

09192 Abstracts Collection
From Quality of Service to Quality of Experience
— Dagstuhl Seminar —

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Abstract. From 05.05. to 08.05.2009, the Dagstuhl Seminar 09192 “From Quality of Service to Quality of Experience” was held in Schloss Dagstuhl – Leibniz Center for Informatics. During the seminar, several participants presented their current research, and ongoing work and open problems were discussed. Abstracts of the presentations given during the seminar as well as abstracts of seminar results and ideas are put together in this paper. The first section describes the seminar topics and goals in general. Links to extended abstracts or full papers are provided, if available.

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

09192 Executive Summary – From Quality of Service to Quality of Experience

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

Joint work of: Fiedler, Markus; Kilkki, Kalevi; Reichl, Peter

Full Paper: <http://drops.dagstuhl.de/opus/volltexte/2009/2235>

Reflection on the network's role for QoE

Patrik Arlos (Blekinge Institute of Technology - Karlskrona, SE)

We are facing challenges with regards to how our future communication systems will work. At this seminar we addressed the issue of Quality of Experience (QoE). QoE has many facets, and equally many interpretations. Some time I note that the majority of these facets are focusing entirely on the user perception, which is needed from the user perspective. However, I do think that we cannot/should not forget the network, as the network have to cater to many different applications and users, as there will not be one network per service, despite the ideas from the P2P community.

Keywords: QoE, Measurements, Human Perception

Towards a QoE Framework

Sergio Beker (Orange Labs - Sophia Antipolis Cedex, FR)

The different quality notions around Quality of Service (QoS) and Quality of Experience (QoE) are used differently through the standardization bodies and the associated research domain. We know better how to measure QoS based on performance metrics on the underlying network. On the other hand, trying to translate or map from the QoS domain to the more subjective domain of QoE constitutes somewhat the way we need to undergo. QoE measurement functions can be obtained from QoS objective metrics by taking into account the human factors impacting the quality perception of the service, including user expectations, effectiveness and performance. Those models can be obtained from passive and active estimation, or from service modelling. Many different research domains need to get to work together in order to model user perception as closely as possible to reality, from network and informatics experts to ergonomists and behavioural psychologists. However, the quality notions are still imprecisely defined, often leading to a misuse of QoS as QoE. A QoE Framework is then needed defining QoS and QoE terminology, interfaces actors and roles as a basis on which future research on QoE could be homogeneously grounded. Such a framework is based on a service modelling including the human-computer interaction (HCI) layers and a communications ecosystem allowing identifying actors and interfaces. A first approach to a QoE Framework is presented during the seminar for further discussion.

Keywords: QoE Framework

Joint work of: Beker, Sergio; Guyard, Frederic

QoS/QoE Performance Evaluation

Anna Brunstroem (Karlstad University, SE)

Protocol optimizations for enhanced E2E QoS have been one of my key areas of interests for a long time. Ongoing work in the area includes efforts to provide more timely message delivery in the stream control transmission protocol (SCTP). Although targeted for time-critical message based traffic, part of the design of SCTP is derived from a bulk traffic assumption. By adapting these protocol mechanisms for message based traffic significant performance improvements can be achieved in terms of the message transfer times. The implicit assumption is that this will also lead to improved QoE. At Dagstuhl I look forward to discussing the relationship between QoS metrics and QoE and how to better measure QoE.

Much of our protocol work is experimental in nature. Our KauNet emulation system has been developed to support protocol evaluations with a high degree of control, flexibility and reproducibility. In the future we hope to also use it for QoE studies in the health care area as well as to connect it to eye tracking equipment. At Dagstuhl I also look forward to discuss appropriate methods for this type of studies.

Research questions in QoS/QoE modeling

Alessandro D'Alconzo (FZ Telekommunikation Wien, AT)

Understanding, measuring and managing Quality of Experience (QoE) is becoming a vibrant area of research. The main reason is that improving QoE directly supports providers in winning and keeping customers and reduce churn. In fact, since users are the ultimate judges of service quality, it has been recognised that it is vital to move beyond traditional QoS metrics and adopt a more holistic understanding of quality as perceived by end-users. However, such a paradigm shift towards QoE raises a number of research questions.

