

# Parametric Packet-Layer Model for Monitoring Video Quality of IPTV Services

Kazuhisa YAMAGISHI and Takanori HAYASHI  
NTT Service Integration Laboratories, NTT Corporation,  
3-9-11 Midori-Cho, Musashino-shi,  
Tokyo 180-8585, Japan  
E-mail: yamagishi.kazuhisa@lab.ntt.co.jp  
Telephone: +81-422-59-4397  
Fax: +81-422-59-5671

**Abstract**— IPTV services will become key services in the next-generation network (NGN). To provide a high-quality service for users, designing and managing the quality of experience (QoE) appropriately is extremely important. To do this, developing an objective quality-assessment method that estimates subjective quality based on physical characteristics of the IPTV system is desirable. We propose a parametric packet-layer model for monitoring video quality of IPTV services. Our proposed model is useful as a network monitoring tool for assessing several video parameters that affect the quality of IPTV services. For constructing the parametric packet-layer model, we derived a relationship between video quality and quality parameters from a subjective quality assessment. The results indicated that cross-correlation was larger than 0.9, and the evaluation error was smaller than the statistical uncertainty of the value of subjective quality. Therefore, our proposed model could be applied to effective design, implementation, and management of IPTV services.

## I. INTRODUCTION

Advances in broadband IP networks, encoders, and decoders (CODECs) have enabled IPTV services that use audio/speech and video. Methodologies for evaluating the quality of IPTV services are indispensable to provide a high-quality service. Developing an objective quality assessment method is important for network planning and monitoring, and CODEC optimization.

Objective quality-assessment models can be categorized into the parametric-planning model, parametric packet-layer model, parametric bit-stream-layer model, media-layer model, and hybrid model from the viewpoint of the input information [1].

The parametric-planning model uses network and application parameters that affect the quality of media [2], [3], [4], [5], [6], [7]. This model is convenient for network planning purposes because it formulates the relationships among subjective quality, network, and/or application parameters. The parametric-planning models have been standardized as ITU-T Rec. G.107 for VoIP and G.1070 for videophones.

The parametric packet-layer model uses packet-header information without media-related payload information [8], [9], [10], [11]. The parametric packet-layer model is mainly used for in-service non-intrusive monitoring, and the computational load is very light because the model estimates quality using only packet-header information without media-related payload

information and media signals. Such models are useful when media-related payload information is encrypted. Parametric packet-layer models for VoIP services such as ITU-T Rec. P.564 have been developed and used.

The parametric bit-stream-layer model uses packet-header information and media-related payload information [12]. This model is also used for in-service non-intrusive monitoring. The model takes into account the dependence of video quality on content, and estimation accuracy of the model is superior to that of the parametric packet-layer model because media-related payload information is used. The model can be used in situations where one does not have access to decoded video sequences. The parametric bit-stream-layer model is being discussed in the video quality experts group (VQEG).

The media-layer model uses media signals [13], [14], [15], [16], [17]. The model can take into account the dependence of video quality on content and decoder characteristics such as using a packet-loss concealment algorithm. The media-layer model is usually used for quality benchmarking. Media-layer models such as ITU-T Rec. J.144 have been developed and used. Now, media-layer models for small video formats and the HDTV format are being studied in the VQEG.

The hybrid model uses a combination of information and has several features of the models mentioned above [18]. Several models for VoIP and HDTV are being studied in ITU-T SG12 and the VQEG, respectively.

Parametric-planning models and parametric packet-layer models for VoIP services have been standardized and used; however, little attention has been given to the parametric-planning model and the parametric packet-layer model for IPTV services. For monitoring QoE at the set-top box (STB) and/or decoder, using the media-layer model is difficult because the quality-estimation model needs to have a light computational load. The parametric bit-stream-layer model cannot be used when media-related payload information is encrypted. To solve those issues we developed a parametric packet-layer model that estimates video quality affected by coded distortion and packet-loss degradation including burst packet loss.

