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Quality of Experience in Communications Ecosystem

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Abstract: Communications ecosystem covers a huge area from technical issues to business models and human behaviour. Due to this extreme diversity various societies need to discuss with each other, each of them using their own language. Engineers talk about network performance and quality of service, business people talk about average revenue per user and customer churn while behavioural scientists talk about happiness and experiences. Thus, everyone who wants to understand, or even analyze, the whole ecosystem, has to deal with all these diverse issues. In addition to the apparent communication problems, the main challenges of ecosystem analysis are to realistically model human behaviour, and to efficiently combine the models developed for different domains. A central concept when solving these problems is quality of experience (QoE). This paper sheds light on the role of QoE by means of a common framework that covers the whole communications ecosystem. Additionally, a research agenda for a holistic ecosystem analysis is outlined.

Keywords: Quality of experience, quality of service, happiness, business objective, holistic, modelling, ecosystem, analysis
Category: H.1.0

1 Introduction

Quality has a strong positive connotation also when it is used in a seemingly neutral context. For instance, if some quality of service mechanisms is added to a network, it is easy to assume that customers will automatically get better service. In reality, QoS does not necessarily imply that the quality perceived by customers would be improved at all. The current Internet with its burgeoning set of services clearly demonstrates that the user experience is more important than any technical mechanisms used inside the network. An objective of this paper is to provide a solid basis to consider the effects of technical performance for end-users and business players. To achieve that goal we need to build an extensive framework with clearly defined concepts. Two key concepts in this endeavour are quality of service (QoS) and quality of experience (QoE).

Traditionally, QoS is used as an acronym primarily in a technical context. In 1999, when an almost passionate effort to incorporate QoS into Internet took place at IETF (Internet Engineering Task Force), I wrote the following definition: QoS is a set of attributes that can be used to define the network's capability to meet the requirements of users and applications (see the glossary in [Kilkki 99]). Now I am inclined to remove users from that definition and keep QoS purely as a technical concept that is used to facilitate the interactions between applications and network services. From this perspective, it is quite meaningless to say that the goal of network operations is high QoS (a similar statement would be to claim that the purpose of life

is to speak perfect English, or whatsoever language you prefer). Thus in a technical context, a more neutral term than *quality* of service could be a better choice (for instance, a set of service properties). However, due to the established use of QoS, it is not reasonable to assume that the term itself will be changed.

The choice to limit the usage of QoS means that we need another concept to describe and manage the interactions between users and applications. As a first approach, quality of experience may serve that purpose, as it naturally refers to the human side of the service provision and consumption. As a result we obtain a tentative picture of three modules and the basic relationships between them as depicted in Figure 1.

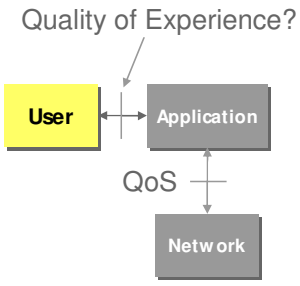

Figure 1: Relationship between user, application and network.

QoS covers the concepts, parameters and methods needed to manage the interactions between applications, typically running in end-user terminals and in network nodes managed by network operators. QoS parameters include bit rates, delay properties, and packet loss rates. It is sometimes thought that each application defines what it requires (using the available QoS parameters) and then the responsibility of the network is to satisfy those needs. Although this is somehow an attractive idea, it also is a very questionable idea if we consider the primary purpose of any commercial network. From a network operator viewpoint network is a tool to make profitable business, or alternatively, to realize some other non-technical goal, like education or research. Therefore, it is reasonable for the operator to perform any QoS action if and only if the action supports the whole business of the network operator. This issue about the general feasibility of QoS is discussed more in [Kilkki 05].

The business of network operator is highly dependent on customer satisfaction. But who is the customer of a network operator? In a current business ecosystem, there often exists a separate service provider that takes care of those persons that finally fund the whole ecosystem. In this framework we call those persons customers, although we need to be aware of the fact that there are various customer-client relationships in the ecosystem. As a result, we obtain a model with six modules: user, application, network, network operator, service provider, and customer.

