

QoE Vadis?

Edited by

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Abstract

This report documents the program and the outcomes of Dagstuhl Perspectives Workshop 16472 “QoE Vadis?”, which was preceded by the three Dagstuhl Seminars 09192 “From Quality of Service to Quality of Experience” (2009), 12181 “Quality of Experience: From User Perception to Instrumental Metrics” (2012), and 15022 “Quality of Experience: From Assessment to Application” (2015). As suggested by the name, the Perspectives Workshop set out to jointly and critically reflect on future perspectives and directions of Quality of Experience (QoE) research. This report reflects upon the organization of the workshop. It also provides a set of personal statements and feedbacks (through the innovative “Advocatus Diaboli” approach), as well as a marriage proposal with the area of User Experience (UX). Finally, an overview of the recommendations in the upcoming Dagstuhl Manifesto is given.

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Edited in cooperation with Markus Fiedler

1 Executive Summary

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During the recent decade, the transition from the technology-oriented notion of QoS (Quality of Service) to the user-centric concept of QoE (Quality of Experience) has become an important paradigm change in communication networking research. Simultaneously, the field of QoE as such has significantly developed and matured. This is amongst others reflected in the series of three Dagstuhl Seminars 09192 “From Quality of Service to Quality of Experience” (2009), 12181 “Quality of Experience: From User Perception to Instrumental Metrics” (2012), and 15022 “Quality of Experience: From Assessment to Application” (2015).



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The QoE-related Dagstuhl Seminars had a significant impact on the understanding, definition and application of the QoE notion and concepts in the QoE community, for instance with respect to redefining fundamental concepts of quality. That work was performed in close collaboration with the COST Action IC1003 Qualinet [1] that has been concentrating on QoE in multimedia systems and services, and is still actively convening experts from all over the world to regular meetings and exchanges. In particular, this collaboration has led to the widely regarded Qualinet White Paper on “Definitions of QoE and related concepts” [1] and to the launch of a new journal entitled “Quality and User Experience” [2], fostering the scientific exchange within and between QoE and User Experience (UX) communities.

Realising the urgent need of jointly and critically reflecting the future perspectives and directions of QoE research, the QoE-related Dagstuhl Seminars were complemented by the present Dagstuhl Perspectives Workshop 16472 “QoE Vadis?”, whose output is compiled in a Dagstuhl Manifesto. Besides of having brought together the two communities much closer, and besides triggering new events such as special sessions at conferences, the main outcome of the workshop has been concretized in terms of 11 recommendations to be communicated to stakeholders in the QoE and UX domains.

The workshop was organised around the writing process of the Manifesto draft: Starting from personal statements instead of talks, two sets of group works were arranged, whose output was critically reviewed by “Advocatii Diaboli” and then refined and extended. A final review round by one representative of each the QoE and the UX group was performed before the Manifesto draft was completed by the end of the week.

References

- 1 European Network on Quality of Experience in Multimedia Systems and Services (COST IC 1003 Qualinet), <http://www.qualinet.eu> (last seen 2017-02-24).
- 2 Quality and Experience (QUEX), a journal published by Springer, <http://link.springer.com/journal/41233> (last seen 2017-02-24).

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3 Organization and Inputs

3.1 Organization

Sebastian Möller (TU Berlin, DE) and Markus Fiedler (Blekinge Institute of Technology – Karlskrona, SE)

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The 5-day workshop was organized as follows:

Monday: In the morning, an introductory session briefly explained goals and structure of the seminar, as well as the main work items to be focused on during the coming days:

1. a state-of-the-art and SWOT analysis of the current research landscape for QoE;
2. a set of anticipations how the area of QoE might develop in the future;
3. a set of theses on how the areas of QoE research will lead to innovative and improved products and services; and
4. a set of recommendations for future funding of these areas.

Then, brief personal introductions and personal statements (see Section 3.2) were given by all participants on the basis of a 1-slide 3-minute presentation. On the afternoon of that same day, the first group work was laid out and started. Group work was organized in two parallel groups and circled around the expected topics of the manifesto. The first session addressed the first two chapters of the manifesto, with marginal overlap between the groups.

Tuesday: The group work continued on the first half of the second day, followed by a social event, involving a visit of the UNESCO World Cultural Heritage Völkinger Hütte and a dinner in Saarlouis with focus on local food.

Wednesday: The results of the first group work were presented on Wednesday morning, followed by an “Advocatus Diaboli” (AD) session where the main results of the group works were thoroughly criticised, and suggestions for improvement were given to the two groups by senior members of the community (see Section 4). In the afternoon, the second group work started, again in two parallel groups, this time addressing the last two chapters of the manifesto.

