

Multimedia Quality of Experience (QoE)

Current Status and Future Requirements

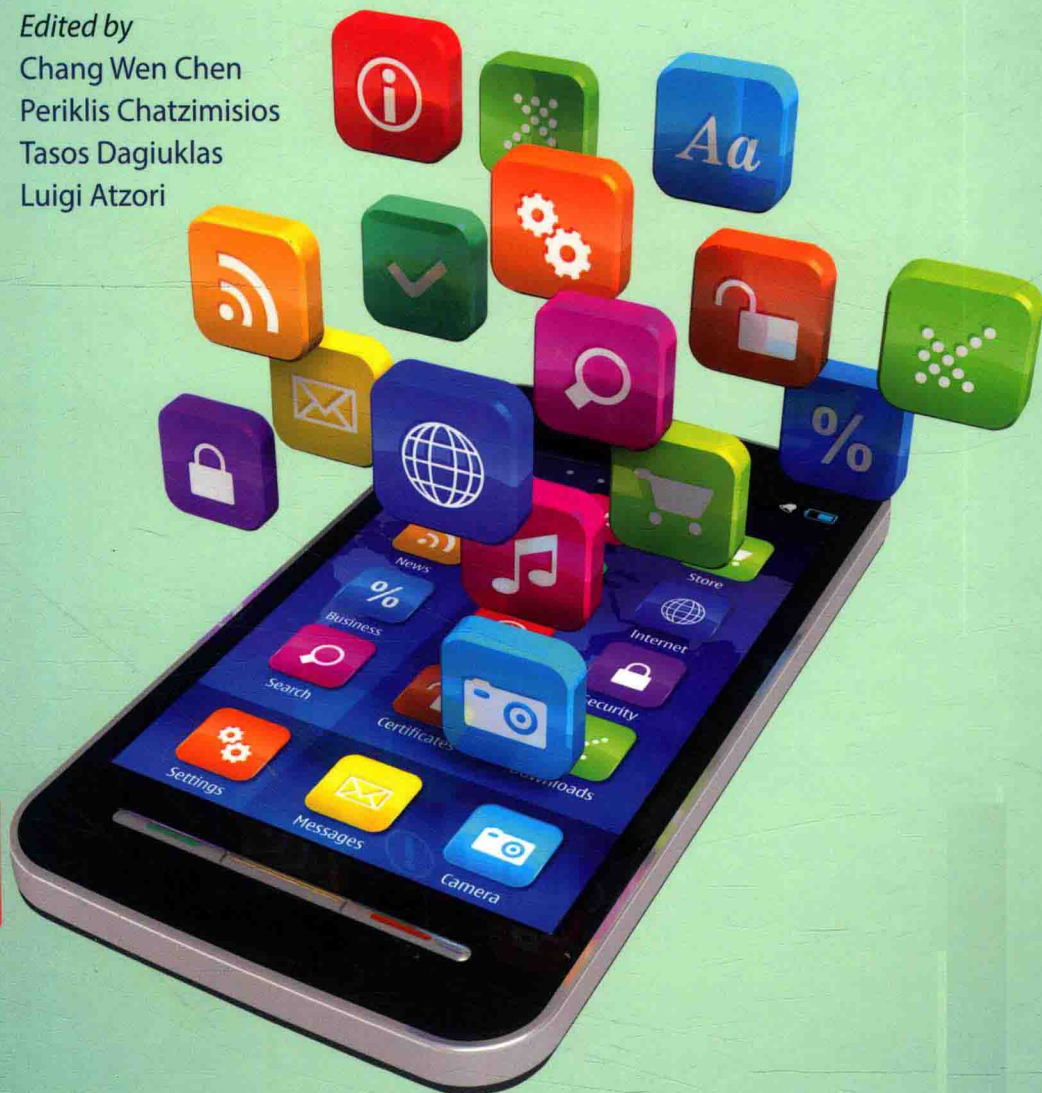
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MULTIMEDIA QUALITY OF EXPERIENCE (QoE)

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Preface

The effectiveness of distributed multimedia applications as well as mobile computing services – which are becoming dominant in the modern telecommunications era – is primarily based on the networking protocols and communication systems that deliver content to the end-user. Research and development in these protocols and delivery systems is currently being driven from a technical perspective for the end-user's benefit. However, it is a fact that the effectiveness of any service presentation is ultimately measured by the end-user's experience in terms of aesthetic quality, accuracy of information, system responsiveness, and many other impacting factors.

Quality of Experience (QoE) can be defined as the overall acceptability of an application or service strictly from the end-user's point of view. It is a subjective measure of end-to-end service performance from the user's perspective, and it is an indication of how well any system and network components meet the user's needs. Encompassing many different aspects, QoE rivets on the true feelings of end-users when they watch streaming video and podcasts, listen to digitized music, and browse the Internet through a plethora of methods and devices.

