

Chapter 2

Background and Literature Survey

Abstract In this chapter, an overview of QoE is given and the current state-of-the-art background for QoE is described. Specifically, the definitions of QoE from different aspects and QoE influencing factors are first presented. Then, QoE assessment methods and QoE models are introduced in the following section. In addition, QoE management and control issues are also investigated. Last but not least the challenges of QoE in 5G wireless networks are discussed.

2.1 QoE Definition

As far as we know, there is no common sense about how to define QoE. Given the description of Wikipedia, QoE is considered as a subjective measure of customer's experiences with a service [1]. That means different types of QoE are involved in various services. For example, when a user shops online, QoE is associated with the process of purchasing and the service. When a user has a meal or haircut, what involves QoE is the process of user being in service.

In this book, we discuss QoE in the scenes of wireless communications. For example, users call others using a mobile phone or browse the web using a tablet computer or watch online video via a notebook. In the process of being in service, users get certain service experiences. In such a scenario, a number of international organizations proposed the following definitions:

According to ITU, QoE is described as *the overall acceptability of an application or service, as perceived subjectively by the end user* [2], while the European Telecommunications Standards Institute (ETSI) defines QoE as a measure of user performance based on both objective and subjective psychological measures of using an ICT service or product [3]. Recently, based on the results of the research project COST Action IC1003, EU Qualinet Community proposes the definitions of QoE as *the degree of delight or annoyance of the user of an application or service*. In the context of communication services, QoE depends on the service, content, device, application, and context of use [4].

In addition, different researchers also give different definitions of QoE according to their own understanding. In [5], Kilkki broadens the concept of QoE to the basic

character or nature of direct personal participation or observation. Khalil believes ITU definition of QoE is hard to involve objective human factors. Therefore, he puts forward his own definition: *a blueprint of all human subjective and objective quality needs and experiences arising from the interaction of a person with technology and business entities in a particular context* [6]. Pyykko presents the definition of QoE in the manner of a mobile video scenario: *the binary measure to locate the threshold of minimum acceptable quality that fulfills user quality expectations and needs for a certain application or system* [7].

Although there is no universal answer for what QoE is, we can draw the conclusion that: QoE is a kind of user satisfaction description during the process of interactions between users and services. That is, users get some subjective feelings which is assessed by QoE.

2.2 Influencing Factors

QoE is a multidisciplinary research topic based on social psychology, cognitive science, economics, engineering science, etc. Researchers always limited QoE only in some situations which they were concerned about, making it difficult to understand QoE factors from a global perspective. It is indicated that the video codec parameters along with user expectations should be considered when evaluating the video services and that the context factors such as actual environmental context and social cultural context also play a critical role [8, 9]. T. Hoßfeld et al. of [10] discover that current page loading time as well as history page loading time has impact on user QoE for web browsing services, which can be summarized as memory effect that current experience is highly related with history experience. A conclusion is drawn in [11] that user's mental mood, context, characteristics of mobile devices, network access capacity will all influence user QoE to different extents. For a better and more comprehensive understanding of QoE influencing factors, K. Kilkki and K.U.R. Laghari consider QoE from the perspective of communication ecosystem [6]. Communication ecosystem is defined as the systematic interaction of living (human) and non-living (technology, and business) in a particular context [5], which is first put forward by K. Kilkki and then refined by K.U.R. Laghari. In this ecosystem, QoE influencing factors can be divided into four domains: human domain, technology domain, business domain and context domain. A summary of QoE factors studied in existed literatures is given in Table 2.1.

However, it is still a challenge to manage these QoE influencing factors. First, it is difficult to quantize some of these factors which mainly include subjective factors such as interests, expectations, etc. It is also hard to analyze and quantize the relationship of QoE with respect to these factors. Second, some of these factors such as some contextual factors (quiet or noisy) are intricate to be obtained in the real application scenarios. Thirdly, it is difficult to accurately model the relationship between these factors and QoE, and we should research more on how those factors influence QoE synthetically. Hence, further study is needed to analyze QoE influencing factors.