First of all, should be defined what user experience is, what impacts on it (expectations, usage context, content, device type, etc.), and how it is possible to measure QoE: Does it really make sense to put numbers on it?

The next step would be to define the properties of such QoE metrics. It seems to be extensively accepted that aggregate metrics are usefull for providers, whereas the individual metrics are usefull for applications design. However, there are several points not yet solved. For example, what kind of metrics do we need to describe user experience on the different layers, and if it is the case to consider

generic QoE metrics (e.g., user happiness/satisfaction) rather than application specific ones.

Therefore, the research question is how to build the (subjective) QoE metrics and how to find out meaningful mapping functions with the (objective) QoS metrics. There are two approaches: A top-down approach, starting from the user perspective, and a bottom-up approach starting from the network side. Both show limitations that can be overcome only by using an holistic approach.

Finally, I present a currently running project, I am involved in, which purpose is to exploit a passive monitoring system in order to estimate network-wide the QoE for some application classes (Web browsing and Voice/VoIP). To this end, we aim to use in a complementary way the user centric and network centric approaches to the QoE modeling.

Keywords: Drop call rate, Anomaly detection, 3G mobile networks, Web browsing QoE modeling

Human to Human Interaction in Mediated Environments

Sebastian Egger (FTW, AT)

To describe the transition from a QoS perspective to a QoE perspective I want to start by first specifying the differences between the two concepts. From my point of view QoS is trying to assess what the packets in an IP network feel, while QoE sets out to measure what the user as a human being feels. Although these concepts do target different problems, they also share commonalities: QoS does matter if one wants to achieve pleasant QoE for his users. The work I presented exemplifies this interconnection. The service under contemplation is a video conferencing system enabling its users to follow a mediated interaction process. People using such a system do interact with each other although some of the interaction cues they exchange get deteriorated. Years ago Erving Goffman has already recommended to study such mediated interaction systems regarding their abilities to convey the interaction cues without distortion. If we classify systems under these aspects, we can also conclude that to a certain degree, different systems impact interaction cues differently e.g. audio-only systems do not convey any gestures, facial expressions etc.

How does this relate to the user? Users with a highly interactive communication behavior might gesture more than the average user; hence, to be able to communicate in such a highly interactive manner they also need the visual channel. In technical terms they demand more bandwidth to be able to communicate with less distortion. The bandwidth is a classical QoS parameter which, in this case, has to be improved to ensure a pleasant QoE. BUT: QoS is only one dimension that adds to the overall QoE. Other dimensions like user expectations and goals, usage context, the device, the other interactant etc. have to be considered as well. Altogether they are components of the multidimensional QoE concept.

Keywords: Human interaction, sociological perspective, QoE, QoX, holistic, QoS

Evaluation of authentication schemes in IMS

Charlott Eliasson (Blekinge Institute of Technology - Karlskrona, SE)

When working on evaluating authentication schemes for IMS (IP Multimedia Subsystem), one of the natural aspects to evaluate is the user point of view. How does the user perceive the authentication? So, we evaluate, not only security and simplicity of the authentication scheme, but also user-friendliness. Those aspects were chosen as our primary criteria.

The user-friendliness in our model consists of sub-criteria like end-user experience and authentication time, where the latter can be seen in some sense as a response time.

Between security and user-friendliness we found a secondary criteria that we call awareness and here we distinguish good from bad awareness. Good awareness does not annoy the user and gives accurate feedback. Bad awareness can come from too much feedback and false feedback to the user, regarding the state security.

Between simplicity and user-friendliness we found the criteria usability. Here we borrow the sub-criteria from the System Usability Scale (SUS), which consists of (amongst others) the criteria effectiveness, efficiency and satisfaction. The first two deal with if a task is sufficiently performed and in what way, regarding resource use, and the third is more or less related to QoE.

We also developed an evaluation methodology, where we perform several analyses, going from qualitative to quantitative, and then put the evaluation results together with the criteria that we already came up with and hopefully get a more or less final result of the entire evaluation that can be visualised.

A SWOT (Strength, Weaknesses, Opportunities and Threats) analysis has been performed. Though it is originally an analysis method for business aspects of development, it seems to have worked quite well.

