QoE-centric Operation for Optimizing User Quality of Experience

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Abstract

NTT Network Technology Laboratories has been researching indices for evaluating user quality of experience (QoE) for a variety of services. Our aim is to achieve QoE-centric operation for optimizing QoE using information that can be monitored during the provision of services. This article introduces the elemental technologies of QoE-centric operation.

Keywords: QoE, operation, quality API

1. Introduction

The recent proliferation of high-functionality and high-performance mobile terminals such as smartphones and tablets has made the Internet into a social infrastructure that is essential to our daily lives. The services made possible by Internet technologies, as well as their usage formats, have been diversifying year by year, and in addition to voice calls, video delivery, and web browsing, the recent trend toward the Internet of Things (IoT)*1 has begun to drive the creation of new services in a variety of industries.

At the same time, studies are progressing on the application of virtualization technologies such as software-defined networking (SDN)*2 and network function virtualization (NFV)*3 to carrier networks. The aim here is to create an economical software-based execution environment that can achieve both scalability and reliability given a network that must handle a plethora of diverse services.

Against this background, providing a wide array of services over the network at a satisfactory level of quality will require more than simply monitoring network device operations as in the conventional approach. That is, it will also be important to implement maintenance operations that can monitor user quality of experience (QoE)*4 and detect any emerging signs of problems. There is particular concern in the era of network virtualization that it will become increasingly difficult to determine how network faults and quality degradation affect different types of services.

Additionally, factors affecting QoE have expanded beyond the network to elements such as servers, terminals, and applications, so achieving high QoE simply by ensuring network quality will likewise become difficult. It can therefore be considered that determining the state of the network from information collected from both inside and outside the network and sharing that information with service providers and end users should enable service provision conditions and service usage methods to be optimized according to the state of the network.

At NTT Network Technology Laboratories, we are promoting research and development that includes a network-science based approach called QoE-centric operation [1]. This approach consists of a maintenance

*1 IoT: Technology for giving all sorts of things communication functions to enable Internet/cloud connections, mutual control, etc.

*2 SDN: Generic term for technology that enables centralized management of network communication devices and alteration of network configuration/settings via software.

*3 NFV: A method for implementing network functions with software on general-purpose servers using virtualization technology.

*4 QoE: The level of quality experienced by a user of communication services.

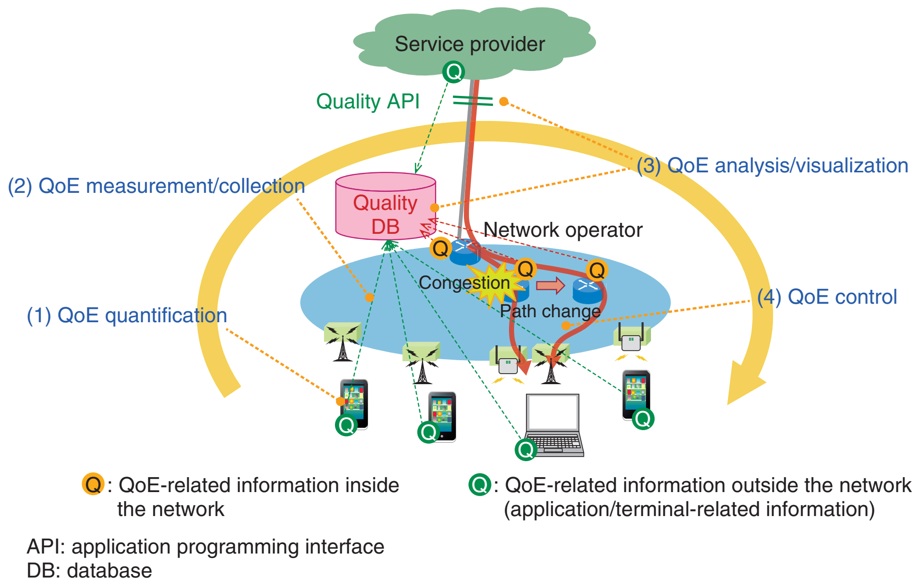

Fig. 1. Achieving QoE-centric operation.

operations cycle that quantifies QoE from parameters that can be monitored during service provision and optimizes QoE accordingly.