An obvious question related to this model is what is the relationship between a customer and a user? From modelling viewpoint, the answer is that there are two distinctly different sets of action to be modelled. First, a person makes a decision

about purchasing a product, for instance, a service package offered by a telecom service provider. Secondly, the person makes a series of decision how much and in which way she will use the selected product. Apparently, the models to predict the behaviour of customers and the behaviour of users differ from each other. Still, it is obvious that there is a strong link between the user and the customer of a certain product; often they are the same person, sometimes they are separate persons, for instance, parent and child, or employer and employee. In any case, the main motivation of purchasing a product lies in the future use of the product.

One of the key factors when making a purchasing decision is the quality of experiences obtained from similar products in the past. We may even argue that people above all want to become happier by making all kinds of everyday decision, for instance, when selecting a service. Thus we are able close the cap between user and customer by adding one more module in the picture, the person itself, with all the needs she or he has. The result is illustrated in Figure 2. The needs and capabilities of the person form the basis for understanding and modelling the behaviour of the person both as a customer and as a user of the product.

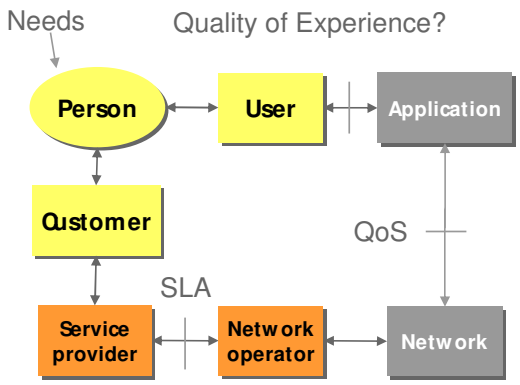

Figure 2: Framework for analyzing communications ecosystem.

Similar approaches as the above framework can be found in literature, see e.g., Figure 1.2 in [Muhammad 06], Figure 2 in [Reichl 07], or Figure 2 in [Van Moorsel 01]. From a modelling viewpoint the framework depicted in Figure 2 provides two important features: firstly, the distinction between user and customer roles, and secondly, the possibility of concretely analyzing the whole ecosystem. Note that the development of the framework is related to an extensive modelling effort, see e.g., [Pohjola 06] and [Kilkki 07]. With a complete model it is possible to assess extremely complex issues. Any service provider would be interested in knowing of what would be the total effect of changing the quality of network service, for instance, the coverage or capacity of a radio access network. That kind of analysis has to include all the modules of the framework, because the benefits of improved quality are achieved by users while the cost of the improved quality is paid primarily by the network operator.

Even when a research problem seems to be limited to one specific domain, it is necessary to understand the general framework. In the first place, we need to apply a terminology that respects the nature of each domain; it is equally misleading to use a technical term in the human domain (e.g., bit rate is not a part of human experience) as to use a human term in the technical domain (e.g., network nodes do not have any opinion about fairness). Therefore, we need a framework that provides efficient conversions from technical parameters to human experience (e.g., how users experience fairness in case of different bit rates).

In this paper we concentrate on the terminology and the structure of the proposed framework. Section 2 clarifies the meaning and task of quality of experience compared to other popular terms in the communications ecosystem. To demonstrate the limitedness of the scope of current technical research Section 3 provides a concise study about the popularity of some key terms in technical papers. Furthermore, we propose a terminology based on the framework presented in Figure 2. The final section provides preliminary thoughts about a new research community that would be responsible for developing a concrete framework that enables an efficient scientific research covering the whole communication ecosystem.

2 Quality of experience

In the previous section we built a framework for communications ecosystem. The framework can now be used to define the key term of this paper, quality of experience. Because our life is a series of experiences related to numerous roles, it is somewhat questionable to limit the concept of quality of experience to any specific role, like user or customer. Hence, it might be better to reserve QoE for the whole person with fundamental needs.

