09192 Executive Summary

From Quality of Service to Quality of Experience
— Dagstuhl Seminar —

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Abstract. From May 05 to May 08, 2009, the Dagstuhl Seminar 09192 "From Quality of Service to Quality of Experience " was held in Schloss Dagstuhl – Leibniz Center for Informatics. The notion of *Quality of Service* has served as a central research topic in communication networks for more than a decade, however, usually starting from a rather technical view on service quality. Therefore, recently the notion of *Quality of Experience* has emerged, redirecting the focus towards the end user and trying to quantify her subjective experience gained from using a service. The goal of this Dagstuhl seminar is to discuss this important paradigm shift in an interdisciplinary international community of key researchers, to investigate innovative research methodologies and to deepen the scientific understanding of this topic which is highly relevant for the economic success of future mobile and fixed communication services.

Keywords. Quality of Service, Quality of Experience, perceptual service quality, usability, content, service pricing

1 Motivation

For at least a decade, *Quality of Service* (QoS) has been one of the dominating research topics in the area of communication networks. Whereas the Internet originally has been conceived as a best-effort network, the introduction of QoS architectures like Integrated Services or Differentiated Services was supposed to pave the way for high-quality real-time services like Voice-over-IP or video streaming and thus to increase the competitiveness of packet-based TCP/IP networks.

Originally, the notion of end-to-end QoS was, according e.g. to ITU-T, aiming at the "degree of satisfaction of a user of the service" [1]. In the course of time,

however, the dominating research perspective on QoS has become more and more a technical one, focussing on monitoring and improving network performance parameters like packet loss rate, delay or jitter. But end users usually are not bothered at all about technical performance; what they really care about is the experience they are able to obtain, and the Internet provided, even without any QoS mechanisms, a lot of new experiences, like web-browsing, e-mail and search engines.

Based on this insight, we have recently observed an important paradigm shift as far as service quality is concerned. While the prior "grand challenges" of QoS research have begun to disappear from the research agenda, e.g. due to large-scale overprovisioning in today's core networks, a counter movement has started to become visible, with the aim of interpreting "end-to-end quality" in the proper sense of regarding the human being as the end of the communication chain. As a result, the notion of *Quality of Experience* (QoE, abbreviated also as QoX) has appeared, describing quality as perceived by the human user instead of as captured by (purely technical) network parameters.

Currently, there are several attempts to define QoE, but the ultimate definition is still lacking. According to [2], Quality of Experience may be defined as "overall acceptability of an application or service as perceived subjectively by the end-use". Hence, Quality of Experience is a subjective measure from the user's perspective of the overall value of the service provided, and thus does not replace, but augment end-to-end QoS by providing the quantitative link to user perception. As such, it extends the current QoS perspective described above towards the actual end user, including technical QoS as well as the expectations of the end users, the content of the service, the importance of service for the end user, the characteristics of the device, the usability of the human-computer interfaces, the joyfulness of interaction, the perception of security, and maybe even the price of the service, to name but a few new ingredients.

Today, research on Quality of Experience faces the challenge of creating a unifying interdisciplinary framework that is able to combine these diverse aspects under a common umbrella in a way that we are able to predict the behaviour of end users when new services are offered to them and to ensure service provisioning and management that actually meets user expectations. Therefore, understanding the transition from Quality of Service to Quality of Experience will become an indispensable prerequisite for taking the subjective user experience into proper account while designing and providing successful future communication services.

2   Goals and Content

Within this emergence process, the Dagstuhl seminar was intended to serve as a key event. It brought together both worlds, i.e. technology-oriented networking people dealing with traditional QoS issues as well as researchers of a more interdisciplinary orientation who focus on the end user from a clearly

non-technical perspective, like psychology, sociology, usability, human-computer interfaces (HCI), micro-economics, or marketing.