First, we conduct a subjective quality assessment for IPTV services, and then, we develop a model for estimating video

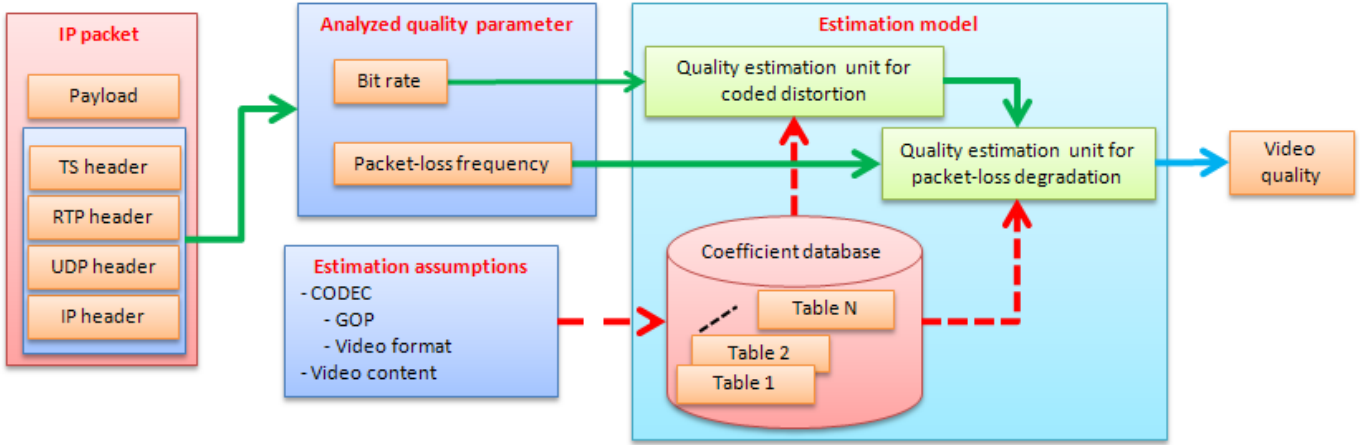


Fig. 1. Parametric packet-layer model for video quality of IPTV services.

quality affected by coded distortion and packet-loss degradation. Finally, we show that our proposed model accurately estimates the quality of an IPTV service.

The remainder of this paper is structured as follows. A parametric packet-layer model for IPTV services is described in Section II. A method of subjective quality experiments is described in Section III. The experimental results are shown in Section IV. We propose a parametric packet-layer model for IPTV services in Section V. Finally, in Section VI, we summarize our findings and suggest possible directions for future studies.

## II. FRAMEWORK OF PARAMETRIC PACKET-LAYER MODEL FOR IPTV SERVICES

We propose a framework of a parametric packet-layer model for IPTV services. This model can be used as a monitoring tool that estimates the quality of IPTV services based on packet-header information. Its input information is packet-header information, as shown in Fig. 1. The output of our proposed model is video quality. The dependence of video quality on content cannot be taken into account because there is no access to payload information. Therefore, in this paper, we propose to manage QoE by using an estimated video quality, which is averaged over video-content sets.

This model has four features: a parameter-extraction unit, quality-estimation unit for coded distortion, quality-estimation unit for packet-loss degradation, and coefficient database. The parameter-extraction unit analyzes a packet header and extracts video-quality parameters. The quality-estimation unit for coded distortion estimates video quality affected by coded distortion. The quality-estimation unit for packet-loss degradation estimates video quality affected by packet loss by taking into account the packet-loss pattern. The coefficient database is used to change the coefficient table for each CODEC to estimate video quality appropriately because the effects of a CODEC on subjective video quality heavily depend on the CODEC implementation. For this reason, we have to

TABLE I  
VIDEO SEQUENCES

No.	Title
1	European market
2	Harbour scene
3	Whale show
4	Soccer action
5	Green leaves
6	Japanese room
7	Ice hockey
8	Weather report

conduct subjective quality-assessment experiments to calculate the coefficient tables of this model.