Various definitions for QoE have been proposed in literature. For instance, Wikipedia [Wikipedia 07] gives the following description: "In business terminology QoE is also known as "Quality of User Experience," and is a subjective measure of a customer's experiences with a vendor." International Telecommunication Union [ITU-T 07] applies the following definition for QoE: The overall acceptability of an application or service, as perceived subjectively by the end-user. Muhammad et al. [Muhammad 06] describes the difference between QoE and QoS as follows: the aim of the network and services should be to achieve the maximum user rating (QoE), while network quality (QoS) is the main building block for reaching that goal effectively. Li-yuan et al. give the following description [Li-yuan 06]: “The function of quality of experience (QoE) evaluation includes two aspects: to monitor the experience of user on-line, then to control and justify the service based on the QoE to ensure that the quality of service can highly meet the requirements of the user.” According to Lopez et al. quality of experience has been defined as an extension of the traditional quality of service [Lopez 06]. It should be noticed that Figure 1 illustrates the perspective on QoE in all these papers.

Although the above definitions are quite reasonable, they still tend to bind QoE to the interface between user and application. In this paper we look for a more general definition. Thus let us start with the fundamental meaning of the key words. Collins dictionary [Collins 07] gives the following definitions:

- *Experience* is direct personal participation or observation; actual knowledge or contact.
- *Quality* is the basic character or nature of something.

As a result, *quality of experience* could be defined as the basic character or nature of direct personal participation or observation. This definition is obviously generic enough to cover all relevant cases—it may even appear too generic. Therefore when dealing with specific roles, like user or customer, we need an additional qualifier. The proposal of this paper is to apply the following practice for making acronyms:

- QoE = quality of experience
- QoUE = quality of user experience
- QoCE = quality of customer experience

Similarly, QoSE may mean quality of social experience. In all cases, each specific experience is related to a role, that is, how something is experienced in that particular role. Another important question is what is the code (or language) used between the role and its environment including other roles, domains, and scientific disciplines. We also shall keep in mind that quality of experience is an established concept in philosophy and psychology, see e.g. [Harman 90] and [LeFevre 88]. Therefore, when discussing with specialists in other disciplines, quality of experience always has a general meaning.

Because quality of experience is something that is created in our mind, we shall not bluntly equate it with any formal parameters used to describe the "quantity" of experience. We may even argue that parameters are always quantitative rather than qualitative (see e.g. [Talbott 07]). From this perspective, quality of service, as it is used nowadays, should rather be quantity of service because QoS parameters describe quantifiable aspects of the service, like packet losses and bit rates. Even more clearly, true experience is something that eludes any quantification effort. Nevertheless, because in a formal model everything needs to be presented numerically, we also need to have QoUE and QoCE parameters. But those parameters are inevitably model-specific and cannot ever embrace all aspects of our experiences. Thus the proposal of this paper is to keep quality of experience as a generic term that is used only when our experiences are considered generally, for instance, when we compare the experiences of different roles.

3 Quality of experience as a part of communications ecosystem

QoE plays an important role in the whole communications ecosystem. How does it associate with other concepts in the ecosystem? To answer this question, we need to consider the codes applied between different parts of the ecosystem. At the interface between customer and service provider two key parameters are average revenue per user (ARPU) and customer churn. From modelling viewpoint the task of customer module is to convert QoE to parameters that describe the concrete behaviour of customers. Are there any usable models available for that purpose? We may study the popularity of this research topic by using the database maintained by the Institute of Electrical and Electronics Engineers (IEEE) that includes over 1.6 million articles [IEEE 07]. As an interesting detail, the first document in the database that mentions "average revenue per user" or ARPU in its abstract was published 2003, and even that

[Tsujimura 03] was not a scientific paper but a quest speech. Thus, the first formal paper mentioning ARPU in an IEEE abstract [Adesemowo 04] was published as late as in October 2004. This is a lucid indication about the narrow scope of technical papers.