The truly interdisciplinary discourse between participants coming from a broad spectrum of scientific backgrounds (ranging from strictly technology- oriented people over technology-affine colleagues with a more holistic and/or interdisciplinary orientation towards representatives from clearly non-technical disciplines like usability, economics or social sciences, cf. the invitation list below) was at the heart of the proposed seminar, and as such provides already a central challenge and objective by itself. More specifically, within this framework the seminar aimed at

- achieving a common understanding for a unified concept and definition of Quality of Experience in general;
- clarifying the nature of Quality of Experience in terms of usability, dependability, availability, reliability, comfort and - last but not least – security;
- developing interdisciplinary models for user perception and experience;
- understanding better the role of the user for successfully providing (and charging) ICT services;
- bridging the gap between user expectations, technical enablers and economic aspects (i.e. to value Quality of Experience);
- discussing the role of quality feedback from and to the user;
- exchanging know-how on quality measurement methodologies;
- discussing the state of international standardization and identifying open issues;
- providing a consistent and clear research agenda for Quality of Experience as a promising area for future interdisciplinary research collaborations.

The challenges and objectives described above lead to a non-exclusive set of research questions that need particular attention and are described in the sequel. To start with, basic conceptual issues regarding the notion of Quality of Experience need to be addressed. This implies amongst others the need for discussing novel user-related experience concepts like joyfulness, happiness, coolness and fun associated with applications and services. Also the user perception of security (helping and hindering at the same time) needs to be included here.

The necessary quantification of Quality of Experience puts forward the need for non-intrusive ways of assessing and evaluating user behaviour and perception. In particular, it is of interest to which extent Quality of Experience can be measured and valued, for which very different and potentially conflicting views exist in different disciplines (behavioural scientists tend to observe, while technicians measure). Corresponding interdisciplinary models need to be developed that allow for relating user behaviour and perception to technology- and economy-related parameters. Both measurements and modelling need to be performed such that they are compatible both with the "subjective" situation- and circumstance-biased user view and the "objective" business-oriented network management view. For instance, the consequences of user dissatisfaction can to a certain extent be seen from network measurements, a relationship which still

needs to be formalized. A specific challenge is the valuation of Quality of Experience problems in flat rate scenarios, implying the risk of churn. Furthermore, the question of reproducibility and representative-ness of (averaged) human ratings needs a thorough investigation, thinking of different to user groups, evaluation methods, etc.

Regarding applications, user perception issues are pretty well researched for audio-related Quality of Experience, whereas video applications are currently about to enter the focus of the research community. In comparison, data services are rather seldomly addressed. Given specific challenges for instance in mobile communications and specific new possibilities such as seamless communications, quantitative analyses of the interplay between users, applications, protocols and networks need much more attention in the future in order to provide a holistic view on Quality of Experience, including clear indications for providers when and how to improve user satisfaction.

Another interesting, but hardly addressed research domain is quality feedback, both from the user towards the provider (communicating the degree of happiness and satisfaction) and from the provider towards the user (communicating success and problems in order to foster user patience). Again, a multidisciplinary approach is required, addressing user psychology, technical challenges and economic incentives. In particular, it is of interest to investigate the degree to which feedback helps to avoid churn.

Expected Results

The expected outcome of this seminar was a clear common understanding of the current status of this important paradigm shift from a broad interdisciplinary perspective. Based on this, emerging research topics and new holistic methodologies were to be discussed and advanced. The intended close interaction of academia and industry ensures that all relevant aspects of development, realization and operation will be taken into proper account. On a longer time scale, this seminar bears the potential to become the source of future collaborative activities like, e.g., special journal issues, dedicated workshops or conferences, or even joint future project proposals, e.g. in the European FP7 or COST programs. Finally, on a more general level, the seminar will strongly foster the dialogue and collaboration between researchers in this area of high economical relevance.

3   Participants

The seminar gathered 20 researchers from the following countries: Austria (3), Finland (3), France (2), Germany (2), Sweden (8), Switzerland (1), and the United Kingdom (1). A list of delegates (except the organisers) will be given in Section 4.1. Although it was strongly intended to have a balanced mix of industry and academia, the seminar was in the end dominated by the latter group. 10 % of the delegates came from industry and 20 % from research institutes in-between industry and academia. The backgrounds of the delegates were computer science,

human-computer interfaces, electrical engineering, and economics. 20 % of the delegates were women, 30 % were young researchers.