Thursday: The group work was again continued on the first half of Thursday, followed again by another AD session. Following this, the groups compiled their final output text. On Thursday evening, a concert titled “Tribute to Tosti” was given by two of the co-organisers (Peter Reichl, song/piano and Markus Fiedler, piano).

Friday: The output of the group work was presented and challenged by one member of the QoE community and one member of the UX community, respectively. After departure of most of the workshop participants on Friday at lunchtime, the organizers and a set of supporters started compiling a first draft of the manifesto, which was handed over for further editing and collaborative optimization to an editing platform.

3.2 Collection of personal statements

Markus Fiedler (*Blekinge Institute of Technology – Karlskrona, SE*)

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Joint work of All participants of this Perspectives Workshop

Before the workshop, the delegates were asking to provide personal statements regarding the main contributions to the Manifesto to be addressed by the seminar, with regards to the questions listed in Section 3. These personal statements were presented during the personal three-minute presentations on the first day, alternatively upon arrival of the participants. This section contains an excerpt of those statements (in anonymous form), grouped around three topics: (1) fundamentals; (2) applications; and (3) values.

3.2.1 Fundamentals

1. Get to know the basics: What is quality perception?
2. New models and standards focusing individuals!
3. Role of IoT and wearable devices in measuring QoE
4. Building on top of what has been achieved in QoE and reinvent a modern version of QoL [Quality of Life].
5. UX vs. QoE: Root causes of the divide? Why is UX mode ubiquitous? Can we go the same road?
6. Key proposals are to marry QoE [and] user behavior using machine learning, how data can be made available from real services and encouragement to tackle the challenge with increasing number of services.
7. Complementary concepts and their relations: QoE, engagement, acceptance.
8. QoE has to join forces with UX research more in the near future.
9. We should change the paradigm from passive media consumption to interactive services, in which the user plays a crucial role for defining QoE by behaving in a certain way. For this, we will need to understand, formalize and simulate user behavior.
10. When a management action about network services is being performed on certain part of our network (e.g., traffic management within an autonomous system), what will be its direct or indirect impact on those social interactions being delivered via the affected or, in some cases, other autonomous systems? If the impacts on social interactions can be quantified, can we then measure and compare the effectiveness and quality of the management decision options? Second, with our near real-time 24/7 information exchanging system, can a network operation and management system leverage this powerful platform to close the gap between network operations and the demands from their customers?
11. How to develop practical QoE solutions applicable in large-scale networks?
12. How to integrate QoE with adjacent areas such as data measurement and machine learning technologies to serve future networks?
13. How to model, quantify, and engage QoE for existing and future networks and services?

3.2.2 Applications

1. Which application (area) next?
2. How to get out of the media (consumption) corner?

3. Candidate application area: Quality of Work Experience. What does QoE contribute more than UX and / or work psychology?
4. Get out of the multimedia comfort zone! There are so many more application domains where QoE provisioning in the sense of “avoid annoyance, create delight” could make a difference.
5. We should address services which adapt themselves to the behavior of the user. In such services, neither the service nor the user are constant, they adapt and learn from each other. QoE then becomes a floating target, which needs to be taken into account when assessing or predicting it.
6. We should extend QoE to services which deviate from a classical human-computer interaction paradigm, such as location-based services, interactions with invisible interfaces in smart environments, and alike. Such services may be relevant only in specific situations of the real life, thus QoE can only be addressed in the field.
7. It’s been just a first step: The role of QoE for the future “Internet of People” (IoP). The transition from QoS to QoE has been hailed as a paradigm change enabling quality models for network services that are aligned to real human needs rather than purely technical parameters. With the advent of the Internet of Things (IoT), however, this step forward will immediately be threatened again, along with a broad range of further issues of high subjective importance for the end users, like privacy and network security. As a consequence, we need a much broader move towards an “Internet of People” (IoP) where humans are put more and more into the center of the Internet design, based on the increasing pervasiveness of personal mobile devices and the decentralisation of functions. Hence, key decision like content management or service provisioning have to be taken locally at my own device which, consequently, becomes my “proxy” while interacting with other devices/proxies. This evolution will have major impact on the way network, data and service management protocols are designed, and at the same time generalize the multidisciplinary path QoE has taken in the last decade towards a much broader human-centric concept for future communication networks.
8. A key challenge with respect to optimizing and managing QoE is to be able to effectively monitor relevant KPIs and determine root causes of QoE degradation. While many solutions exist, questions still remain as to what extend existing solutions are effective, and whether there is a need for new QoE monitoring tools in the context of different service scenarios (e.g., network probes that estimate QoE for encrypted OTT services, conversational services, etc)?
9. Finally, going beyond today’s audio/visual communication services, future communication (conversational) services will likely move towards further immersive and interactive services that utilize advances in technologies such as VR/AR/3D, multi-sensory devices, etc. What key challenges do we need to address both from a user perspective as well as a networking perspective, for such services to become a reality? In particular, for such emerging services we are missing models relating QoS to QoE. Need for a multidisciplinary approach!