2. Elemental technologies of QoE-centric operation

There are four steps to achieving QoE-centric operation: (1) QoE quantification, (2) QoE measurement and collection, (3) QoE analysis and visualization, and (4) QoE control (**Fig. 1**). First, in QoE quantification, the task is to clarify the relationship between QoE and network-quality measures (packet loss/delay, delay fluctuation, etc.) and application-quality measures (sound quality, picture quality, response time, etc.) and to quantify QoE by such objective measures using information that can be monitored during service provision. Next, in QoE measurement and collection, the aim is to efficiently measure and collect quantified QoE information to facilitate the uniform management of this information, and then, in QoE analysis and visualization, to speed up maintenance operations by comprehending the state of service provision, isolating the causes of QoE degradation, and detecting signs of QoE degradation. Finally, the QoE control step uses this analyzed and visualized QoE information to optimize QoE according to network conditions by allocating network resources appropriately and controlling policy and content delivery as needed. The following provides a more detailed explanation of each of these elemental technologies making up QoE-centric operation.

2.1 QoE quantification

The QoE quantification step clarifies service quality design and service management guidelines by elucidating human perceptive and cognitive characteristics with respect to the quality of communication services. This step also establishes a methodology for estimating QoE using quality-related information from the network, servers, and terminals—that is, information that can be monitored during service provision. NTT has been promoting the study of QoE quantification with a focus on voice calling via voice over Long Term Evolution (VoLTE)*5 and VoIP (voice over Internet protocol) applications, video delivery including ultrahigh-definition television (4K/8K) [2], and web browsing and cloud-based business applications. In view of the desirability of achieving QoE on the basis of a globally uniform index, QoE-related discussions are proceeding within the ITU (International Telecommunication Union) and other international standardization bodies. For example, discussions have recently been held on a

*5 VoLTE: Service that provides voice communications using an ultrahigh-speed communication service (LTE).

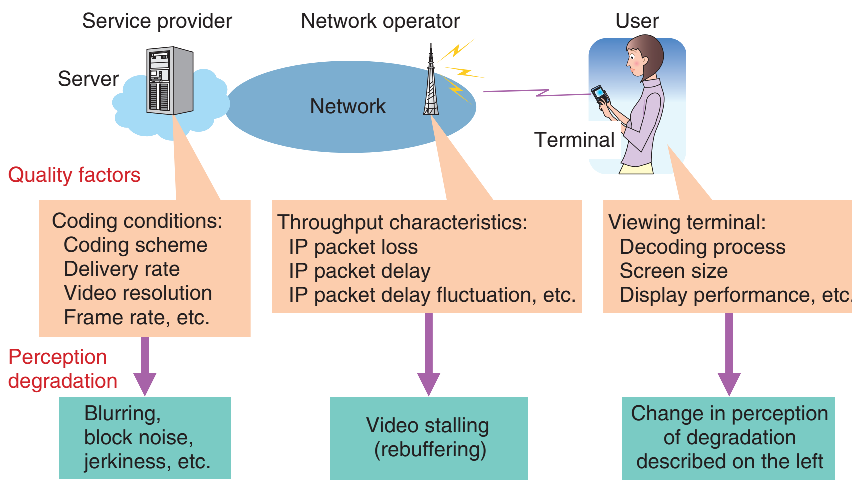

Fig. 2. Quality degradation factors in video delivery services.