4   Program

4.1   Presentations

On day 1 and beginning of day 2, each delegate had twelve minutes to present own past, current, future and planned work and activities in the area of QoS and QoE/QoX. The organisers encouraged the delegates to use visual presentations (illustrations, figures, etc.), eventually accompanied by a couple of keywords (not more than ten) instead of voluminous textual descriptions, and to confine oneself to a small number of slides.

The talks, found in the the abstracts collection, are given below in alphabetical order of the presenters:

- **Patrik Arlos**, Blekinge Institute of Technology, Karlskrona, Sweden:
  Reflection on the network's role for QoE
- **Sergio Beker**, Orange Labs, Sophia-Antipolis, France:
  Towards a QoE framework
- **Anna Brunstöm**, Karlstad University, Sweden:
  QoS/QoE performance evaluation
- **Alessandro A'Alconzo**, FZ Telekommunikation Wien, Austria:
  Research questions in QoS/QoE modeling
- **Sebastian Egger**, FZ Telekommunikation Wien, Austria:
  Human to human interaction in mediated environments
- **Charlott Eliasson**, Blekinge Institute of Technology, Karlskrona, Sweden:
  Evaluation of authentication schemes in IMS
- **Sara Eriksén**, Blekinge Institute of Technology, Karlskrona, Sweden:
  The map service quality project
- **Tobias Hoßfeld**, University of Würzburg, Germany:
  Towards QoE management
- **Gunnar Karlsson**, KTH, Stockholm, Sweden:
  The experience of quality of service
- **Andreas Kassler**, Karlstad University, Sweden:
  QoE aware multihop networks
- **Hendrik Knoche**, University College London, United Kingdom:
  . . . to QoE in mobile TV
- **Sebastian Möller**, TU Berlin, Germany:
  Modeling QoS and QoE aspects for multimodal interactive services
- **Olli-Pekka Pohjola**, Helsinki University of Technology, Finland:
  User experience modeling and user's conceptual models
- **Virpi Roto**, NOKIA Research Center, Helsinki, Finland:
  Quality of Experience versus user experience
- **Gerardo Rubino**, IRISA, France:
  Introduction to the Pseudo-Subjective Quality Assessment (PSQA)

– **Burkhard Stiller**, University of Zürich, Switzerland:
  Management in the Internet – do QoS and QoE effect service management?
– **Hans-Jürgen Zepernick**, Blekinge Institute of Technology, Sweden:
  QoE-based cross-layer design of mobile video systems

4.2   Group work

The group work was introduced in the end of day 1. The participants were given
the possibility to locate their point of gravity of interest into a triangle with
the tentative topics "user – metrics economics" and into a matrix with the two
dimensions "users vs. technology" and "conceptual vs. application/practice".
Subsequent clustering helped to identify the topics of the group work, "user" and
"metrics". The group discussions took place in the morning of day 2, and the
outcomes were presented between lunch and the social event, with the purpose
to allow further interaction on the topics discussed.

User The discussion, led by Kalevi Kilkki, dealt with the role and relationship of
the user to service provider, application, device, network and content. Moreover
the terminology of and the relationship between QoS and QoE was discussed.
Some participants argued that QoE should be considered as an extension to
QoS. However, according to most of the participants QoE should be considered
as a separate, human viewpoint compared to the more technical viewpoint of
QoS. The importance of user expectations and acceptability was highlighted,
the latter with a clear link towards outcomes, decisions and actions based on
QoE. It was realised that QoE actually has a functional part in addition to the
more familiar emotional part. New QoE levels were proposed: delight, invisible,
bearable (all acceptable); unacceptable.

