QoE Assessment Model for Video Streaming Service using QoS Parameters in Wired-Wireless Network

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Abstract— **In this paper, we propose QoE assessment model for video streaming service such as IPTV and VoD using QoS parameters in wired-wireless network. Existing perceptual quality assessment models are unsuitable for experienced quality assessment of a streaming service which passed through the IP-based network because they only take account of the characteristic of used codec and bit rate. However, QoS parameters for measuring video experienced quality must be considered because reliable delivery of real-time video streaming services is guaranteed by the network performance. Network and service providers can predict perceptual quality and quality satisfaction using the proposed model. Also, they can provide optimal service environment through selection of video streaming data rate and network traffic control based on video QoE assessment model.**

Keywords— **QoE Assessment, QoS, Video Streaming, IPTV, wired-wireless network**

I. INTRODUCTION

Multimedia services like IPTV, VoD and VoIP have been merged into the Internet since its emergence. A sharp increase of IP network bandwidth makes it possible to provide IPTV service that has a real-time requirement. Especially, IPTV service environment has been under a dramatic change along with the IPTV market growth and subscribers' demanding requirements[1]. However, real-time video streaming service providers and users still suffer from the legacy of IP network, the uncertainness of packet transmissions.

In these challenging scenarios, it is critical to guarantee an appropriate QoE (Quality of Experience) for the end user, according to the application to be developed. As various multimedia services are provided in the integrated network environment, QoS(Quality of Service) and QoE concept is introduced in the IP network to describe satisfactions about end user's quality requirements. QoE can be defined as the overall performance of a system, from the user perspective. Many factors can affect the QoE, depending on the application and users expectations. Video perceptual quality is one of the most important aspects to consider in the user QoE.

QoE is the term which is used to describe how it is satisfied by subscribers to the provided service quality. The poor QoE will cause dissatisfied subscribers and fall behind in contestants due to the ultimately bad market competitive power to contestants. QoE is composed of not only the network performance parameter but also the service quality parameter such as cost, reliability, availability, usability, and fidelity. Although QoE is very subjective in nature, it is very important that a strategy is devised to measure it as realistically as possible. The ability to evaluate QoE will give the provider some sense of the contribution of the network's performance to the overall level of subscriber satisfaction.

There are numerous network-related features affecting IPTV service quality. To manage the service quality effectively, the IPTV QoE should be monitored and kept in good condition by service providers. However, QoE-related QoS parameters have the different influence and cannot be treated in a same weight. Network performance objectives are recommended by the ISO (International Organization for Standardization) to provide the IPTV service, but it is not sure that provided network guarantees user's quality satisfaction. Thus, objective video QoE assessment model is needed.

Therefore, we propose QoE assessment model for video streaming service such as IPTV using QoS parameters. Through our proposed model, service provider can predict subscriber's QoE in provided network environment and analogize service environment which meet the optimum QoE, conversely.

The paper is organized as follows: Section II describes related works of multimedia service quality measurement method and investigation of a correlation between QoS and QoE. Section III describes QoS parameters related with QoE of multimedia service. In section IV the proposed video QoE assessment model is presented and section V presents its evaluation and analysis results. Section 6 summarizes the results and main contributions.

II. RELATED WORKS

A. The Voice and Video Service Quality Measurement method

Existing quality assessment technologies can be classified into two categories: subjective quality assessment schemes and objective ones. Current research status of these two kinds of evaluation methods are illustrated as followed paragraphs:

Currently, the evaluation methods for the speech service are mature. For subjective evaluation methods, opinion rating (MOS; Mean Opinion Score) based on customer's satisfaction has been studied to assess the perceptual QoS. It is specified in ITU-T recommendations E.800 initially [2]. On another hand, several objective quality assessed methods has been proposed in ITU-T, such as P.861[3] PSQM (Perceptual Speech Quality Measure), P.862[4] PESQ (Perceptual Evaluation of Speech Quality) and G.107 E-Model[5].