One obvious parameter to be used between user and application is Mean Opinion Score (MOS). Moreover, anyone who profoundly considers the fundamental reasons for spending time and money with communication services, likely mentions Maslow's hierarchy of needs. Finally, a paper dealing with the business part of the ecosystem probably mentions business objective. Table 1 summarizes the popularity of these terms in the abstracts of papers in IEEE database. The term *network* can be used as a baseline that determines the overall amount of relevant papers.

Term	1996-98	1999-2001	2002-04	2005-07*
Network	20397	23420	33229	43187
Quality of service	1025	1585	2362	2627
Network performance	250	281	430	575
Service level agreement	1	39	116	204
Mean opinion score	28	36	58	52
Business objective	7	13	7	24
Quality of experience	2	2	6	16
Customer churn	0	2	4	5
Average revenue per user	0	0	3	4
Hierarchy of needs	0	0	1	3

Table 1: Terms appearing in the abstracts of IEEE papers
(statistics by 26 October 2007)*

The popularity of the terms service level agreement (SLA), business objective, and quality of experience seems to be increasing. However, the numbers are so small that we cannot make strong conclusions except in the case of SLA; SLA definitely is now much more popular than ten years ago. References to experiences are still very rare when compared to quality of service. In the whole IEEE database, one paper has mentioned "quality of user experience" [Chu 04], whereas no paper so far has mentioned the term "quality of customer experience" in abstract. A recent paper [Reichl 07] proposes another term, quality of design, to handle the same issues that are covered by quality of user experience in our framework. Regardless of the scarcity of QoE in the IEEE database, we may still argue that quality of experience is now the new 'magical word', as De Marez et al. have expressed it in a recent paper with 66 references [De Marez 07].

In some cases, particularly when the customer is an enterprise instead of a consumer, a natural approach is to use SLAs between service providers and customers. Note, however, that then the customer is a business player, not an individual person. It is very questionable to assume that a major part of the interactions between an ordinary consumer and a service provider could be managed by formal SLAs, because individual persons primarily want to obtain experiences, not measurable benefits. The same remark is valid as well with the interface between user

and application: very few users are interested in bit rates or delays. Still, some part of the contract between customer and service provider is usually formalized—but who does read the small print anyway? In reality the main language used by service providers towards customers is that of marketing.

Customers' "language" towards providers consists of concrete actions, like purchasing a product or changing the service provider. In addition, customers may complain about poor service, but that is a discussion service providers are eager to avoid. Then if we consider the term QoS at the interface between provider and customer, customers tend to response "yes, of course, we want quality of service". This positive customer response does not, however, indicate that QoS is actually needed between applications and network; the same word in two different languages may mean essentially different things.

The interface between business and technology is somewhat tricky but still manageable. There is a huge amount of network management standards to be utilized in that interface. As a result we obtain the basic terminology presented in Figure 3.

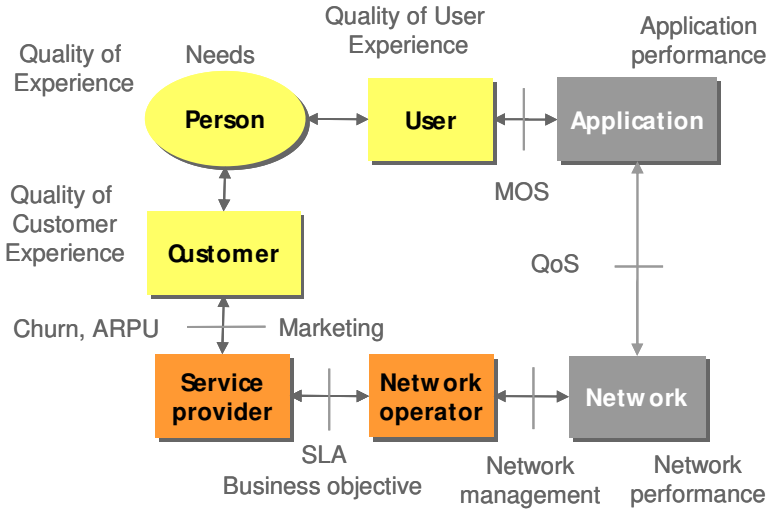

Figure 3: Key terms in communications ecosystem.