Table 2.1 Summary of QoE factors

	Application scenario	Factors considered	Details
[12]	Not given	Technical performance	Application, service, network, device performances
		Usability	Application, network, device usability
		Subjective assessment	Application, network, device assessment
		User expectation	Decided by application types, user personality and history experiences
		Context	Physical, social, technical, cultural context
[13]	Video, VoIP, multi-player game	Application dimension	Content type, video codec resolution, frame rate
		Resource dimension	Network resource parameters (delay, jitter, packet loss rate), hardware resource parameters (memory, screen resolution)
		Context dimension	Light, position, time, social environments
		User dimension	Individual property, preference, expectation, requirement and mental mood
[4]	Multi-media services	Human dimension	Human property, social and economical background, physical and psychological status
		System dimension	Content parameters (content type), media parameters (encoding, sampling rate, frame rate), network parameters (bandwidth, delay, jitter), device parameters (memory, screen resolution)
		Context dimension	Physical context (position, time), economical context (cost, brand image), task context (single or multi task)

(continued)

Table 2.1 (continued)

	Application scenario	Factors considered	Details
[6]	Communication systems	Technical domain	Service factors (service content), network factors (delay, jitter, throughput), device factors (device feature, function)
		Business domain	Consumer business model factors (advertisement, brand effect), inter-company business model (commercial strategy), intra-company business model factors (service level agreement)
		Human domain	Population property (age, gender), role factor (consumer, user)
		Context domain	Real context (time, position, climate), virtual context, social context (social relationships)
[14]	Mobile video	Human domain	Population attribute, requirements, mood, expectations, motivations
		System domain	Device factor (memory, battery life, screen size), network factor (network bandwidth, channel condition), video provider factor (encoding algorithm, business model)
		Context domain	Physical context (position, time), social context (alone or in groups), task context (single or multi task)

2.3 Assessment Method

In general, QoE evaluation methods can be divided into three categories, that is, subjective assessment, objective assessment and hybrid assessment. The detailed descriptions are as follows.

2.3.1 *Subjective Assessment*

Subjective evaluation method is conducted based on psychological/visual experiments, which is the most reliable but also the most complicated and expensive method of evaluating user' QoE. It has been researched for many years, giving researchers deeper understandings of QoE subjective dimension. Most of the output of the subjective evaluation experiment is the opinion score when the user is being served or has been served, and these scores are ultimately averaged into Mean Opinion Score (MOS) [15]. Meanwhile, ITU also sets some corresponding standards of conducting the experiment. The QoE evaluation for video services is the most complicated and some standards are set to conduct the experiment of evaluating subjective video quality. For example [16], the different experiment settings include Single Stimulus (SS), Double Stimulus Impairment Scale (DSIS), Double Stimulus Continuous Quality Scale (DSCQS), Single Stimulus Continuous Quality Evaluation (SSCQE), Simultaneous Double Stimulus for Continuous Evaluation (SDSCE), and Stimulus Comparison Adjectival Categorical Judgment (SCACJ). These settings are similar and the changes mainly reflect in metrics, video reference, video length, number of users, number of observers, etc.

The results of subjective evaluation method are the most accurate, owing to a direct gain of data from the users. Nonetheless, the human cost of this method is too high and cannot be used to automation and real-time situation.

2.3.2 *Objective Assessment*

Objective evaluation method is defined as using separately the measurement of objective quality to evaluate the subjective quality [17]. In other words, objective evaluation method provides a mapping model from the objective quality to the subjective quality. A variety of objective quality evaluation and prediction models have been studied. Each model has its applicable scenarios and corresponding constraints.

There are many objective evaluation methods to assess QoE which can be generally classified into three kinds: full reference, no reference and partial reference [18]. We take the video business for example to illustrate the difference of these three categories. The full reference method is to compare reference video and test video frame by frame while no reference method is to analyze test video only without reference video. Partial reference method is the compromise of the first two which extracts some characteristics from the reference video and then analyzes the test video according to these characteristics.