For the video service evaluation, subjective video quality evaluation method is the most reliable video quality measurement method. A group of viewers is selected and gathered in a room, the measurement environment is specified in the ITU-T Recommendation P.910[6]. For the research of objective video quality method, some estimation software has been developed which can analyze the video signals and produce the quality evaluation results. One traditional objective video quality measurement, Peak Signal to Noise Ratio (PSNR), has been widely used in many applications to assess video quality.

PSNR does not take the visual masking phenomenon into consideration. In other words, every single pixel error contributes to the decrease of the PSNR, even if this error is not perceived. So, MPQM (Moving Pictures Quality Parameter) was proposed for the objective the video quality measurement[7][8]. MPQM is an objective quality parameter for moving picture which incorporates human vision characteristics. MPQM represents the typical image quality assessment models based on the error sensitivity. The widely adopted assumption of these models is that the loss of perceptual quality is directly related to the visibility of the error signal.

From current research status of evaluation method, we can see that the subjective method based on user survey can reflect the experience of user more directly and match well to the feeling of user. However, this kind of method has several problems, such as, it required special environment and equipments, needs a mass of people to participate the test. In conclusion, subjective video quality measurement cannot provide real-time and in-service quality monitoring for real-time video applications. So the application of the method is limited.

B. The Studies of Relationship between QoS and QoE

Currently, the investigation of QoS and QoE correlation is continued. Khirman and Henriksen were trying to relate the objective network service conditions with the human perception of the quality of the service. Their subject has been widely investigated for voice delivery and it is widely acknowledged that the relationship between voice transmission conditions and the human perception of quality is far from linear[9]. They discuss in detail how the human satisfaction of HTTP service is affected by the two main network QoS parameters, namely network delivery speed and latency. However, it is difficult to represent the feature of the provided and various services from only the bandwidth and latency time in the integrated network environment.

In [10] the authors thought that pervasive computing environment brings the method of evidence context related to QoE. They studied the QoE evaluation method in pervasive computing environment, and proposed the enhanced QoE evaluation parameter model. In [10] rough-set based algorithm is proposed to reduce context attributes and determine the weight of each attribute, the algorithm has been validated on video streaming service, and the architecture of QoE evaluation system is described. As a mass of evidence information related to the experience of users can be gathered through the context-awareness computing, the calculation results of QoE evaluation method can highly match the real feeling of users. However, the method needs to be enhanced along with the development of pervasive computing.

Also, the existing research[11] for QoE just deduced the major video quality elements of the IPTV service. They just analyzed a relationship of QoS parameters and QoE items and do not present a method for QoE measurement.

To solve the problems of previous studies, we have studied a model for measuring video quality at application layer using QoS quality parameters. In [12], we just showed the possibility to analyze the causes of the quality degradation through our idea of QoS/QoE correlation model. In previous works, however, we did not present the fair value of parameters, variables and constants in this model.

In order to solve the problem of the existing researches, we propose the QoE assessment model for video streaming service to numerically measure video QoE by using QoS parameters and their weight. Also, we analyze the patterns of changes in video quality according to QoS parameters change, and derive reasonable variables and constants for the proposed model. Through our proposed model, network and/or service providers can predict subscriber's video QoE in provided network environment and analogize service environment which meet the optimum QoE, conversely.

III. QoS Parameters Related With QoE of Multimedia Service

This clause addresses the QoS quality parameters which can be considered for the video QoE assessment. Transfer capacity is a fundamental QoS parameter having primary influence on the performance perceived by end-users. Many user applications have minimum capacity requirements; these requirements should be considered when entering into service agreements. And lost bits or octets can be subtracted from the total sent in order to provisionally determine network capacity. An independent definition of capacity is for further study.