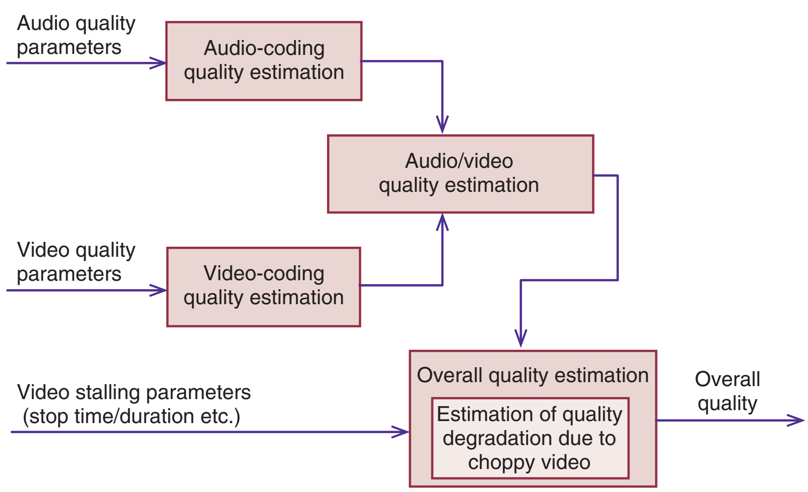

Fig. 3. Framework of QoE estimation algorithm for video delivery services.

method for estimating QoE with respect to progressive-download video delivery[*6] services. Specifically, studies have been done on an algorithm for estimating QoE from IP packet information that can be obtained during service provision. This algorithm will target quality degradation factors particular to video delivery services such as temporal fluctuation in coding quality and video stalling (**Fig. 2**).

The framework of this QoE estimation algorithm is shown in **Fig. 3**. The ITU Recommendation in question is being studied under the provisional name of P.NATS (Parametric non-intrusive assessment of TCP (Transmission Control Protocol)-based multimedia streaming quality, considering adaptive streaming). The plan is to finalize the Recommendation in 2016 after comparing algorithms proposed by multiple institutions in a technical competition.

2.2 QoE measurement and collection

To use QoE information effectively in operations, information needed in the next step of QoE analysis/visualization must be efficiently measured and collected and uniformly managed. Since QoE is affected

*6 Progressive-download video delivery: A delivery method that enables viewing while downloading a video file.

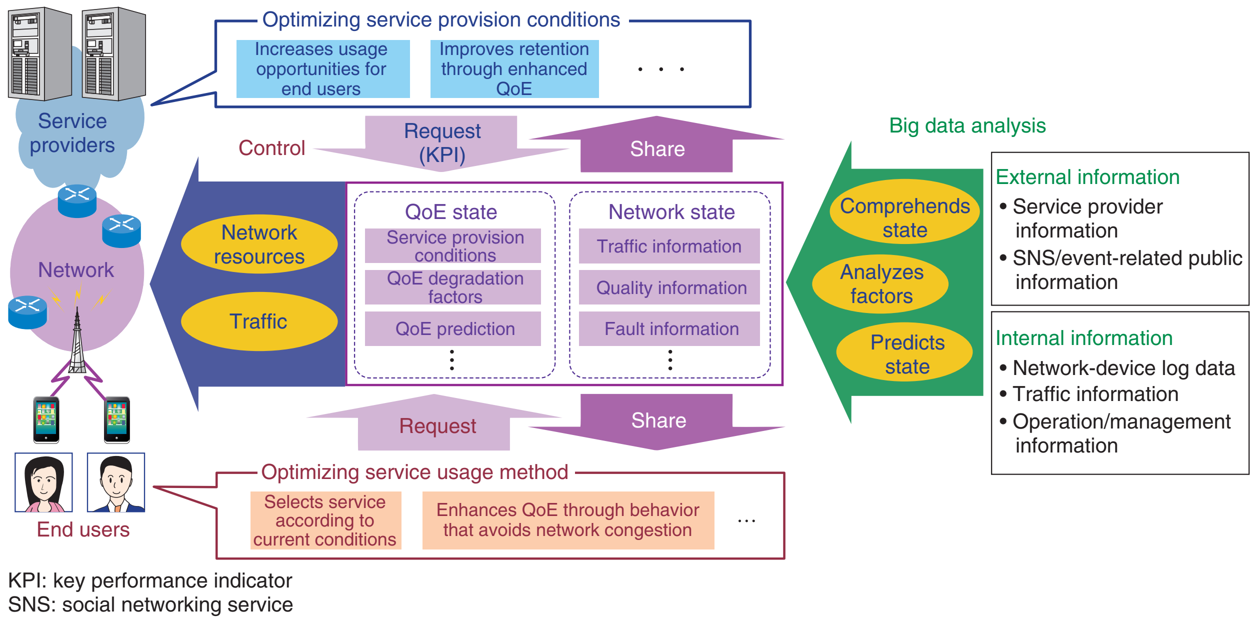

Fig. 4. Effects of QoE analysis/visualization and QoE control.