3.2.3 Value

1. Determine the business value of QoE provisioning! This will be mandatory for the future success of the area, both in terms of funding and adoption.
2. What’s next? As a next step, the QoE eco-system needs to be considered. A couple of questions emerge from the QoE eco-system. Can we utilize QoE for network & service management? Or are complementary concepts more appropriate like user engagement or acceptance? Or is context information more valuable in QoE management? How to

compare QoE across apps and for different user groups? Which metrics are appropriate when looking at QoE (quantiles vs. MOS) or QoE fairness? How to transform QoE into business models, SLAs, etc.? Or can we trade QoE?


3. Who needs QoE (and QoE research)? The different stakeholders involved in the delivery of services and apps need to be considered. The question arises whom of them will benefit from QoE (research and concepts) and how. To advance in the field of QoE, there is a need to tackle QoE models for any kind of app (e.g. cloud services, IoT, ?) or even QoE models for data. This may require to integrate aspects like privacy, but also accuracy, pricing, etc. Complementary concepts like engagement or acceptance may be more appropriate, e.g. for monitoring in an encrypted Internet.
4. QoE framework from QoS to well-being and business profit
5. QoE needs to take application reliability and economics into consideration.
6. What are the ways in which we can exploit the move from QoS to QoE management? This question needs to be addressed from different perspectives: (a) network operator: What metrics are important? Is there a need for new QoE-driven network resource allocation mechanisms, algorithms? Will this reduce customer churn? Operator role in the context of OTT service delivery? (b) service provider: how to design QoE-driven service adaptation strategies meeting heterogeneous end user capabilities, requirements, and expectations? (c) end-user: what quality gains do users care about? What are user expectations with respect to service quality? To what extent are users willing to pay for quality?
7. With new networking paradigms emerging, such as virtualized networks and everything in the cloud, what is the position and potential of QoE management? What business models will dominate when considering different players involved in service delivery, and how will QoE be addressed in the context of these business models?
8. There are two main types of challenges when thinking about QoE management, one related to the technical aspects of how to implement it (which I would guess is more interesting to the audience of this seminar), and another one related to the business and political aspects of getting the different stakeholders involved cooperating. Depending on which field of research one hails from, either type of challenge can be more interesting, but, if QoE management is to take off in practice, both problem areas need solving.
9. Regarding the technical aspects, the progression of networks and services towards the cloud dictates a set of (quite interesting) technical challenges. Among these we can identify the definition of suitable SDN applications (and maybe even data-plane functionality, using e.g., P4) that enable QoE management. In the second area, we find business challenges, such as finding incentives and mechanisms for OTTs and telcos to cooperate, but also legal ones, such as the tighter net neutrality regulations in Europe.
10. A non-scientific but nonetheless relevant challenge to research on this area is that of funding. At least in Finland, it has been very hard to get any traction with the public funding authority, and even companies that are interested in the concepts, seem reluctant to invest in it. A valid question is whether the topic will actually leave the academic environment at some point (one would hope so, but we'll have to wait and see)
11. What are the benefits of QoE for customers and industry?

4 “Advocati Diaboli” feedbacks

In this section, we present some selected feedback from the “Advocatus Diaboli” (AD) sessions, in order to give an impression of how the AD concept was realized:

4.1 “Advocatus Diaboli” feedback, first example

Henning Schulzrinne (Columbia University – New York, US)

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The AD reviewed the outcome of the first group work of group 1.

The first group of question regards the State-of-the-Art (SOTA) analysis.

- What’s the scope of QoE? The definitions include applications TripAdvisor and RateMyProfessors. Is it telecommunications? Entertainment?
- QoE seems to be on relatively simple information transmission channels, *i.e.* fidelity of transmission. Does this exclude more complex interactions? What is the temporal scope? It seems to imply single sessions.
- What about predictability of experience?
- Producer vs. consumer – does this cover the OTT world, *i.e.* software vendors, “channel” providers, equipment vendors (smartphones). This means controllable and external, uncontrollable factors, such as “feelings” (did I like this?), performance and “actions” (will I drop the service? how much am I willing to pay?)

