Chapter 1
Introduction

Abstract In recent years, with the advancement of wireless communication networks, there is an increasing demand especially on mobile Internet services. Users' Quality of Experience (QoE) becomes one of the main issues for future wireless networks when designing personal and customized services to maintain and attract more users. Furthermore, the research on wireless resource management is moving forward from enhancing objective system performance to improving users' subjective experience. A better QoE-oriented resource allocation policy is preferred and many new challenges are brought out accordingly, including how to quantify and measure QoE, how to design a set of unified wireless resource management strategies and how to make use of a huge amount of available data to derive an optimal QoE model, etc. Therefore, personalized QoE management, efficient estimation, and optimal resource allocation need to be studied and implemented in future wireless networks.

1.1 Mobile Technology Evolution

With the mobile terminal greatly changing our lives over the past decades, the mobile networks and services are playing an increasingly important role and become indispensable for many people. In addition to traditional voice communication service, many new data services are emerging and become popular in the mobile terminal. As the Cisco Visual Network Index (VNI) reported, the number of global mobile users is expected to reach 5.2 billion in 2019 [1].

One reason for this phenomenon is the significant advance in the mobile network technology era. In the last fifty years, the tremendous development of mobile network technologies has been witnessed together with the evolution of mobile services. The Second Generation technologies (2G), e.g., Global System for Mobile communications (GSM) and Code Division Multiple Access (CDMA), have extended the voice-only service to data access service such as Short Messaging Service (SMS) and Wireless Application Protocol (WAP) services. Afterwards, the Third Generation (3G) technologies, e.g., Wideband CDMA (WCDMA) and Time Division Synchronous CDMA (TD-SCDMA), have improved the data access greatly and led

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to the variety of mobile multimedia services. The Orthogonal Frequency Division Multiple Access (OFDMA) technology enables the Long Term Evolution (LTE) and LTE Advanced (LTE-A), i.e., the Forth Generation (4G), to provide an even better Quality of Service (QoS) to users with improved data rate. The standardization process for the 4G technologies (LTE, LTE-Advanced) was finished in 2011, and LTE-A networks for business use have been deployed around the world today [2]. In addition, many projects are driven by different countries and organizations around the world for the Fifth Generation (5G) mobile technologies [3, 4]. And in 2015, the relevant testing was launched by both Huawei [5] and Ericsson [6].

1.2 Motivation for Personalized QoE Management

During the development of 5G, it is a consensus that QoE is one of the major issues, considering the user acceptability. In general, QoE is based on the quality of interactions between users and applications, while QoS depends on the quality of interactions between applications and networks. The technologies based on QoE can satisfy the requirements of end users in a better manner than QoS. In the era of 2G, the main service of communication systems is voice service. Thus, the QoS parameters such as Peak Signal to Noise Ratio (PSNR), delay, and coding rate, etc. are well suited to evaluate the quality of communication systems. In 3G and 4G, however, with the popularity of smart phones, there has been a large number of different types of wireless data services, supported in particular by mobile Internet applications. According to the report released by International Telecommunication Union (ITU), by the end of 2014, mobile Internet traffic accounted for 12 % of the total Internet traffic [7]. In China Mobile Intellectual Property Center (CMIPC), top ten applications of mobile Internet are summarized including mobile social, mobile advertise, mobile game, mobile TV, mobile electronic reading, mobile location services, mobile search, mobile content sharing, mobile payment and mobile e-commerce [8]. In addition, a large amount of novel mobile Internet applications are emerging and growing greatly. More complicated parameters are thereafter designed to represent video quality, such as Video Structural Similarity (VSSIM), Video Quality Metric (VQM), and Moving Picture Quality Metric (MPQM).

However, those parameters are still not good enough for the new services, especially when it comes to service context and human subjective factors. In 5G, a greater transmission capacity requirements led to higher carrier frequency, greater bandwidth and larger peak transmission rate. Moreover, the diversities of users within various locations, occupations and economic classes are expected to be concerned in addition to the support of the personalized service. The mobile users tend to pay more attention to their experiences, which leads operators and vendors to provide the products with better user experiences. How to improve the users' QoE of course becomes a key issue when designing customized services. The recent convergence of the mobile Internet has accelerated the demand by changing research direction from original enhancing the system in objective performance to improving user subjective experience. Consequently, in the era of 5G, the more user-oriented parameters are expected to be identified. QoE, as a direct measurement of human perception on the communication service qualities, is promising and beneficial for future communication systems.