The advantage of an objective evaluation method lies in its convenience and tractability. Researchers only need concern about QoS parameters which can be measured and related mathematical problems. It also has its disadvantage of inaccuracy, i.e., the QoE obtained is only an approximation rather than a precise value for each user.

2.3.3 *Hybrid Assessment*

Except the above two grading methods, there is another method of mixing both and evaluating users' QoE more accurately which is Pseudo Subjective Evaluation Method (PSQA) [19]. This method is a kind of method which is based on statistical learning and uses the Random Neural Network (RNN). In its evaluation, it usually needs to go through four stages:

- Generating influencing factors. At this stage, a lot of service samples after parameter optimization will be generated in the database.
- Measuring the subjective quality. At this stage, testers of the experiment will grade service samples of step 1.
- Training the neural network model. This is the core of this approach. Data collected by the former two steps will constitute the training data set and is used to train the random neural network. The random neural network can be substituted by other machine learning tools, such as the Bayesian network, the Support Vector Machine (SVM).
- Using the neural network model for evaluation. After the third step, a trained RNN will be obtained. So in the evaluation, it is only needed to put the target service data into RNN. Then it can calculate the corresponding QoE of the user.

PSQA is a kind of widely used QoE evaluation methods, applied in [20–26].

2.4 QoE Models

2.4.1 *Mathematic Model*

Mathematical models are one of the traditional ways which map the influencing factors to the users' QoE. The data of related factors and users' QoE are obtained in a laboratory environment in general. Researchers conduct statistical analysis to formulate the specific relationship between QoE and the parameters. Some models which belong to this type are depicted below.

The E-model recommended by ITU-T SG12 is a classic linear model which is used to predict the overall quality in a voice conversation at the network planning stage. Although E-model is a mature one, it is restricted in voice service over telecommunication networks.

Peter Reichl argues that QoE has a logarithmic nature based on the Weber-Fechner Law (WFL) [27]. The basic idea of WFL is that the human sensory system can be traced back to the percipience of so-called “just noticeable differences” and the differential perception is directly proportional to the relative change of physical stimulus. By taking network QoS as stimulus and QoE as the perception, we will obtain a logarithmic relationship mapping from QoS to QoE. Although the logarithmic model is very convincing which lies in that it is based on the psychological theory, there are

limitations that the input QoS should be viewed as a physical stimulus. However, the fact is that many factors could not be regarded as physical stimulus. Furthermore, this model only processes limited numbers of factors, which indicates that it cannot be extended.

Another mathematical QoE model is based on the “IQX hypothesis” in [28], which argues that a change of QoE depends on both the identical QoS changes and the actual level of the QoE. After the integration of the formulation of QoE and QoS, a negative exponential function of QoE w.r.t QoS impairment factors such as packet loss can be acquired. It is found that QoE relates to the QoS impairment factors such as packet loss or network delay in the model of IQX hypothesis, while QoE is related to the perceivable QoS resource like bandwidth or bit rate in the logarithmic model.

2.4.2 Machine Learning Model

In recent years, researchers find out that it is hard to formulate the relationship between influencing factors and users’ QoE explicitly by a mathematic model in most cases, not to mention the unobtainable system parameters. Machine learning methods are widely applied to solve the problem of the connotative relationship between QoE model and the influencing factors.

The Recurrent Neural Network (RNN) model is a classical one of machine learning models which is applied in the Pseudo Subjective Quality Assessment (PSQA) assessment. RNN is made up of a group of neurons which can communicate with each other by signals. In the RNN network, the state of every neuron is a nonnegative integer named potential and it can be changed by the signals coming from other neurons. At the end of the training, every neuron shall have a computed potential. Accordingly, the QoE assessment will be obtained by synthesizing the potentials of the RNN.

In [29], T. Hoßfeld et al. uses Support Vector Machine (SVM) method to assess QoE. A hyperplane can be calculated according to training set data and validated with test data set, then the trained SVM model will be applied to evaluate user current QoE with input factors including current page loading time and user history ratings.