From a broad(er) perspective, it was observed that:

- QoE shares the “QoS problem” , which is managing scarcity: make it just tolerable enough that people won’t leave [Tragedy of the Commons].
- Where is this still relevant? In home networks? Or in mobile networks?
- Or is it about improving experiences? What about UX? Does it offer a more positive message?
- Is there something distinctive in approach, tools and methods?

The second set of feedbacks addressed the SWOT analysis.

From an internal perspective:

- What would a QoMEX technical program committee think about a new paper?

With regard to weaknesses:

- Is QoE treated as “free” goods? The price-performance trade-off not easily considered.
- Evaluation (“sucks”) vs. iterative refinement.
- Which are 10 key insights? What about the “end-to-end principle”?

From an external perspective:

- Why should I (dean) hire a new faculty in that area as opposed to (say) cybersecurity?
- Why should I (funding manager) spend money on this as opposed to cancer research?

From an outcomes perspective:

- Who exactly benefits from more research, beyond the researchers?
- In the old days: easy – codec and network designers
- Is this something that every [fill in the blank] should know? Who? Why?
- Should this become something that’s part of the system design process? Where? Cf. “security by design” equivalence or “test-driven development?”

From a cost perspective:

- “Might not be cost effective”? Why? What is the cost? Research? “You don’t have a choice anyway, so suck it up”? signed, your friendly ISP.

Last but not least, some comments about new research topics:

- What makes IoT and e-health different from the existing topics?
- Why do we have differentiating experience and insights compared to people who understand work places?
- What is the channel, “noise”, evaluation metric? How does this overlap or differ from HCI, usable security, user interface design, . . .
- What would be part of a theoretical framework?
- More Dagstuhl seminars on QoE definitions?

4.2 “Advocatus Diaboli” feedback, second example

Sebastian Möller (TU Berlin, DE)

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The AD provided input to the group work of group 2 regarding 2 questions. The first question addressed was the one regarding how QoE research would develop in the future. The following comments were given:

1. It was stated that system instrumentation is needed, e.g. for measuring interaction. This point seems to be very valid, however new questions arise from it, namely:
 - For which purpose is this necessary? For system adaptation and/or optimization? For service prioritization? Or for the prediction of QoE/UX/user state/business impact?
 - What type of data is to be collected? User interaction with the system? Should user feedback be captured with a feedback button?
 - How can privacy be maintained with all this data collection?
2. One of the guiding ideas of the Dagstuhl seminar was to bring the QoE and UX communities, as well as the research fields, together. To be effective in this aim, the following questions need to be clearly answered:
 - What is the difference between QoE and UX?
 - What can QoE research bring to UX, and vice versa?
 - Which tools or best practices are helpful for this aim? Can we automate user research by a “semantic layer”?
3. User modelling was mentioned as a necessary and helpful step. The following questions arise:
 - What aspects of the user should be modelled? QoE perception and judgment? User behavior, and (if yes) at which level?
 - What is the purpose of the modelling? Adaptation? And what is the outcome? MOS?

The second block of feedback from the AD to group 2 addressed the recommendations to be given as an outcome of the workshop. This related to the following recommendations proposed by group 2:

1. Societal impact:
 - Are open data and privacy conflicting goals? If not, how can these be addressed?
 - Is a “coherent, functional” theory of QoE and UX a requirement? Why? Can such a theory be expected, given the diversity and complexity of the services?

2. Business impact:
 - “QoE and UX will be key aspects for the adoption of new technologies”: What is the link between QoE/UX and acceptance?
3. Academic/scientific impact:
 - If the question is still “where are we?”, is this then a good topic to educate Master students in?
 - Collaboration: UX has been approached by QoE for a while; what are the showstoppers?
4. Industry impact
 - Is it reasonable to think of a “QoE-collecting framework that could be used in a wide range of applications?”

5 Outputs

5.1 The QoE-UX wedding proposal

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Obviously, QoE and User Experience (UX) are very closely related. Thus, the idea came up to “marry” both areas. The question arises: What does each partner bring to the marriage?

