. The degree to which the service in question fulfills its intended use is also likely to have a big impact on QoE.

- User's Psychology

The user's past experiences, their current emotional state, and their personality can all influence their perception of what the QoE of a given service is, and how it is affected by different factors. In practice, it is likely impossible to sufficiently understand the user's psychological context so as to accurately assess its effects on QoE. It should be possible, however, to use certain characteristics of the users' psychology to establish user profiles, into which users could be classified. These profiles might be useful in understanding QoE.

⁹Cf. work by S. Jumisko-Pyykkö et al., for example: "Framing the Context of Use for Mobile HCI", Intl. Journal of Mobile HCI, 2(4), pp. 1-28. Also, "A Hybrid Methods for Quality Evaluation in the Context of Use for Mobile (3D) Television", Intl. Journal of MM Tools and Appl, special issue on Mobile Media Delivery.

¹⁰Cf. work by K. de Moor et al., for example in De Pessemier, T., De Moor, K. et al. "Exploring the Acceptability of the Audiovisual Quality for a Mobile Video Session Based on Objectively Measured Parameters", in Proceedings of QoMEX'11.

- Socio-economic Factors

Another important context aspect of QoE relates to the socio-economic factors around the user or groups of users. These affect not only user expectations, but other factors as well (e.g. for media services, the effect of different content types on QoE can vary between different cultures, or different economic strata).

2.1.7 Temporal Aspects

The use of a service is not an instantaneous event, but instead it takes place over a period of time. More precisely, we can consider different time scales on which the user experiences the service. We can identify at least two such scales, one related to a concrete instance of using the service (*session scale*), and another scale related to long-term use of the service, which affects the user's expectations for future sessions (*historic scale*). The quality experienced by the user can vary in both of these scales. For example, there are well-known results about overall perception of quality in media services¹¹ and their relation to the times at which impairments occur in the session scale. There are also new results related to historic scale temporal effects on QoE in non-media domains¹².

3 QoE in Practice

As discussed above, the sheer number of considerations needed to fully understand QoE, added to the fact that some of them are hard, if not outright impossible to fully comprehend, make that understanding of QoE a sizable challenge.

The question becomes then, how do we

- define what QoE means in concrete cases, and
- manage to do something meaningful with that definition.

¹¹E.g. recency effect in VoIP.

¹²Cf. work by T. Hoßfeld et al. "The memory effect and its implications on web QoE modeling", in Proceedings of ITC'11, for example.

3.1 Practical Considerations

It seems clear to me that several considerations should be taken into account when working in our understanding of QoE, to wit:

- it requires a multi-disciplinary approach
- it requires an iterative, evolving approach
- it is likely that (for the foreseeable future), our understanding will be dominated by technical issues related to the service, and some limited issues related to the user and usage context.

3.1.1 Multi-Disciplinary Approach

Given the large scope of issues to be considered, ranging from the very technical aspects of service performance to the socio-economic context of the users, it is unlikely that a single specialty can cover them all with sufficient depth. In this respect, there has been a positive trend in QoE research over the last few years, with experts in HCI, sociologists, psychologists and people from other non-technology oriented fields becoming involved.

3.1.2 Iteration and Evolution

QoE is a complex problem, and complex problems are often best solved by attacking the easy parts first, learning from those, and then moving on to the harder parts, which will by then hopefully be slightly easier. Then, with a better understanding of the problem and possibly basic solution, we can revisit the whole thing again in search of better and more elegant solutions. This has been the case in the field of perceptual quality assessment for media services, and there's no apparent reason why it cannot be applied to QoE at a more general level.

3.1.3 Dominance of the Technical Aspects

QoE has so far been a field dominated by technologists, and we tend to do best inside of our comfort zone. We understand what makes the services

work, we understand to some degree how users perceive the functioning of these services, and we further our understanding from what we currently know. Recently we have received the much needed help from experts in other fields, who bring their own understanding. We now have some ideas about psychometric approaches to measuring quality, we have a better understanding of some issues related to usage context, etc., but the core of QoE research today is still largely dedicated to technical issues.

This is not necessarily a problem *per se*, as many QoE-related problems are related to service performance and its optimization. We can certainly hope that as we gain a better understanding of the non-technical issues surrounding QoE, the accuracy of our assessment techniques and the impact of our optimizations will increase.

3.2 From Generality to Specificity

Having understood the components that make up QoE (or at least some of them), and considering our strengths and weaknesses with respect to them, how can we move from a meta-definition of quality to a concrete understanding of it?

I propose that we start by considering the service (or type of service). The technical aspects are, as discussed, our strong point today. What objective notions of performance can we identify in the service? How can we quantify them?

Once the technical aspects of the service are understood, we can move (with the help of suitable experts) to understanding what the users' expectations will be based on. Are the users experienced, or is it a new service? How long has the typical user used the service? Do we need to focus on utility, or on enjoyment, or both? How can we define scales (qualitative or quantitative) for them in the context of the service studied? What is the purpose of the service? Is it for private use or work? Is it free? Do the users expect to earn something out of it? How does all this relate to the technical issues that we've identified and are able to measure?

Having understood what we can expect the users to expect, we can focus on the users themselves. What do we know about the users? What are their

cultural and social backgrounds, and how do they relate to the service in question? Among the different possible user profiles, are there significant differences in that which relates to the service being considered? Do we have access to any extra information about individual users of the service? Can we use that somehow?

By answering all these (and likely many more) questions for a given service, I believe we can gain an actual, if basic, understanding of what quality means in the concrete case under consideration. With a basic understanding of QoE, we can repeat the process, looking for issues we might have missed, or better explanations for the issues we've learned, and iterate on each component of QoE until we reach a suitable working definition of what QoE means.

4 Conclusions

In this essay I have (clearly, I hope) summarized what I believe are important issues in the current state of QoE research, namely, why the existing, too-general QoE definitions are not sufficient to understand QoE, and how this problem might be solved. I advocate creating, from a high-level definition of QoE, specialized QoE definitions for different services, user profiles and usage contexts which convey what QoE actually *means* under those considerations.

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