Besides, Decision Tree (DT), another machine learning model, can also be applied to build QoE model. DT is a widely used classification model and the relationship between QoE and researching influencing factors can be learned by decision tree building and pruning as in [30]. In [30], a training data set with input (continuous parameters including time, spatial, bit rate, frame rate information) and output (binary values indicating whether current quality is acceptable or unacceptable for users) is utilized to train the tree model after some pre-processing measures. QoE model established in this way can then be used to predict user’s attitude towards the service and [30] illustrates that QoE prediction by DT is more precise than that by SVM.

To sum up various QoE models, a comparison for QoE modeling approach is given in Table 2.2.

Table 2.2 Comparison for QoE modeling approach

Method	Type of service	Factors	Metric	Precision	Complexity
Logarithmic function [31]	File downloading	Bandwidth, file size	MOS	RMSE = 0.063	Low
Exponential function [32]	VoIP	Packet Loss	MOS	R = 0.998	Low
		Rearrangement	MOS	R = 0.993	
	Web browsing	Waiting time	MOS	R = 0.966	
		Bandwidth	MOS	R = 0.951	
SVM (Support Vector Machine) [30]	Video (Cellphone, Tablet PC, PC)	Time, space, bit rate, frame rate	Acceptability (Binary)	Precision 88.592.85 % 89.382.77 % 91.452.66 %	Medium
Decision tree [30]	Video (Cellphone, tablet PC, PC)	Time, space, bit rate, frame rate	Acceptability (Binary)	Precision 93.551.76 % 90.292.61 % 95.462.09 %	Medium
Random neutral network [24]	Video	Packet loss, packet loss time	MOS	Unaccounted	High

2.5 QoE Management and Control

Based on the QoE models and real-time QoE monitoring, intelligent QoE management can be further conducted by network operators based on actual network conditions. Appropriate measures are taken according to the network problem and optimization methods. On one aspect, quality improvement of a current flow, or maximization of system average QoE can be achieved by reasonable network controls, e.g. admission control, priority decision, congestion control and packet scheduling. A common used way to optimize QoE is to perform cross layer optimization (CLO). For example, in [28], a cross-layer model is established for multimedia traffic in mobile communication systems. QoE is obtained by mapping from the network layer parameter symbol rate. The maximized QoE can be achieved by adjusting the symbol rate for each user with a greedy algorithm. A wise resource allocation strategy with QoE awareness can be realized to efficiently save network resources without user experience degradation.

Similar optimization scheme for wireless video transmission is provided in [21] for stream transmission. First a video stream is divided into two sub-streams using multiple description coding scheme and then two paths with the highest available bandwidth are selected by the server to send these two streams to the client. User QoE is assessed by PSQA based on packet loss rate when two sub-streams arrive at the client. The server will make a decision to redirect the two sub-streams over new

paths with higher available bandwidth if the assessed QoE cannot meet the users' requirement.

Selecting a proper access point is another way to improve QoE. In [33], Kandaraaj presents a user-based and network assisted scheme for network selection in wireless IEEE 802.11 technology. In the scheme, a PSQA tool is implemented to evaluate users QoE for each access points (AP). When a new user comes, he or she will get a score based on the evaluated QoE and status from each AP. So a better quality of connection can be chosen, resulting in a higher QoE for the user.

In some literatures, researchers consider QoE optimization from a system architecture level. Latre et al. in [34] proposed a QoE-based network management architecture in multimedia services with a three-plane approach (a monitor plane to monitor network parameters, a knowledge plane to determine the optimal QoE decisions and an action plane to conduct decided actions). Optimization actions include applying Forward Error Correction (FEC) to reduce the packet loss caused by errors on a link and switching to different video bit rate to avoid congestion or to obtain a better video quality.

Additionally, QoE-driven network access selection control, handover decision control and rate adaptation control are also studied in many literatures as [33, 35, 36].

2.6 Challenges of QoE in 5G

In the era of 5G, a fiber-like access data rate and a “zero” latency user experience is expected to be provided. Delivering a consistent experience is required across a variety of scenarios including the cases of ultra-high traffic volume density, ultra-high connection density, and ultra-high mobility. 5G will also be able to provide ability on intelligent optimization based on services and users awareness, and improve energy and cost efficiency by over a hundred of times. These expectations above all inspire us to achieve the vision of 5G—“Information a finger away, everything in touch.”