1. *A set of unique features:* While QoE brings the quantification of users (audio-visual) quality, UX brings qualitative and quantitative methods. QoE contributes measurement tools and models technical efficiency, while UX contributes individual and social UX models. Main factor studied by QoE are latency, accuracy, synchronization, etc., in contrast to pragmatic and hedonic qualities by UX. QoE extends a.o. towards user perception and Mean Opinion Scores (MOS), while UX extends towards user acceptance, trust, safety, emotions, wow as well as engagement, fun, flow, immersion, presence. QoE contributes standards, and UX contributes design guidelines and principles. QoE brings technical expertise with a good ability to talk to businesses, while UX brings expertise on understanding users, their interaction, and needs.
2. *A set of aspirations:* QoE aims at adding more subjective user data, automation, and interactivity (interaction patterns), while UX would like to be able to measure the added value of UX and to have numbers. QoE intends to improve users quality of life, and to make users and businesses happy. Similarly, UX would like to improve users personal wellbeing (long term value), and make users (and society) happy.
3. *Different, complementary stakeholders:* For QoE, these are infrastructure providers and operators; content providers and creators, while for UX, these are consumers, designers, and artists.

Indeed, a combination of QoE and UX will make a difference in the fields of multimedia/entertainment/gaming; IoT/wearable interfaces; and multisensory interaction.

5.2 Special Session “QoE Vadis?” at QoMEX 2017

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As an immediate follow-up of the Perspectives Workshop, we proposed and got accepted a Special Session at the predominant conference in the QoE area, QoMEX [1].

Motivation and objective of the Special Session

This session is based on the recent Dagstuhl Perspectives Workshop “QoE Vadis?”, with a special focus on contributions on future directions of QoE research beyond the multimedia comfort zone. Of particular interest are amongst others the exploration of services beyond multimedia consumption, investigation of new emerging technologies such as VR and AR, and stimulation of discussions on the design of multisensory experiences through opening up partnerships with adjacent research areas such as User Experience (UX) and Human-Computer Interaction (HCI), which attract huge investments by major players such as Apple, Google, etc. Pressing questions are amongst others: (i) How cross- and multi-disciplinary design perspectives can improve the quality of service creation, delivery and perception? (ii) What new processes, methods and measures can be applied to ensure the role of QoE in innovation? (iii) What new business and societal values can be envisaged for QoE research? Overall, this session shall provide a forum for researchers and practitioners from industry to look into the future of QoE research, joining forces with experts from other communities such as UX, HCI, as well as Economics, Management, etc.

Session outline

- Keynote (candidate: David Geerts, University of Leuven, Belgium)
- 2 sessions with 5 papers in total
- Short panel on “The marriage of QoE and UX: what do both communities bring into the partnership?”

Specific topics of interest

- The Devil’s Advocate’s view on different aspects of QoE research
- Value of QoE research beyond multimedia consumption
- New applications and services relevant to QoE research
- New approaches and tools relevant to QoE research (e.g. Big Data analytics)
- Joint efforts between QoE and User Experience research
- Relationship between qualitative and quantitative data, user behavior and churn
- QoE by design for future and emerging technologies (e.g., Virtual and Augmented Reality)
- Business and societal aspects of QoE
- Innovation through QoE research
- Industrial aspects of QoE
- Lifecycle aspects (e.g. requirements engineering and upgrade strategies) for services
- Application of QoE research results “in real life”

References

- 1 9th International Conference on Quality of Multimedia Experience (QoMEX 2017), May 31– June 2, 2017, Erfurt, Germany, <http://www.qomex2017.org> (last seen 2017-02-24).

5.3 A glance at the upcoming Dagstuhl Manifesto

Sebastian Möller (TU Berlin, DE)

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The current manifesto draft is a 19-page document which has been started during the Dagstuhl workshop, compiled in several post-workshop sessions, and re-iterated with all participants of the workshop in order to ensure correctness and readability. It is structured as follows: Section 2 provides a state-of-the-art and SWOT analysis of the current research landscape for QoE. Section 3 contains projections of how the area of QoE might develop in the future, and how it will lead to innovative and improved products and services. Finally, Section 4 provides a set of recommendations for future funding of QoE-related activities.

The main outcome of the manifesto is a list of 11 recommendations to stakeholders in the QoE and UX communities. They may be summarized as follows:

- R0: Put the end user into the focus of all your considerations.
- R1: Promote interdisciplinary research.
- R2: Provide access to open data and tools.
- R3: Drive investigation beyond the comfort zone.
- R4: Turn QoE from reactive to proactive research.
- R5: Implement mechanisms for direct quality feedback.
- R6: Join forces within industry.
- R7: Support QoE research as scientific approach to a substantial and unsolved problem.
- R8: Respect QoE as key paradigm for the future digital society.
- R9: Create a cross-disciplinary and cross-institutional research community.
- R10: Support market diversity and sustainability.

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