It is assumed that the user and network provider have agreed on the maximum access capacity that will be available to one or more packet flows in a specific QoS class (except the unspecified class in Table 1. A packet flow is the traffic associated with a given connection or connectionless stream having the same source host (SRC), destination host (DST), class of service, and session identification. Other documents may use the terms microflow or subflow when referring to traffic streams with this degree of classification. Initially, the agreeing parties may use whatever capacity specifications they consider appropriate, so long as they allow both network provider enforcement and user verification. For example, specifying the peak bit rate on an access link (including lower layer overhead) may be sufficient. The network provider agrees to transfer packets at the specified capacity in accordance with the agreed QoS class.

The network performance objectives may no longer be applicable when there is packets submitted n excess of the capacity agreement or the negotiated traffic contract. If excess packets are observed, the network is allowed to discard a number of packets equal to the number of excess packets. Such discarded packets must not be included in the population of interest, which is the set of packets evaluated using the network performance parameters. In particular, discarded packets must not be counted as lost packets in assessing the network's IPLR performance. A discarded packet might be retransmitted, but then it must be considered as a new packet in assessing network performance. Each network QoS class creates a specific combination of bounds on the performance values. This clause includes guidance as to when each network QoS class might be used, but it does not mandate the use of any particular network QoS class in any particular context.

TABLE 1. IP NETWORK QOS CLASS DEFINITIONS AND NETWORK PERFORMANCE OBJECTIVES[13]

Network performance parameter	QoS Classes					
	Class 0	**Class 1**	**Class 2**	**Class 3**	**Class 4**	**Class 5**
IPTD	100 ms	400 ms	100 ms	400 ms	1s	U
IPDV	50ms	50ms	U	U	U	U
IPLR	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$	U
IPER			$1x10^{-4}$			U

A. Delay

Delay manifests itself in a number of ways, including the time taken to establish a particular service from the initial user request and the time to receive specific information once the service is established. Delay has a very direct impact on user satisfaction depending on the application, and includes delays in the terminal, network, and any servers. Note that from a user point of view, delay also takes into account the effect of other network parameters such as throughput.

B. Delay Variation(Jitter)

Delay variation is generally included as a performance parameter since it is very important at the transport layer in packetized data systems due to the inherent variability in arrival times of individual packets. However, services that are highly intolerant of delay variation will usually take steps to remove (or at least significantly reduce) the delay variation by means of buffering, effectively eliminating delay variation as perceived at the user level (although at the expense of adding additional fixed delay).

C. Packet Loss Rate

Packet loss rate has a very direct effect on the quality of the information finally presented to the user, whether it be voice, image, video or data. In this context, packet loss is not limited to the effects of bit errors or packet loss during transmission, but also includes the effects of any degradation introduced by media coding for more efficient transmission (e.g. the use of low bit-rate speech codecs for voice).

D. Available Bandwidth

The aforementioned delay, jitter and packet loss rate, in addition to available bandwidth is an important quality indicator for video streaming service. A video server that has an estimate of the available bandwidth can steam high quality data if the bandwidth is available, or stream data that needs lower bandwidth (perhaps with a lower size, lower frame rate, etc.) if the available bandwidth is limited. The available bandwidth is shared among multiple users, thereby reducing the actual bandwidth available to any particular user. The lack of available bandwidth causes QoE degradation of the end user.

IV. PROPOSED VIDEO QOE ASSESSMENT MODEL

A. QoS Value Normalization Reflecting Network Performance

As mentioned in the above, the user quality satisfaction about video streaming is under the influence of various QoS parameters. So, we limit a scope of QoE in this paper to the satisfaction about the video QoE of the video streaming service because overall QoE of the multimedia service complexly consists of the variant QoE items.

It is known from the QoS/QoE relationship analysis that the most of QoE items are related with the QoS parameters. Moreover, according to the analysis results of QoS correlation, many QoS parameters show the positive correlation with QoE items. In order to reflect variance QoS quality parameters in QoE evaluation, the QoS value should be calculated. QoS value is a numerical data to normalize network performance. The QoS parameters having an effect on these QoE items are IP packet loss(L), IP packet delay(D), IP packet jitter(J), bandwidth(B), and etc. These QoS parameters are network-related quality elements which the standardization organizations like ITU-T and IETF recommend.