To realize these expectations, several new technologies, e.g., heterogeneous networks, millimeter-wave (mm-wave), device-to-device (D2D)/machine-to-machine (M2M), cloud-based radio access network (C-RAN), and smart devices are addressed in the 5G network to cater to the notable trends of 5G, such as explosive growth of data traffic, massive increase in the number of interconnected devices, continuous emergence of new services and application scenarios, etc., which will inevitably impact user QoE, positively or negatively. New challenges are raised for QoE management in 5G and better QoE performance is capable to be achieved if these issues are well handled.

2.6.1 Challenges from Various Communication Scenarios

In 5G, the scenarios of communications are greatly broadened, typically, e.g., when people are working or at entertainment, stationary or moving, at home or in stadiums, subways, highways. For the various scenarios above all, a consistent QoE is desired to achieve for end users. However, QoE management is significant but challenging in the high complicated scenario including ultra-high traffic volume density, ultra-high connection density, and/or ultra-high mobility, etc. For example, it is important to maintain a satisfactory level of service continuity in high speed scenario. Similarly, improving QoE is also important in the ultra-dense small cells scenarios. Those requirements are demanding more appropriate mobility management strategies. Therefore, how to control QoE to satisfy the various requirements in the various scenarios needs to be comprehensively investigated accordingly. A QoE-based dynamic resource allocation for mobile cloud computing environment to satisfy the requirements of end users is proposed in [37]. In [38], a QoE-based resource allocation problem is pointed out in a D2D scenario, where user QoE is evaluated from the both perspectives of stall events and video qualities. While key QoE influencing factors and user expectations may vary for distinct scenarios, QoE becomes a comprehensive metric and an important topic about how to provide personalized user experience through a more refined resource management.

2.6.2 Challenges Due to Emerging Applications

The cellular technology has changed the way we communicate and our social life [39]. Over the past era of 2G, phone call and SMS are the main functions of the mobile terminals. Today 3G/4G become mainstream and the smart terminals are so popular that makes the applications more diverse, such as mobile game, mobile music, mobile video, etc. In the future of 5G, more stunning new technologies and applications will be integrated and enter into human life such as virtual reality, 3D videos etc., which accordingly leads to two challenges for QoE research.

One challenge is the demand to develop appropriate and reasonable QoE models for the emerging applications. Due to the rapid increase of intelligent terminal on capacity and performance, there are a large number of new applications emerging [40]. For example, unlike traditional terminals, the new smart wearable terminals have various forms, such as smart watches, smart glasses, sports wristbands, smart jewelry, etc. Meanwhile, mobile services, which are based on the intelligent terminals, are no longer limited to telephone, text messaging and video services, but involved in medical monitoring, interactive games, information exchange and other emerging businesses. However, the state-of-the-art research works on QoE focus on VoIP, video, and HTTP services. Further study is needed for the new developed applications in order to build up a proper QoE model.

Imagine a medical monitoring service running on a wearable equipment, which monitors blood pressure, displays status on pulse and even identifies whether the user has an irregular heartbeat. In this case, the QoE model should utilize the individual user's information to make accurate decisions to achieve a high level of QoE. For example, for a user with hypertension according to the historical records, when symptoms appear, the system is required to ensure realtime transmission and a certain level of reliability to activate the emergency alarm and other corresponding medical-related services. It is essential to combine the various factors to guarantee QoE.

The smart mobile terminals for human life provide a great convenience, so that people are increasingly dependent on their smartphones. Consequently, the people are increasingly sensitive to the life of the battery. If a service consumes too much power, the users will have very bad feelings, which leads to a lower QoE degree. As a result, the energy efficiency is also an important QoE factor in 5G.

2.6.3 Challenges Related to Big Data

In the 5G era, due to the network data traffic explosion and applications diversification, a huge amount of data is expected to be transferred during the mobile communications [41], which leads to some new challenges in the QoE management field.