At the moment we are performing a user experiment on how users perceive a login on a webpage. We know from several previous studies, by both academia and industry, that a user browsing a webpage notices a couple of 100 ms of delay, gets bored after some 4 s and that after 10 s the risk of the user leaving the webpage rises. The goal of our user experiment is to see whether the same thresholds apply when dealing with a webpage with a login.

In the near future, we expect to develop a more mobile solution for the client, e.g. a mobile phone client, and also develop a flexible authentication server where we can test all the concerned authentication schemes. We also hope to use this setup for user experiments and make measurements on both user and network level.

Keywords: IMS authentication, evaluation criteria, user experience, evaluation methodology

The Map Service Quality Project

Sara Eriksen (Blekinge Institute of Technology - Karlskrona, SE)

The mapping Service Quality project was a multi- and inter-disciplinary research project which was financed by the Swedish Internet Fund .SE 2007-2008. In this project, we focused on examining how users of map-based services online experience the quality of these services when the traffic load is high, and how the users' experiences of acceptable or not acceptable quality can be related to measurable parameters which can be used to manage network traffic and improve technical solutions.

The project was run in co-operation between researchers within Human Work Science and Informatics, and researchers within Telecommunication Systems. Additionally, there were two external partners in the project; a provider of Internet-based map services, and a municipality which uses this provider's map services regularly. One of the main methodological issues addressed in the project was how laboratory based, quantitative research methods from research on Quality of Service in the telecommunication systems area can be related to qualitative research methods focusing on work-place or other live-world based use-situations and Quality of Experience as defined by users of services. How can experiments and studies be designed, such that both network traffic measuring and evaluation of user experiences retain their own paradigmatic validity and relevance, while fruitfully informing service design? By the end of the project, we found we had only begun to scrape the surface of an area which needs much more research attention and effort. Thus I am happy to be part of this Dagstuhl seminar.

Keywords: Quality of Service, Quality of Experience, User Experience, Measure, Use situation, Use context

From QoS to QoE – Position Statement

Markus Fiedler (Blekinge Institute of Technology - Karlskrona, SE)

QoE has somehow become what QoS was supposed to be once upon a time when it was defined by ITU-T: a set of parameters reflecting user satisfaction with a service. Both notions are used in a broad manner, and there is work going on to encircle and clarify QoE-related notions. For now, we will regard QoE as customer/user-oriented and QoS as network-oriented performance parameters.

While QoE is important for business – happy customers stay with their provider, happy users surf more – QoS parameters are typically easier to measure than their QoE counterparts. Thus, equations interrelating QoE and QoS are important enablers for QoE control based on QoS monitoring. We recently identified a generic exponential dependency of QoE from QoS parameters with appealing properties and simple configurability.

Some QoE parameters such as the perception of waiting times within interactions are well-researched, others not. Rather little insight is given how the degree of user happiness evolves over time. Knowing the transients of QoE in face of QoS changes will equip providers with possibilities to (re-)act in time before a user loses goodwill and starts considering churn.

QoE control is important business for the provider. On the other side, the application on behalf of the user – or the user itself – has the power to choose the provider that provides the best satisfaction-price ratio. Thus, QoE parameters are important input for decision making in seamless communication solutions that are used for automatic network selection on behalf of the user. To find possibilities how to measure QoE in a direct way (e.g. through user interactions with a system) and to price QoE are challenging tasks for future work. They clearly involve the need for trans-disciplinary research teams.

Keywords: Quality of Experience, Quality of Service, measurements, user patience, seamless communications, pricing

Towards QoE Management

Tobias Hossfeld (Universität Würzburg, DE)

QoE management and provisioning requires three basic steps, (1) understanding QoE, (2) monitoring QoE, and (3) controlling QoE. It is necessary to understand the application's requirements and the impact of disturbances on the user perceived quality. This allows for cost savings by appropriate QoE dimensioning and avoiding QoE overprovisioning. A good understanding or even a reduced reference metric, as proposed by the IQX hypothesis, allows to easily monitor QoE at the edge or to assess QoE within the network. Then, the QoE may be controlled in such a way that the user may not get dissatisfied and even leaves the service. QoE control aims at reacting before the user reacts. Open questions in this context are (a) where to react, at the edge or within the network, (b) when to react and on which time scales, and (c) how to react and which control knobs (at the edge or within the network) to adjust.