The weight of the QoS parameters can be assigned through the relative importance degree of the QoS parameter about the IPTV video QoE and QoS/QoE correlation analysis results because QoE-related QoS parameters have the different influence. We can assign the weight of QoS parameters according to the quality standard bounds recommended in the standardization organizations(e.g. ITU-T, IETF etc) and its relative importance degree represented in the Table 2.

TABLE 2. THE EXAMPLE OF NETWORK-RELATED QOS PARAMETERS AND ITS RELATIVE IMPORTANCE DEGREE

QoS parameters	Relative Importance Degree
Packet Loss(L)	58.9%
Packet Jitter	15.1%
Packet Delay(D)	14.9%
Bandwidth(B)	11.1%

The normalized QoS value(QoS(X)) reflects the network performance which can be calculated through the formula (1). The QoS value can be simply calculated with the total sum of the values multiplying the measured QoS parameter in network layer with the allocated weight like the formula (1). Here, B is the ratio of available bandwidth to the video streaming data rate(B=data rate of streaming/available bandwidth).To avoid confusion, the family name must be written as the last part of each author name (e.g. John A.K. Smith).

$$QoS(X) = L \times Wl + U \times Wu + J \times Wj + D \times Wd + B \times Wb \qquad (1)$$

In the formula (1), it is just referred to the major QoS parameters influencing on the video streaming QoE. The QoS parameter items used in this formula may be expanded and applied according to the characteristic of a service in case of considering the other multimedia services.

B. Video QoE Assessment Model

We devise video streaming QoE assessment model referring to quality change aspect of MPQM according to network condition. The numerical formula model to measure the video streaming service QoE(QoE_v) by using the normalized QoS value is as follows:

$$QoE\_v = Qa \times (1 - QoS(X))^{\frac{QoS(X) \times A}{R}} \qquad (2)$$

In the formula (2), *Qa* is a constant factor which determines the overall QoE of video streaming service according to the service environment. For example, when using video streaming service in the wireless network user's QoE may decrease due to interference caused by wireless link in spite of the same network performance. Next, the *QoS(X)* is the QoS value which is calculated by the formula (1), and is determined by quality parameters of the network layer.

The constant A expresses the resolution class like SD(Standard Definition) or HD(High Definition). If we use the HD quality video, the constant A is assigned in the higher value than SD. It means that QoE level which the HD class service user's request is high than the SD class service user in the same network condition. Finally, R is determined as the constant reflecting the structure of the video frames according to the GoP(Group of Picture) length. Because an encoding is not progressed in case of losing an I-Frame until the next I-Frame is received, the loss of an I-Frame more induces the poor quality(frame skipping, frame freezing etc) than the other frames(P/B-Frame). So, we can use the variable R as the factor for the video QoE measurement.

A variable and the constant used in this model are determined by elements causing an effect in the video QoE. These elements include a service environment where the terminal is positioned, a service kind, a used codec, and etc.

V. EVALUATION AND ANALYSIS

We use the VLC media player[14] for video streaming and set up de-jitter buffer size to 100ms. We use the VLC media player for video stream delivery in experimental network set to a certain delay, jitter and loss rate. We use the UDP/RTP protocol for video stream delivery. Table 3 show the video source for evaluation of the proposed video streaming QoE assessment model.