One challenge concerning big data is the subjective QoE influencing factors. The main research issue on this topic includes two aspects. The first is the subjective QoE factors including a user specific preference, users' mood, attention, expectation etc. The factors above all are qualitative and highly related with social psychology and cognitive science fields. In order to use these factors in practical applications, some problems should be concerned including: (1) how to quantize these factors? (2) how to normalize these factors after quantization? and (3) how to capture and monitor these factors in a practical real-time application scenario. In addition, it is difficult for a certain application/service to decide which factors are essential and which are not. How to smartly model QoE given a service/application is quite important issue for further investigations.

Another challenge is about QoE evaluation from the perspective of big data. Most existing research on subjective QoE evaluation is conducted based on users' direct feedback of the service. It is suitable for a relative small scale of evaluation. When more data is needed which makes the results more reliable, it is too expensive and even unaffordable by using the above evaluation ways. With the development of big data technologies, many user specific information is preserved and can be used to infer the user's subjective feelings, which is the basis of QoE. As an example of online video services, the viewing time, the total number of clicks on a certain video, the number of daily accesses etc. could be measured and analyzed for user's QoE. For Web services, the online reviews is the knowledge resources in which the relevant features could be extracted reflecting user experience feedback on the web services. Many similar research works had been carried out in the manner of

the data-driven way in other areas such as natural language processing (NLP) and unstructured data processing. Thus, it is meaningful to use data-driven approaches in the topic of mobile QoE in the future.

It is also challenging to handle the security and privacy related to intelligent terminals, which comes along with the trend that intelligent terminals play a key role in 5G, especially in the big data era. For those who use intelligent terminals, intentionally or unintentionally, their personal information such as contacts, download histories, application usage records, the system logs, etc., are saved in either client end or cloud end. It is of course beneficial to make use of those data to facilitate QoE. But those data are possibly used for the wrong purpose, even illegal use. How to balance the protection requirement of user's privacy and the QoE management usage on the personalized data is one of the major challenges.

2.7 Summary

In this chapter, an overview for the state-of-the-art QoE is given, including QoE influencing factors, QoE assessment methods, QoE models, QoE management and control applications, and QoE challenges on 5G. QoE definitions are summarized at first. The QoE influencing factors are then discussed in a systematic way, followed by the sequential part which QoE assessment methods are introduced and QoE models are summarized. QoE management and control issues are also discussed in this chapter. Furthermore, the challenges of QoE in 5G wireless networks are discussed finally.

References

1. Quality of experience. <http://www.wikipedia.org>.
2. ITU Telecommunication Standardization Sector and OF ITU. "Definition of quality of experience (QoE), liaison statement". *ITU-T Recommendation P.10/G.100, Amd 1*, 2007.
3. European Telecommunication Standards Institute TC HF (Human Factors). "Quality of Experience (QoE) requirements for real-time communication services". Technical report, European Telecommunication Standards Institute, 2010.
4. P. Le Callet, S. Moller, and A. Perkis. "Qualinet white paper on definitions of quality of experience (QoE)", 2013.
5. K. Kilki. "Quality of Experience in Communications Ecosystem". *J. UCS*, 14(5):615–624, 2008.
6. K. U. R. Laghari and K. Connelly. "Toward total quality of experience: A QoE model in a communication ecosystem". *Communications Magazine, IEEE*, 50(4):58–65, 2012.
7. S. Jumisko-Pyykkö, V.K. Malamal Vadakital, and M.M. Hannuksela. "Acceptance threshold: A bidimensional research method for user-oriented quality evaluation studies". *International Journal of Digital Multimedia Broadcasting*, 2008.
8. H. Rifai, S. Mohammed, and A. Mellouk. "A brief synthesis of QoS-QoE methodologies". In *Programming and Systems (ISPS), 2011 10th International Symposium on*, pages 32–38. IEEE, 2011.