The problem of understanding and enhancing QoE in complex, distributed, and diverse environments has been and is continuing to be the subject of intense research investigation. Considerable effort has been devoted to assessing QoE via objective or subjective means for new and emerging multimedia services over modern fixed/mobile devices (e.g., IPTV/HDTV/3DTV, tablet video calls, 3D smartphones). Many researchers have looked at this as a usability problem, while others have studied the correlation between specific technological settings and user-perceived QoE. However, as of today, we do not know how to manage and control QoE in a diverse heterogeneous environment. The variables that affect QoE are just too many and span several interdisciplinary areas, including multiple technologies, but also psychological and sociological factors. Despite the effort devoted to QoE study, managing and controlling user QoE is still an open issue. Currently, services and applications offer QoE as a by-product of QoS management. Most commonly, QoE is achieved by over-provisioning and over-committing network and computational resources. Therefore, QoE is still a best-effort service, which is not a viable option when applications become multimodal (a complex combination of voice, video, and data). In these cases, resources have to be managed and controlled more accurately and proactively for a successful, QoE-assured, service delivery.

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Introduction

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During recent years, Quality of Experience (QoE) has established itself as a topic in its own right for both industrial and academic research. With its focus on the end-user in terms of acceptability, delight, and performance, it is about to take over the role of Quality of Service (QoS) as the key paradigm for provisioning and managing services and networks.

According to Wikipedia, “Quality in business, engineering and manufacturing has a pragmatic interpretation as the non-inferiority or superiority of something; it is also defined as fitness for purpose. Quality is a perceptual, conditional, and somewhat subjective attribute and may be understood differently by different people. Consumers may focus on the specification quality of a product/service, or how it compares to competitors in the marketplace.” Quality is a term that has been defined since ancient times. In philosophy, quality (from the Latin *qualitas*) is an attribute or property. The Ancient Greek philosopher Aristotle analyzed qualities in his logical work *Categories*, where all objects of human comprehension are classified into ten categories. Quality is one of these categories.

The term “quality” appears in various standardization fora. As an example, the International Organization for Standardization (ISO) has defined various standards related to quality, as indicated below:

1. ISO 8402-1986 standard defines quality as “the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs.”
2. ISO 9000 is a series of standards that define, establish, and maintain a quality assurance system for manufacturing and service industries. The ISO 9000 family addresses

various aspects of quality management and contains some of the ISO's best-known standards. The standards provide guidance and tools for companies and organizations who want to ensure that their products and services consistently meet customers' requirements, and that quality is consistently improved. Standards in the ISO 9000 family include the following:

- ISO 9001:2008 – sets out the requirements of a quality management system.
- ISO 9000:2005 – covers the basic concepts and language.
- ISO 9004:2009 – focuses on how to make a quality management system more efficient and effective.
- ISO 19011:2011 – sets out guidance on internal and external audits of quality management systems.

In order to lead in today's communications services market, network operators and content/service providers must offer customers the best user experience for premium services. In the past, networks have been examined objectively by measuring a number of criteria to determine network quality using QoS. In effect, QoS refers to the ability of a network to achieve more deterministic behavior, so data can be transported by optimizing parameters such as packet loss, delay, jitter, and bandwidth consumption. One should note that QoS does not consider the end-user's perception.

The perceived quality of media services is a crucial subject for service and content providers, with growing market competition. QoE for next-generation multimedia applications will be a combination of measurable QoS parameters considering both network and service environment and non-quality parameters. Network-based parameters include bandwidth, delay, jitter, packet loss, and PER (Packet Error Rate); service-oriented parameters (especially in the case of video services) may be metrics such as PSNR (Peak Signal-to-Noise Ratio) or MSE (Mean Square Error). Other factors that are not quality based but are important to quantify QoE include: screen size (e.g., mobile phone vs. large TV set), screen illumination (e.g., mobile terminal on a cloudy day vs. high contrast in a cinema environment), viewing distance, content (e.g., movie with action vs. news from a broadcaster), application (e.g., social networking vs. medical vs. distance learning), price (Skype videoconferencing vs. regular cellular video call), user profile (e.g., teenager vs. professional).

QoE is a new research topic that is currently being addressed by the various standardization fora. In the networked media delivery industry, guarantee of user experience is a key factor for many media-aware applications and services. Therefore, contrary to QoS, the concept of QoE has highlighted concerns for the media delivery industry – referring to “the overall acceptability of an application or service, as perceived subjectively by the end user.” The media delivery industry views end-user QoE monitoring as either “critical” or “very important” to their media initiatives; meanwhile, the foremost issue reported by industry is that the current QoE assessment solutions are too costly and not accurate enough to measure end-user experience.

QoE is a subjective metric that involves human dimensions; it ties together user perceptions, expectations, and experiences of applications and network performance. It is now widely acknowledged that the adoption of new multimodal media necessitates mechanisms to assess and evaluate perceived multimedia quality. QoE is defined as a metric to assess end-user experience at the perceptual pseudo-layer located above application and network layers.