TABLE 3. THE VIDEO SOURCE FOR EVALUATION OF THE PROPOSED QOE ASSESSMENT MODEL

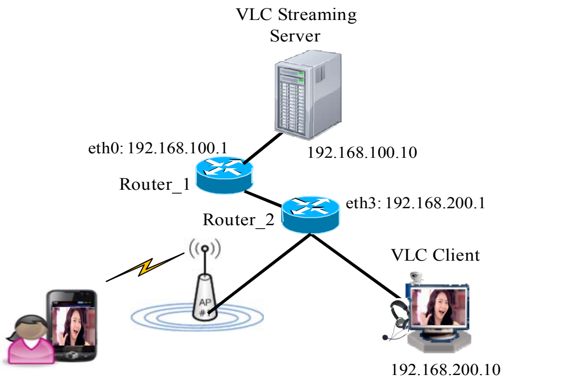
No.	Frame Rate	Resolution	Used Codec	Data Rate
1	30.0fps	1280*720	XVID	2325Kbps
2	30.0fps	1280*720	XVID	1528Kbps
3	30.0fps	1280*720	XVID	932Kbps

We compare 300 original images and 300 test images passed through various network environments. We configure test network like Fig. 1 to verify justification of the proposed model, and measure video quality using MSU video quality measurement tool[15]. We choose SSIM(structural similarity) score to accurately measure video quality because SSIM is quite similar to MOS. Since SSIM method can derive experienced video quality through measurement of similarity between original still images and tested still images, we can predict satisfaction of video quality passed through the experimental network using SSIM score.

We use the emulator command of Linux router in order to control network conditions. For example, we can control delay, jitter, loss rate and link bandwidth using the following commands.

```
#tc qdisc add dev eth0 root netem delay 200ms
#tc qdisc change dev eth0 root netem delay 200ms 30ms
#tc qdisc change dev eth0 root netem loss 0.01%
#tc qdisc add dev eht0 root handle 10: cbq bandwidth
3Mbit avpkt 1000
```

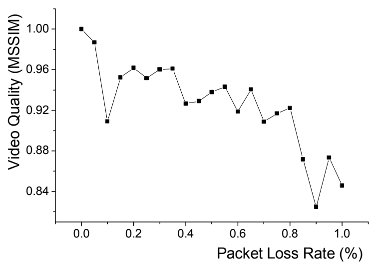
Network environment for test is configured for minimum required packet loss rate(0.01%) and jitter(30ms) which are recommended by ITU-T and IPTV standard organization. We consider packet loss rate, jitter and available bandwidth among various network QoS parameters related with video quality because they are most influence on video quality. Test is performed in follow condition; packet loss rate is between 0% and 1%, jitter is max 60ms with normal distribution to 200ms delay, and available bandwidth is between 3Mbps and 0.9Mbps.



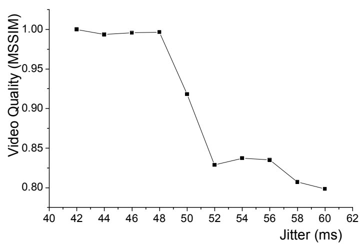

```
#tc qdisc add dev eth0 root netem delay 200ms
#tc qdisc change dev eth0 root netem delay 200ms 30ms
#tc qdisc change dev eth0 root netem loss 0.01%
#tc qdisc add dev eth0 root handle 10: cbq bandwidth 3Mbit avpkt 1000
```

Figure 1. Test network configuration for video quality measurement

Fig. 2 shows video quality deterioration with MSSIM (Mean SSIM) according to packet loss rate and jitter. It shows that video quality deterioration to packet loss linearly changes while jitter's sharply change around 50ms. Video quality is uniform at high jitter because high inter-arrival packets are dropped and video streams are normally played after receiving next key frame. Video quality more quickly deteriorates when packet loss and jitter are combined because they are taking quite different in the video quality.



(a) Video quality deterioration by packet loss



(b) Video quality deterioration by jitter

Figure 2. Video quality deterioration with MSSIM according to packet loss rate and jitter

Video quality is sharply deteriorated when packet loss and jitter are combined because they are taking quite different in the video quality. Figure 3 shows the example of aspect of video quality change to packet loss and jitter. Although network providers offer network guaranteed packet loss and jitter within recommended QoS level, serous quality decline is caused when packet loss and jitter are combined like figure 3-(c).