The understanding of QoE also remains a topic of future research. The QoE depends on several factors: type of application and corresponding human perception, user's expectations (and payments for a service), user's experience from the past (long-term and short-term), offered contents / popularity of service, GUI and usability of application software, technical environment (user equipment, network access, etc), ... For assessing QoE, a typical approach is to calculate mean opinion scores out of huge user tests. Thus, the opinions of individual users are aggregated and meant to reflect the opinion of an average user. As we have seen on the exponential interdependency of QoE and QoS parameters (IQX hypothesis), the QoE might be quite sensitive in certain areas, as users have widely different opinions (e.g. due to unknown context of individual users).

Therefore, I do the following provoking statements: 1) Let the users decide! On the example of video streaming, a long startup delay is annoying, but allows a smooth video playout, while a short startup delay is appreciated by the user, but may result in a rough playout. Thus, let the user adjust the pre-buffering time. The user will get used to it and adapts its expectations. 2) User, application and network have to communicate! Integrate feedback from the users in the control loop of QoE management. 3) Mean opinion scores are not enough! I propose to consider SOS, the standard deviation of opinion scores, in addition to MOS for properly reflecting the sensitivity of users.

Full Paper:

<http://www3.informatik.uni-wuerzburg.de/research/p2p/>

See also: <http://www3.informatik.uni-wuerzburg.de/staff/hossfeld/>

The experience of quality of service

Gunnar Karlsson (KTH - Stockholm, SE)

I briefly review our contributions to QoS for the internet and wireless networks and outline current research on opportunistic wireless networks. When the network is largely unconnected, the issue of quality of service is ill-defined but the quality of experience by the end user is a valid performance metric. I also show how advanced mobility simulations can be used to assess the application level performance for DTNs.

Keywords: Quality of service, delay tolerant networks, mobility modeling

QoE aware Multihop Networks

Andreas Kessler (Karlstad University, SE)

Multihop networks such as Ad-Hoc, Mesh or sensor networks will be an intrinsic part of the future internet. In such networks, nodes relay traffic wirelessly, which imposes several challenges on QoS management. On the other hand, different types of media needs to be transported over such networks originating from different users. The impact of resource availability has however a different impact for each media type. Therefore, optimizing such networks for different services and users require the development of novel mechanisms and metrics that allow to quantify the user satisfaction for a given service delivery. Once such metrics are in place, network and service parameters need to be mapped onto such metrics. This will allow then to develop optimization functions which take into account resource constraints, user profiles and operator policies. Such Quality of Experience Management combined with self-awareness and self-learning will allow to develop networks which adapt their operation to match user satisfaction with resource availability, learn from such adaptations over time to optimize their operation automatically.

QoE from scientific and practical viewpoints

Kalevi Kilkki (TKK, FI)

Quality of Experience is an ambiguous concept. It can be viewed from numerous perspectives that may result in different definitions, different methods and different goals. From scientific viewpoint the fundamental question is: What is QoE? Then from practical viewpoint the question is: How can QoE serve a practical goal, like improving the business of a service provider? In addition, we need somehow harmonize these two primary viewpoints; scientific knowledge shall be used to answer the practical questions, and practical needs shall be taken into account in scientific studies.

Because experience is, by definition, a subjective issue, it can be assessed only by the person who has an experience of something. Quality of Experience is thus a multidimensional description that can, to some extent, be measured by means questionnaires. Each element of QoE obviously needs separate, well-defined questions. Then the measured QoE is the set of answers, likely described by numerical parameters (while it is also possible to include qualitative descriptions that are then somehow systematically interpreted for further analysis).

In a practical task, e.g., related to the management of services, there is an evident need to assess QoE by technical measurements. Therefore we also need systematic methods to convert the obtained technical data to numerical representation of obtained QoE. Finally, the numerical estimations of QoE can be used to make practical decisions, for instance, how the network services shall be developed in order to satisfy real customer needs.