by quality factors both inside and outside the network, information on the user's service usage environment and terminal conditions is necessary in order to identify and deal with QoE degradation factors on a user-by-user basis. In mobile communications in particular, it is necessary to determine the temporal and spatial fluctuation characteristics of quality. An effective approach to achieve this is to obtain the cooperation of users in a crowdsourcing*7 manner to collect quality information on communication services and on the network and terminals as measured by users' mobile terminals.

2.3 QoE analysis and visualization

Useful information for improving customer satisfaction and network value can be visualized by making full use of information collected from both inside and outside the network and applying big data analysis techniques such as machine learning. This information includes the degree of network congestion, state of service provision, signs of service faults, quality degradation factors, and the scope of quality degradation on services. Visualization of QoE information in this way can support network quality improvements and initial assessments when responding to faults and can play a role in reducing the cost of maintenance operations and in raising customer satisfaction (**Fig. 4**).

2.4 QoE control

QoE control refers to actions taken when detecting QoE degradation or its signs by QoE analysis/visualization with the aim of improving QoE or avoiding such degradation. However, QoE optimization is difficult in a best-effort type of network in which network resources are shared between users and services. Thus, the network operator requires a new form of network-resource and traffic control to support service providers in providing services. To this end, the goal is to optimize QoE by sharing with service providers and end users the state of the network and QoE as analyzed and visualized from information inside and outside the network and by controlling network resources and traffic in accordance with network and QoE conditions (Fig. 4).

3. Specific example of QoE-centric operation

We consider here a specific example of QoE-centric operation targeting a progressive-download video delivery service.

As described above, the main factors in the degradation of quality in video delivery services also exist outside the carrier network, so QoE control performed

*7 Crowdsourcing: A process for performing a task by obtaining the cooperation of a large group of people.

by the network operator and service provider in a collaborative manner is an effective means of optimizing QoE. Even when delivering video at a high coding bit rate with the aim of providing users with high-quality video, a congested network may prevent a sufficiently high level of throughput from being obtained, resulting in video stalling and a significant drop in QoE. An effective response to such a situation would be to deliver the video at a coding bit rate for which QoE could be optimized taking network congestion into account. In other words, delivering the video at a coding bit rate for which choppy playback does not occur would be an appropriate action to take from the viewpoint of QoE even if video quality should drop by some degree.

For the service provider and end user, this form of control improves QoE, while for the network operator, it can reduce traffic that does not contribute to improving QoE, while achieving a reduction in network load (i.e., a reduction in the required facilities). In short, controlling the network in this manner can result in a win-win relationship. Such a QoE optimization measure linking the service provider and network operator has been proposed [3].

NTT is studying an interface called quality API for exchanging quality-related information between operators [4]. Joint experiments are being performed with Dwango Co., Ltd., the provider of the Niconico video streaming service, to test the effectiveness of this quality API.

4. Future developments

In this article, we proposed QoE-centric operation as a new operation framework based on user QoE and introduced the elemental technologies needed for its implementation.

Current QoE quantification technologies are based on studies that focus on human perception and cognition with respect to the media quality of audio and video. Going forward, we envision the further application of network science, the use of sensitivity analysis and behavior theory, and the development of techniques for clarifying and modeling the way in which QoE affects user satisfaction and user behavior. In this way, we aim to achieve network design and management directly connected to key performance indicators (KPIs)*8 of service providers.

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*8 KPI: An index for assessing performance and for quantitatively measuring progress toward corporate goals.

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