As a summary, each domain has its own, special terminology, language and way of thinking and those cannot be directly applied in other domains. Persons are not machines nor are they business players when using communication services. As a generic result, we have to respect the natural language of each domain (human, business, technical), while we need to very carefully considering how the interactions between the domains should be arranged. If, as proposed in this essay, QoE belongs to the core of the human domain, it shall not be used in other parts of the model. This also means that we need to use other concepts than QoE at the interfaces between human and technical domains, and between human and business domains.

4 Further work

How could we, as a scientific community, proceed with this intricate matter of analyzing communications ecosystem and quality of experience? We can identify two main challenges. Firstly, even though behavioural psychology has a long tradition, the area of human behaviour requires a lot of concrete studies and modelling effort before we are able to make any concrete analysis to support business decisions. Secondly, we need to establish extensive research effort that covers the whole ecosystem, not only specific areas.

As to the first issue of human behaviour, the framework introduced in this paper includes two interfaces located inside the human domain, between user and person, and between customer and person. Because in reality those interfaces lie inside our brain, it is not reasonable to standardize them. Still, in an analytical model we have to define both what is happening inside the modules and what parameters are used at the interfaces. In this field, some valuable models are available. Maslow's need of hierarchy is a feasible starting point to define the fundamental needs we all have [Maslow 62]. Richard Layard has made outstanding studies about happiness [Layard 05]. Prospect theory developed by Kahneman and Tversky can be used to assess how the real-world outcome, e.g. loosing three euros, affects our feelings and behaviour [Kahneman 79], [Tversky 92]. Marc Hassenzahl has made noteworthy studies in the area of evaluating user experience [Hassenzahl 06a, 06b]. We also have made research on user experience and behaviour, see [Pohjola 06]. Yet, a vast research effort is needed to build efficient models about human behaviour both in the user role and in the customer role.

The popularity of a term seems to fall exponentially as a function of its distance from QoS, if the popularity is measured as the commonness of the term in IEEE papers. In a way, this dependency is natural as IEEE is an engineering society. However, the almost total absence of many terms which are essential when considering the real purpose of the whole system is conspicuous. For instance, in the IEEE database there is not a single abstract in which QoS is mentioned together with happiness, joy or pleasure. Maybe the goal of QoS is something else; still for most of us happiness would be the ultimate justification for using and paying for services. Thus, we need, in addition to all specific studies, a truly holistic research that is able to provide justified conclusions about effects of specific actions on the whole ecosystem. In practice, we need to establish an own research community to consider the big picture covering the whole ecosystem. This community shall develop its own methods, tools and even a language that makes it possible to successfully discuss with all the specialists of other areas.

Anyone who tries to sincerely take a holistic approach that embraces human, economic and technical domains will encounter severe communication problems because the corresponding research communities use fundamentally different languages. Besides, there are even more than three societies related to a holistic approach, most notably mathematicians that often speak a language that is incomprehensible for others. The worst scenario is that the new holistic community will establish an isolated research area. This is a serious problem that needs to be solved somehow; otherwise any holistic ecosystem research is deemed to be rejected by the authors of other domains or societies. Niklas Luhmann's writings about social

systems and communication [Luhmann 89, 95] provide a solid basis for understanding the unavoidable problems when different domains interact with each other. The communication problem is so central that everyone doing research on the whole ecosystem has to be aware of the issue and needs efficient instruments for solving the problem. You may start with a brief essay written by Dustin Kidd [Kidd 99] that nicely demonstrates the applicability of Luhmann theories to any area of human activity. Note particularly that the topic discussed in the essay is the most powerful driving force for all human activities including communications.

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