Considerable effort has been devoted to assessing QoE via objective or subjective means for new and emerging multimedia services over modern fixed/mobile devices (e.g., IPTV/HDTV/3DTV, tablet, 3D smartphone). Many researchers have looked at this as a usability problem, while others have studied the correlation between specific technological settings and user-perceived QoE. As of today, we do not know how to manage and control QoE in a diverse heterogeneous environment. The variables that affect QoE are just too wide and too many. Hence, managing and controlling user QoE is still an open issue. Currently, services and applications offer QoE as a by-product of QoS management. Most commonly, QoE is achieved by over-provisioning and over-committing network and computational resources. Therefore, QoE is still a best-effort service. As applications become multimodal, resources will have to be managed and controlled more accurately and proactively for successful QoE-assured service delivery.

The overall structure of the book is as follows:

Chapter 2 outlines the QoE defining a user-centric concept of service quality. It provides QoE in various standardization fora such as ITU, ETSI, and IETF. It provides factors influencing QoE such as human Influencing Factors (IFs), system IFs, and context IFs. QoE is defined for different services such as speech, video, HTTP streaming, and cloud-based services. Moreover, it outlines a set of factors at the human, system, and context level that – either independently or interlinked – may influence QoE. Finally, the role of QoE in communication ecosystems is defined so that the user experience is optimized.

Chapter 3 reviews existing objective QoE methodologies and provides a taxonomy of objective quality metrics that may be grouped using the characteristics of the human visual system and the availability of the original signal. The chapter also presents the basic computational modules for perceptual quality metrics; quality metrics for images, video, and audio/speech; and joint audiovisual quality metrics.

Chapter 4 describes QoE for HTTP adaptive streaming services and presents QoE-based optimization strategies for Internet video. As a relatively new technology in comparison with traditional push-based adaptive streaming techniques, the deployment of Http Adaptive Streaming (HAS) services presents new challenges and opportunities for content developers, service providers, network operators, and device manufacturers. One of these important challenges is developing evaluation methodologies and performance metrics to accurately assess user QoE for HAS services, as well as effectively utilizing these metrics for service provision and optimization of network adaptation.

Chapter 5 emphasizes visual quality assessment covering both opinion-aware and opinion-unaware models. Most of the approaches are based on understanding and modeling the underlying statistics of natural images and/or distortions using perceptual principles. These approaches measure deviations from statistical regularities and quantify such deviations, leading to estimates of quality. The chapter presents the motivation and principles underlying such statistical descriptions of quality, and describes such algorithms in detail. Exhaustive comparative analysis of these approaches is provided, together with a discussion of the potential applications of no-reference algorithms.

The discussions so far have highlighted an increasing emphasis on QoE compared with QoS in audiovisual communication, broadcasting, and entertainment applications, which signals a transition from technology-driven services to user-centric (or perceived) quality-assured services. **Chapter 6** focuses on the issues underpinning the theoretical framework/models and

methodologies for QoE subjective and objective evaluation of visual signal communication services. Issues relevant to human visual perception and quality scoring or rating for television and multimedia applications are discussed, while readers are referred to the standards documents and/or other monographs regarding specific details of the aforementioned standards.

In recent years, the concept of QoS has been extended to the new concept of QoE, reflecting the experience of the end-user accessing the provided service. Experience is user- and context-dependent. However, subjective QoE evaluation is time consuming and not suitable for use in closed-loop adaptations. Hence, objective (rather than subjective) QoE evaluation enables optimal use of available resources based on the defined objective utility index. The main aim of achieving a satisfactory QoE for the users of a system can be afforded at different layers of the protocol stack. On this basis, **Chapter 7** presents a review of recent strategies for QoE monitoring, control, and management, including new solutions for a variety of different service types. The chapter also considers QoE management and control in different scenarios, including wireless scenarios, adaptive streaming over HTTP, and transmission to multiple users.

Finally, **Chapter 8** completes the book by providing conclusions drawn from each of the previous chapters.

QoE—Defining a User-Centric Concept for Service Quality

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2.1 Introduction

Quality of Experience (QoE) has, in recent years, gained a prominent role in the research and related work of several fields, notably networking and multimedia, but also in other domains such as network economics, gaming, or telemedicine. It has, to some extent, also become a buzzword for marketers, network operators, and other service providers.

Historically, its origins can be traced to several sources, which are nowadays converging toward a common, mature understanding of what QoE actually is. Several of the key ideas behind QoE can be traced several decades back to research done, for example, by telephone operators into the quality of calls made through their systems, and of TV broadcasters in a quest to understand how users perceived the quality of television pictures. The issues involved here relate not only to the transmission aspects, but also to coding and equipment ones.

With the advent of Internet-based multimedia communication services, such as Voice over IP (VoIP), video streaming, video conferencing, etc., the role of the network's performance (often referred to as Quality of Service, QoS) became more important in determining the perceived quality of those services, and thus a part of the networking community also became involved in the research of *perceived QoS*, which has itself evolved to be called Quality of Experience (QoE) within the networking community.

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