... to QoE in mobile TV

Hendrik Knoche (University College London, GB)

People are interested in using services that include presentation of media. This typically involves content and/or other information displayed by an application on a device and delivered by a network.

Quality of experience is supposed to help us understand how people attribute value and derive pleasure from using a service. The scope of QoE is still undefined and confusion, on which factors in this ambitious goal need to be considered, has ensued. The factors will depend on people's context and expectations and I'm arguing for an iterative multi method approach to elicit and measure these factors in a human centered design way. This should help in translating human needs into system requirements and closing the gap with what is currently described through hard- and software parameters and QoS parameters, which describe the performance of the network.

Modeling QoS and QoE Aspects for Multimodal Interactive Services

Sebastian Möller (TU Berlin, DE)

There is still confusion about what Quality of Service (QoS) and Quality of Experience (QoE) are about. I argue that QoS is not related to quality, but to the performance of the service and its underlying components. In turn, QoE encompasses an entire set of aspects perceived and judged by the user. For a mediated communication service, these aspects range from transmission quality, effectiveness, efficiency, usability, user satisfaction up to the acceptability of a service (sometimes called Quality of Customer Experience, QoCE). For a human-machine interaction service, QoE aspects are similar, however the performance of user and system behavior can be defined and displayed more explicitly. I will argue that – like QoS performance indices – QoE aspects can be measured as well, but not necessarily via standard questionnaires.

Both QoS and QoE can be displayed via taxonomies which are proposed for media transmission services and for multimodal interactive services. For the latter, a simple model is developed which aims at describing the relevant perception, judgment and action processes which take place inside a human user. Although most of these processes are still unknown, an initial approach is presented for modelling the action processes in speech- or web-based interaction scenarios. This approach may ultimately lead to QoE prediction by means of user behavior modelling.

Key statements of my presentation are:

- Quality of Service is a collection of performance characteristics, and not a quality aspect.
- Quality of Experience involves human perception and judgment processes, and can only validly be quantified via human measurement.
- The human cannot be separated into a “user” and a “customer”, i.e. Quality of User Experience and Quality of Customer Experience are closely related and may be subsumed under the term QoE
- Models for individual QoE aspects can be defined, but care should be taken to not apply these models beyond their range of validity, i.e. beyond the quality aspects they really predict.

Keywords: Taxonomy, QoS aspects, QoE aspects, multimodal interactive services, user simulation

User experience modeling and user’s conceptual models

Olli-Pekka Pohjola (Helsinki University of Technology, FI)

I give a short overview on our past, present, and future research activities:

1) modeling how users get benefits from the stuff that the communications ecosystem provides for users to experience and how changes in user experiences impact user's benefits and behavior, 2) development of a new top-level conceptual model for communications ecosystem that enables better experiences to users.

Keywords: User experience modeling, conceptual models

User experience beyond QoE

Peter Reichl (FZ Telekommunikation Wien, AT)

Whereas the original concept of Quality-of-Service has been explicitly aiming at achieving user satisfaction (cf. ITU-T E.800), subsequent research has more or less focussed on QoS parameters than on QoS itself. Thus, recently the notion of Quality-of-Experience (QoE) has been introduced into the current research agenda in order to shift the quality perspective back to the user. However, we can already today observe first trends pointing into the direction that actual research on QoE might suffer a similar fate as QoS did. Therefore, I am convinced that at the moment it is still necessary to further **open** and **broaden** this topic by bringing it into a fully interdisciplinary environment closely integrating social and economic sciences in order to answer the central questions:

1. What is the difference between QoS and QoE?
2. What is - beyond that - the difference between QoE and User Experience?

Hassenzahl's distinction between hedonic and functional aspects provides most probably the initial starting point for a comprehensive research agenda covering these topics up to the question of even how to charge for user experience rather than technical quality.

Quality of Experience vs. User Experience

Virpi Roto (NOKIA Research Center - Helsinki, FI)

User experience (UX) is investigating how a person feels about using a system. There are lots of things affecting this experience, from brand image to the cost of the system, from ease of use to network speed, from current mood of the person to the value of the content, etc. User experience is subjective, so you need to ask how user feels about X in order to measure (and improve) it.