(a) Comparison original and test image at packet loss 0.01%

(b) Comparison original and test image at jitter 30ms

(c) Comparison original and test image at packet loss 0.01% and jitter 30ms in same time

Figure 3. Example of an unacceptable low-resolution image

We experiment and analyze relation between RSSI of radio signal and video quality to allocate Qr in wireless network environment. Fig. 4 shows relation between RSSI of a WLAN and mean video quality(MSSIM: Mean Structural Similarity). As see in the Fig. 4, data rate of video steams does not influence video quality when bandwidth is sufficiently provided. However, we show that video quality sharply decline when RSSI of a WLAN is lower than -80dBm. We analyse the average video quality in -80dBm or more of RSSI. As the results, Qr is assigned to 0.95.

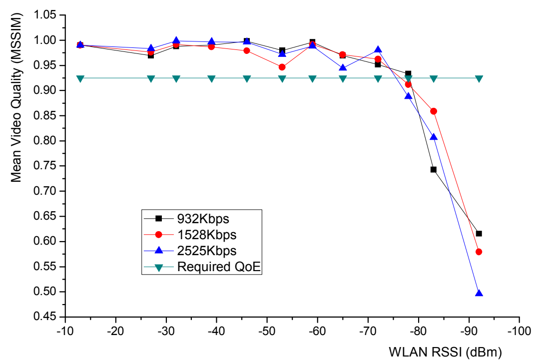


Figure 4. Relation between RSSI of a WLAN and mean video quality(MSSIM)

Fig. 5 shows the measurement results of video QoE using the proposed video streaming QoE assessment model. Through the analysis result of patterns of changes between network conditions and image quality, we can assign Wj, Wl and Wb in formula (1) to 0.5, 10 and 0.01 respectively to calculate normalized QoS(X). Also, we assign constants A and R of the proposed model in formula (2) to 250 and 12 respectively considering used video resolution, codec and network environments.

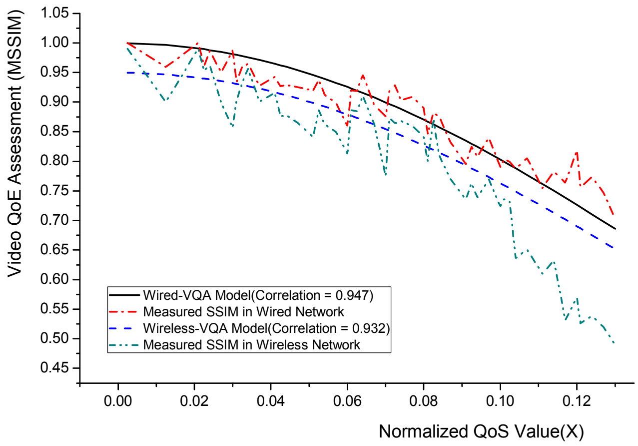


Figure 5. The measurement results of video QoE using the proposed QoE assessment model

Although measurement results using VQM tool has fluctuation because of limitation of the number of used frames and video streaming characteristics, the video QoE measurement using the proposed video streaming QoE assessment model is very similar to VQM measurement results (correlation coefficient of wired network and wireless network is 0.947 and 0.932, respectively). Through the analysis results, we can objectively measure video quality in application layer using network QoS parameters in wired and wireless network environment.

VI. CONCLUSIONS

We propose the video steaming QoE assessment model to numerically measure the video QoE of multimedia service by using the QoS parameters in network layer. Through our proposed model, network providers can predict subscriber's QoE in provided network environment and analogize service environment which meet the optimum QoE. On a real time basis, it is more rapidly able to correspond to the poor quality by monitoring the QoE of the video streaming service. The service provider can provide the multimedia service of the improved QoE through the proposed QoE assessment processes. And moreover, the network operator can prevent the unnecessary investment for the enlargement, maintenance and repair of the network.

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