Metrics This discussion, led by Markus Fiedler, tried to approach the measura-
bility of QoE, e.g. as (numerical) input to QoE control and management. During
the brainstorming, dimensions of metrics were described by pairs such as sub-
jective/objective, individual/aggregate, single/multiple, application-dependent/
-independent. Bottom-up construction (starting from QoS) was traded against
top-down construction (user- and perception-driven), relative against absolute
values, and quantitative against qualitative measures. It was proposed to use
iterative design of measures; to (re-)consider the (mis-)use of the Mean Opinion
Score (MOS) and the introduction of a Standard deviation Opinion Score (SOS)
as a measure of importance. There was no bottom-line at the end, but many
open details, and the fundamental question "What is user experience?".

4.3   Social Activities

User experience is at the heart of QoE, and the Saarland region has the po-
tential to meet even formerly unknown expectations. The *Quality of Saarland
Experience* (QoSE) consisted of a visit to the french-german city and "secret

capital of Saarland" Saarlouis, followed by "Schwenkbraten" and local draught beer. QoSE has shown to be an excellent catalyst for successful discussions on QoE.

4.4   Plenary discussion

The plenary discussion, led by Peter Reichl, revisited some of the topics from the group discussions and addressed some additional aspects. A selection of questions and statements is given as follows: If you need metrics for something (e.g. management), define them. Why not apply different viewpoints? Avoid loaded notions, better define new ones. Relate metrics to economics. Address methodologies to build tests. You need to measure it, but you need to understand what it means. Separate content experience from other factors. QoE is multi-dimensional. How to design an experiment to find out the relevant dimensions? Overall satisfaction: is this a good product for me?

Furthermore, two categorisations were presented and discussed:

1. **Scores.**   The performance impact on user behaviour can be expressed by functional scores (utility; usability) and emotional scores (fun; social), together with corresponding weight factors.
2. **User Groups.**   Users can be grouped in a two-dimensional matrix according to context (leisure vs. business) and degree of emotionality, which has consequences a.o. for the types of questions to be asked.

The seminar ended with a round of final comments by the delegated, some of which are reflected in the results section.

5   Results

The seminar as such provided an ideal environment for starting up badly needed discussions. The latter could not be finished given the half week allocated; the organisers and delegates felt that more time (i.e. a full week) would have been required to go beyond problems and challenges and to reach conclusions. In particular, definitions of QoE, QoE metrics and assessment methods remained open issues, while other aspects such as economy, feedback ans standardization were hardly touched at all. Furthermore, the delegates asked amongst others for more hands-on and modelling approaches and methodologies, the inclusion of socio-psychological, psychophysics and networking dimensions, numbers on QoE in order to make the concept survive, and links between QoE and user behaviour. Delegate's comments were "there are thousands and thousands, even hundreds of details", "we agree that we do not agree", and "we have just seen the top(s) of an iceberg".

The positive aspect of "having to finish in the middle of things" and of delegates realising this fact is that there is a pronounced interest in continuing the discussions, which actually took off in the form of tangible action such as

– a one-day QoE seminar co-organised by Sergio Beker (one of the delegates) just after the 21st International Teletraffic Congress on September 18, 2009, in Paris;
– the forming of a Special Interest Group on QoE within the COST TMA Action (IC 0703);
– submissions to journals and memberships in various paper committees;
– expression of interest of the delegates in another Dagstuhl seminar on some more specific, unanswered QoE-related topic.

Summarizing, we observe that community is forming with many complementing and promising competences, ideas and initiatives.

6   Conclusion

The Dagstuhl Seminar 09192 was an important "kick-off" to reconsider the concept of QoE, leaving more questions open than there were before the seminar, and for the formation of a community which already has taken first steps to drive the questions further. As Dagstuhl offers perfect surroundings for creative and open discussions, both community and organisers would be very much interested in a follow-up Dagstuhl Seminar.

7   Acknowledgements

References

1. ITU-T Recommendation E.800: Terms and definitions related to quality of service and network performance including dependability (1994)
2. ITU-T Recommendation P.10/G.100 (incl. Amendment 2): Vocabulary for performance and quality of service (2006 (2008))