9. S. Möller, A. Raake, M. Wältermann, and N. Côte. "Towards a universal scale for perceptual value". In *Quality of Multimedia Experience (QoMEX), 2010 Second International Workshop on*, pages 142–146. IEEE, 2010.
10. T. Hoßfeld, S. Biedermann, R. Schatz, A. Platzer, S. Egger, and M. Fiedler. "The memory effect and its implications on Web QoE modeling". In *Proceedings of the 23rd International Teletraffic Congress*, pages 103–110. International Teletraffic Congress, 2011.
11. S. Ickin, K. Wac, M. Fiedler, L. Janowski, et al. "Factors influencing quality of experience of commonly used mobile applications". *Communications Magazine, IEEE*, 50(4):48–56, 2012.
12. S. Baraković, J. Baraković, and H. Bajrić. "Qoe dimensions and QoE measurement of NGN services". In *Proc. Telecommunications Forum*, 2010.
13. L. Skorin-Kapov and M. Varela. "A multi-dimensional view of QoE: the ARCU model". In *in Proc. International Convention MIPRO*, pages 662–666. IEEE, 2012.
14. W. Song, D. Tjondronegoro, and M. Docherty. "Understanding user experience of mobile video: framework, measurement, and optimization". INTECH Open Access Publisher, 2012.
15. ITUT Rec. "P. 800.1, mean opinion score (mos) terminology". *International Telecommunication Union, Geneva*, 2006.
16. I. Rec. "Bt. 500-11, methodology for the subjective assessment of the quality of television pictures". *International Telecommunication Union*, 2002.
17. W. Cherif, A. Ksentini, D. Négru, and M. Sidibé. "A_PSQA: Efficient real-time video streaming QoE tool in a future media internet context". In *Proceedings of 2011 IEEE International Conference on Multimedia and Expo (ICME)*, pages 1–6. IEEE, 2011.
18. Fernando Kuipers, Robert Kooij, Danny De Vleeschauwer, and Kjell Brunnström. "A Techniques for measuring quality of experience". Springer, 2010.
19. G. Rubino. "The PSQA project". *INRIA Rennes*, <http://www.irisa.fr/armor/lesmembres/Rubino/myPages/psqa.html>, 2010.
20. M. Ghareeb and C. Viho. "A multiple description coding approach for overlay multipath video streaming based on QoE evaluations". In *Proceedings of International Conference on Multimedia Information Networking and Security (MINES)*, pages 39–43. IEEE, 2010.
21. M. Ghareeb and C. Viho. "Hybrid qoe assessment is well-suited for multiple description coding video streaming in overlay networks". In *Proceedings of 2010 Eighth Annual Communications Networks and Services Research Conference (CNSR)*, pages 327–333. IEEE, 2010.
22. K. Piamrat, A. Ksentini, J. Bonnin, and C. Viho. "Q-DRAM: QoE-based dynamic rate adaptation mechanism for multicast in wireless networks". In *Proceedings of IEEE Global Telecommunications Conference*, pages 1–6. IEEE, 2009.
23. X. Sun, K. Piamrat, and C. Viho. "QoE-based dynamic resource allocation for multimedia traffic in IEEE 802.11 wireless networks". In *Proceedings of 2011 IEEE International Conference on Multimedia and Expo (ICME)*, pages 1–6. IEEE, 2011.
24. K. Piamrat, C. Viho, J. Bonnin, and A. Ksentini. "Quality of experience measurements for video streaming over wireless networks". In *Proceedings of 2009 Sixth International Conference on Information Technology: New Generations*, pages 1184–1189. IEEE, 2009.
25. K. Piamrat, K. D. Singh, A. Ksentini, C. Viho, et al. "QoE-aware scheduling for video-streaming in high speed downlink packet access". In *Proceedings of 2010 IEEE Wireless Communications and Networking Conference (WCNC)*, pages 1–6. IEEE, 2010.
26. P. Reichl, B. Tuffin, and R. Schatz. "Economics of logarithmic quality-of-experience in communication networks". In *Proceedings of 2010 9th Conference on Telecommunications Internet and Media Techno Economics (CTTE)*, pages 1–8. IEEE, 2010.
27. P. Reichl, S. Egger, R. Schatz, and A. D'Alconzo. "The logarithmic nature of QoE and the role of the Weber–Fechner law in QoE assessment". In *Proceedings of IEEE International Conference on Communications (ICC)*, pages 1–5. IEEE, 2010.
28. S. Khan, S. Duhovnikov, E. Steinbach, and W. Kellerer. "MOS-based multiuser multiapplication cross-layer optimization for mobile multimedia communication". *Advances in Multimedia*, 2007(1):1–11, 2007.
29. T. Hosfeld, S. Biedermann, R. Schatz, A. Platzer, S. Egger, and M. Fiedler. "The memory effect and its implications on Web QoE modeling". In *Proceedings of 2011 23rd International Teletraffic Congress (ITC)*, pages 103–110, 2011.

