

EDITORIAL

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QoE-centric Analysis and Management of Communication Networks

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The heterogeneity and variability of Internet applications has increased considerably in recent years. Applications such as video streaming are responsible for a large part of data traffic on the Internet. Internet telephony and video conferencing systems have become part of our daily lives. At the same time, the Internet of Things is striving to exceed previous expectations regarding the number of devices. Furthermore, the proliferation of video games, virtual reality applications, and 360° video applications is increasing. All this leads to specific but different requirements from applications to frameworks, service platforms, and networks. For each service, users desire special service criteria, such as smooth interactivity, fast downloads, high availability, or extensive content. Such requirements can usually be summarized under the term Quality of Experience, i.e., the overall satisfaction of a user with the system currently in use. In the age of big data and dynamic networks, Quality of Experience is still looking for its place, and good solutions are in high demand. This Special Issue addresses the latest advances and challenges in analysis, design, modeling, measurement, and performance evaluation of Quality of Experience and Quality of Experience-oriented metrics and management.

KEYWORDS:

Quality of Experience, QoE Management, Communications Networks

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In recent years, the heterogeneity and variability of Internet applications, both in multimedia as well as in interactive environments, has increased substantially. Nowadays, video streaming is responsible for a large portion of traffic in the Internet. Internet telephony and video conferencing systems have become part of our daily life. At the same time, the Internet of Things strives to surpass any previous expectations towards the number of devices. Smartphones and tablets contribute to the ever-growing demands on the networks. Furthermore, the proliferation of all types of media hubs also fosters the acceptance and development of video games, upcoming virtual reality applications, 360° video, and further interactive applications.

All this leads to specific but different requirements from applications to frameworks, service platforms, and networks. For each service, users desire special service criteria, such as smooth interactivity, fast downloads, high availability, or extensive

content. Such requirements can usually be summarized under the term Quality of Experience (QoE), i.e., the overall satisfaction of a user with the system currently in use.

On the technical side, this opens up new paths towards analytics, big data, and automated machine learning techniques. Today, analyzing data to understand QoE touches at least one of these topics. In the era of big data and dynamic networks, QoE is still looking for its place, and good solutions are in high demand.

The research community has recognized QoE as a new discipline. Many new research challenges are being investigated, such as the realization of QoE in applications and communication networks. This is primarily due to the explicitly non-technical definition in terms of the subjective satisfaction of the end user. Today, QoE research overlaps with many existing fields and brings new challenges to the surface, such as technical solutions for QoE monitoring in communication networks; the development of new services and applications based on human perception and QoE; the development and evaluation of improved QoE frameworks.

One such new research challenge is *QoE Management* with its integration in applications and communication networks. Although it is an increasingly relevant topic, there is little direct research that deals with the integration in the management of a service or a network. This Special Issue is devoted to the latest advances and challenges in analysis, design, modeling, measurement, and performance evaluation of QoE and QoE-oriented metrics.

In total, seven articles were accepted from three different areas: (A) QoE Monitoring, (B) Video Streaming, and (C) Unified Communications. In “*Impact of VNF Placements on QoE Monitoring in the Cloud*”, Dinh-Xuan et al. discuss challenges for QoE Monitoring. Over the past decade, Internet services have evolved tremendously, and the emergence of cloud computing has revolutionized the Internet ecosystem by providing the users with everything as a service. Cloud computing provides users with an arbitrary type of service: from entertainment services, like video streaming and cloud gaming, to office services, like Web-based word processors and office suites. Equipped with only a thin client, customers can access their applications from anywhere, enjoy the best user experience, and take advantages of a scalable cloud.

However, a high demand for cloud services also poses challenges to network operators who want to maintain their quality of the provisioned services and retain the prospective customers in a competitive market. If the users experience a low service quality—for example, if a video stream is frequently interrupted—users may stop using the service and search for alternatives, leading to a decrease in revenue for the service provider. Thus, now more than ever, operators need to be aware of what users expect from their services. In the paper by Dinh-Xuan et al., the authors design a virtual network function (VNF) using deep packet inspection and an algorithm to estimate the video buffer on the client to detect stalling events. From that point, they are able to measure the QoE based on a predefined model. To evaluate the performance of the VNF, the authors set up a testbed with the VNF deployed in a commercial cloud at different points of presence. They then evaluate the level of accuracy of the QoE estimation depending in relation to the concrete VNF placement.

The papers “*An Objective and Subjective Quality Assessment Study of Passive Gaming Video Streaming*” by Barman et al., “*Improving Video QoE with IP-over-ICN*” by Xylomenos et al., “*Dissecting the Performance of YouTube Video Streaming in Mobile Networks*” by Schwind et al., “*Game of Protocols: Is QUIC Ready for Prime Time Streaming?*” by Arisu et al., and “*MUSLIN: A QoE-Aware CDN Resources Provisioning and Advertising System for Cost-Efficient Multi-Source Live Streaming*” by Da Silva et al. focus on video streaming in the context of QoE.

Barman et al. examine video streaming dedicated to gaming, such as Twitch and YouTube Gaming. For the continued success of such services, it is important that the QoE remains high, which is usually assessed using subjective and objective video quality assessment methods. The results in the paper indicate that Video Multi-Method Assessment Fusion (VMAF) best predicts subjective video quality ratings, while Naturalness Image Quality Evaluator (NIQE) turns out to be a promising alternative as a no-reference metric in some scenarios. In the following articles, QoE for video streaming is examined in different scenarios. Xylomenos et al. deal with video streaming in information-centric networking. The work shows the results of the POINT research project. Schwind et al. perform a study in which over 1500 videos were streamed in mobile networks across Europe. Network and application data were collected and evaluated. The transport protocol QUIC was analyzed by Arisu et al., and Da Silva et al. specify a system for provisioning a video streaming architecture.

The final part of the Special Issue addresses Unified Communications platforms. In a survey, Barakovic et al. describe influencing parameters and key data for Unified Communications with regards to QoE. A deep and comprehensive understanding of the influencing factors and their impact on QoE for a given service is an essential precondition for successful QoE management with the overall goal of prominently optimizing end-user QoE, while making efficient use of network resources and maintaining a satisfied user base.

All in all, the works collected here cover a broad range of QoE research questions in relation to network management. This clearly indicates the importance this topic has and why it is suggested to put questions of QoE in network management under consideration in the future. The guest editors would like to thank the authors and also the reviewers for their great work. The Special Issue is the outcome of many efforts towards the research topic.

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