The state-of-the-art research work on QoE focuses on how to map between network parameters and allocate resources according to some QoE prediction criteria. Two factors are highly relevant with QoE expectations, including service types and user characteristics. In the meantime, various approaches have been presented and evaluated including fuzzy comprehensive evaluation method, TOPSIS method [9], gray relational analysis [10], neural networks [11], Bayesian networks [12] and contact points [13], etc. In Tele Management Forum (TMF), an end to end Customer Experience (CE) model based on Kilkki model [14] is proposed, and QoE is subdivided into three types including Quality of Customer Experience (QoCE), Quality of User Experience (QoUE) and Quality of Group Experience (QoGE). ITU-T Study Group 12 (2009–2012) proposed Quality Management Framework (QMF) in their Q4/13 [15]. In 3rd Generation Partnership Project (3GPP), the research works on user experience are currently focusing on QoE metric definitions, QoE reporting formats and measurement protocols of QoE negotiation. In addition, since the industrial utility of QoS is pretty mature, it could be a solution to mapping QoE expectation given various service types to QoS parameters such as data rate, delay and packet loss rate, etc. [16] had formulated such mapping as a log linear model. The above research works are also followed by industrial companies and the corresponding infrastructures are established.

In 2010, the Huawei company launched Voice Quality Index (VQI)—National road test program which can monitor the quality of voice, find and locate network quality issues. Given the current network verification, VQI provides abilities to visually identify the network status and the voice quality. Huawei also established a comprehensive network optimization platform named Nastar. Nastar primarily utilizes the measurement report (MR) and call history (CHR) statistics for network analysis and targeting optimization. In the ZTE company, three core user experience management propositions are abstracted including detecting, locating and professional rapid troubleshooting. Although many researches and industrial works are launched on QoE, there are still many issues should to be further explored.

The above works mainly focus on the way to define QoE-oriented parameters. Given those QoE parameters, how to carry out the QoE management is still an open and challenging task. Since the mobile service providers actually do not have unlimited network resources, the high service quality is generally unaffordable by over-provisioning resources. An even allocation strategy is also not suitable due to the diversities of various users and different services, leading to a desperate need of a careful design of the management granularity for each pair of user and service. In order to clarify this issue, we use a soccer video game example illustrated in Fig. 1.1 which has two types of users. One is soccer fan, the other is not. The expectation for service quality of fan is obviously much higher than that of non-soccer fan. Under the limitation of the network resources, a good strategy is to allocate more network resources to fan to obtain a better compromise between user satisfaction and limited resources. Furthermore, an efficient or even real-time solution is essential for estimation and resource allocation. From the above example, both users and services are quite diversified. Therefore, taking advantage of those diversities and smartly

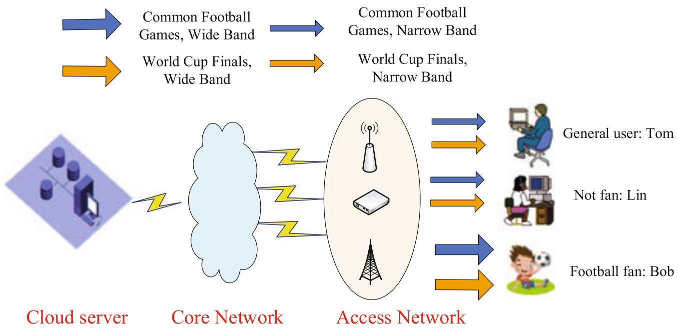

Fig. 1.1 An example of personalized QoE management

designing the resource allocation strategy are beneficial for saving system resource and improving user experience.

In the era of big data, personal user data collection and reservation are feasible under the premise of protecting the human being privacy. In the wireless communication infrastructure, the service data on both mobile terminal and network side can be preserved within a certain period, such as users' cookies stored in the mobile terminals [17] and web log stored in the web server [18]. How to utilize those data becomes an important research issue to optimize QoE. However, the highly diversified data in huge amount makes it impossible to summarize the rules using manual methods. Data-driven approaches originally developed in machine learning area are more promising to trigger an optimal QoE model.

To summarize, currently a huge amount of new services and applications are emerging and growing. How to satisfy the diversified user demanding under the limited wireless resources becomes the critical problem for the service/network providers. Numbers of research issues are prompted on personalized QoE, which is also the key insight within this book. A theoretical background, new architecture for QoE management, QoE-oriented resource allocation and analysis are presented accordingly with practical technical examples.

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