30. V. Menkovski, A. Oredope, A. Liotta, and A. C. Sánchez. "Predicting quality of experience in multimedia streaming". In *in Proc. the 7th International Conference on Advances in Mobile Computing and Multimedia*, pages 52–59. ACM, 2009.
31. P. Reichl, S. Egger, R. Schatz, and A. D'Alconzo. "The logarithmic nature of QoE and the role of the Weber–Fechner Law in QoE assessment". In *Proceedings of 2010 IEEE International Conference on Communications (ICC)*, pages 1–5. IEEE, 2010.
32. M. Fiedler, T. Hossfeld, and P. Tran-Gia. "A generic quantitative relationship between quality of experience and quality of service". *IEEE Network*, 24(2):36–41, 2010.
33. Kandaraj Piamrat, Adlen Ksentini, César Viho, and Jean-Marie Bonnin. "AqoE-aware admission control for multimedia applications in ieee 802.11 wireless networks". In *Vehicular Technology Conference, 2008. VTC 2008-Fall. IEEE 68th*, pages 1–5. IEEE, 2008.
34. S. Latré, P. Simoens, B. De Vleeschauwer, et al. "An autonomic architecture for optimizing QoE in multimedia access networks". *Computer Networks*, 53(10):1587–1602, 2009.
35. N. Amram, B. Fu, G. Kunzmann, T. Melia, D. Munaretto, S. Randriamasy, B. Sayadi, J. Widmer, and M. Zorzi. "QoE-based transport optimization for video delivery over next generation cellular networks". In *in Proc. IEEE Symposium on Computers and Communications (ISCC)*, pages 19–24. IEEE, 2011.
36. S. Thakolsri, W. Kellerer, and E. Steinbach. "QoE-based cross-layer optimization of wireless video with unperceivable temporal video quality fluctuation". In *in Proc. IEEE International Conference on Communications (ICC)*, pages 1–6. IEEE, 2011.
37. W. Ying, M. Sachula, C. Yongce, S. Ruijin, Xinshui W., and Kai S. "Multi-leader multi-follower stackelberg game based dynamic resource allocation for mobile cloud computing environment". *Wireless Personal Communication*, to appear.
38. Hao Zhu, Yang Cao, Wei Wang, Boxi Liu, and Tao Jiang. "Qoe-aware resource allocation for adaptive device-to-device video streaming". *Network, IEEE*, 29(6):6–12, 2015.
39. G. Fettweis and S. Alamouti. "5G: Personal mobile internet beyond what cellular did to telephony". *IEEE Communications Magazine*, 52(2):140–145, 2014.
40. B. Bangerter, S. Talwar, R. Arefi, and K. Stewart. "Networks and devices for the 5G era". *IEEE Communications Magazine*, 52(2):90–96, 2014.
41. W. Hummer, S. Schulte, P. Hoenisch, and S. Dustdar. "Context-Aware Data Prefetching in Mobile Service Environments". In *Proc. IEEE Fourth International Conference on Big Data and Cloud Computing (BdCloud)*, pages 214–221, 2014.

QoE Management in Wireless Networks

Wang, Y.; Zhou, W.; Zhang, P.

2017, XII, 60 p. 26 illus., 12 illus. in color., Softcover

ISBN: 978-3-319-42452-1