Quality of Service is about the quality of network connection, and traditionally, it has been measured by objective technical metrics such as throughput and number of lost packets. When looking Quality of Service from the user's perspective, user's goals and expectations and the current context affects the perceived quality of the connection a lot. Quality of Experience (QoE) has come to the picture to measure the perceived connection quality in the current context. Because so many other aspects affect the experience as well, evaluators

need to understand the whole picture and identify the reason behind each good or bad experience.

Quality of Experience is focusing on improving the network connection experience. The metrics needed for this are different from user experience in general, since the network can hardly provide valuable, engaging experiences. The network can delight the user by exceeding her expectations on the connection quality.

Introduction to the Pseudo-Subjective Quality Assessment (PSQA)

Gerardo Rubino (IRISA, FR)

As usual in science, one way to address a complex problem is to attack it in a particular case, in some limited context. Defining and measuring QoE is a complex problem, because as a user-centric concept, it has a strong subjective component, with the associated psychological and social aspects, plus other connections that are hard to study (connections with the content, with the own expectations of the user, with how much she pays, or she is willing to pay, etc.).

Our approach to this problem consists in focusing on the (subjective) perceived quality of audio or video flows, as a main component of QoE, and in a networking context. Then, we avoid defining a prior QoE. Instead, we use as a definition the result of mapping QoS metrics plus specific parameters associated with the flow (e.g. codec used, redundancy factors, etc.) with a MOS value coming from subjective testing experiments. Using statistical learning tools, we then capture the ways humans see quality, and produce a mapping from those QoS metrics and other parameters into quality (MOS-like). We call this mapping PSQA (Pseudo-Subjective Quality Assessment).

For the practitioner, PSQA appears as a module that, situated at the receiver side, measures the considered QoS metrics and communication-related parameters and produces a QoE (here, perceived quality) value. This is done in real time, so that it can be used for controlling purposes. It has been tested on audio and video, for one way and interactive application.

Keywords: QoE

Management in the Internet – Do QoS and QoE Effect Service Management?

Burkhard Stiller (Universität Zürich, CH)

Service management will not be effected by a shift from QoS to QoE, since the mechanisms in use and feedback loops as such will remain unchanged. However, the QoE principles will support positively service economics and service classes,

since the valuation of the user will increase the value of the service as such as well as the usefulness of classes due to a clear user-driven specification.

Nevertheless, the needs in service management today do not comply with all QoS ideas by far. Therefore, the risk of services need to be evaluated and specified, the control-loop (including the human for QoE reasons) need to be optimized, and non-voice QoS measurements and valuation schemes are needed in a standardized manner.

The community does know about service specifications, usage, delivery, provisioning, accounting, economics, classes, QoS, ... and its respective algorithms/systems/models in support of them partially and separately. But only service economics and classes tend to be differently judged for QoE compared to QoS. Observation effects and service management are classifiable, but they do not change for QoE as such.

Nevertheless, risks of services, time- and control-loop generalities as well as non-voice-QoE measurements are a must for tomorrow's systems. Providers start to shift into that direction at this time already. While operationally the move is a small one, the findings on concrete parameter settings etc. is an interesting step. Thus, concluding: QoE does effect positively services offered, used, and sold (economics). Additionally, the shift into QoE support will benefit users and providers. Finally, application-independent schemes, metrics and validations determine the emerging needs for tomorrow.

Keywords: Service management, QoS, QoE, effects, mechanisms

QoE-Based Cross-Layer Design of Mobile Video Systems

Hans-Juergen Zepernick (Blekinge Institute of Technology - Karlskrona, SE)

This contribution focuses on revealing challenges and discussing concepts associated with the incorporation of the Quality of Experience (QoE) paradigm into the design of mobile video systems.

The corresponding design framework combines application, middleware and networking layer in a unique cross-layer approach, in which all layers shall jointly analyse the quality of the video and its delivery in face of volatile conditions. Particular ingredients of the framework are efficient video processing, advanced realtime scheduling, and reduced-reference metrics on application and network layer.

Joint work of: Zepernick, Hans-Jürgen; Fiedler, Markus; Lundberg, Lars; Pettersson, Mats I.; Arlos, Patrik