## III. SUBJECTIVE QUALITY-ASSESSMENT EXPERIMENTS

We built a viewing system for deriving subjective-quality characteristics that are necessary for constructing the parametric packet-layer model. We used eight video sequences that lasted 10 seconds each [19], as shown in Table I. The displayed video format was high definition (HD:  $1440 \times 1080$ ).

The experimental parameters were coded bit rate ( $Br$ ), packet-loss rate ( $Ppl$ ), and burst packet-loss length ( $BL$ <sup>1</sup>), as shown in Table II. In this experiment, burst packet-loss lengths are constants. We generate packet loss by using a network emulator. The video encoder was H.264. The decoder did not have a packet-loss concealment algorithm. One IP packet consists of seven TS packets, which are  $7 \times 188$  Bytes. There were 110 test conditions for each video sequence, which is the number of combinations of the above-mentioned three experimental parameters.

In the subjective-quality assessment, video quality was evaluated using a DCR (degradation category rating) method [20]. Subjects watched test sequences presented in pairs: the first

<sup>1</sup> $BL$  indicates the number of consecutive lost packets. When two IP packets were lost consecutively,  $BL$  is 2. When two IP packets were lost nonconsecutively, each  $BL$  is 1.

TABLE II  
EXPERIMENTAL SETTINGS

Parameter	Abbr.	Range	Unit
Coded bit rate	$Br$	2 - 20	Mbps
Packet-loss rate	$Ppl$	0.00 - 1.63	%
Burst packet-loss length	$BL$	0 - 10	Packets

TABLE III  
IMPAIRMENT SCALE

Score	Impairment scale (in Japanese)
5	Imperceptible
4	Perceptible but not annoying
3	Slightly annoying
2	Annoying
1	Very annoying

sequence presented in a pair is always the source reference, while the second sequence is the same source with various levels of quality. Subjects are asked to rate the impairment of the second sequence in relation to the reference by using the five-grade impairment scale, as shown in Table III. The quality descriptions on the rating scale were given in Japanese.

Ninety six subjects aged 20 - 39 participated in the experiments. They were non-experts who were not directly concerned with video quality as part of their work, and, therefore, not experienced assessors. The subjects viewed each video sequence at a distance of  $3H$  (111 cm), where  $H$  indicates the ratio of viewing distance to picture height.

Video quality ( $Vq$ ) was represented as an MOS (mean opinion score) averaged over eight video sequences.

#### IV. EXPERIMENTAL RESULTS

We analyzed the characteristics among video quality and quality parameters and obtained two characteristics for coded distortion and packet-loss degradation as follows.

##### A. Coded-distortion characteristics

For the case where the packet-loss rate,  $Ppl$ , is 0, we show a coded-distortion characteristic. As the coded bit rate,  $Br$ , increased, the video quality,  $Vq$ , increased and saturated, as shown in Fig. 2. That is, this curve is formulated by a logistic function.

##### B. Packet-loss degradation characteristics

Next, we show packet-loss degradation characteristics. Although curve gradients for each burst packet-loss length,  $BL$ , are different, subjective video quality,  $Vq$ , degraded as packet-loss rate increased, as shown in Fig. 3. Curve gradients for each burst packet-loss length are smaller in proportion to burst packet-loss length,  $BL$ , so we found that subjective video quality,  $Vq$ , degraded as packet-loss frequency,  $PLF^2$ , increased, as shown in Fig. 4. That is, this curve is formulated by an exponential function. The gradients for each coded bit

<sup>2</sup> $PLF$  indicates the number of packet-loss events within 10 seconds. When packet-loss events happened twice with  $BL = 10$  within 10 seconds,  $PLF$  is 2.

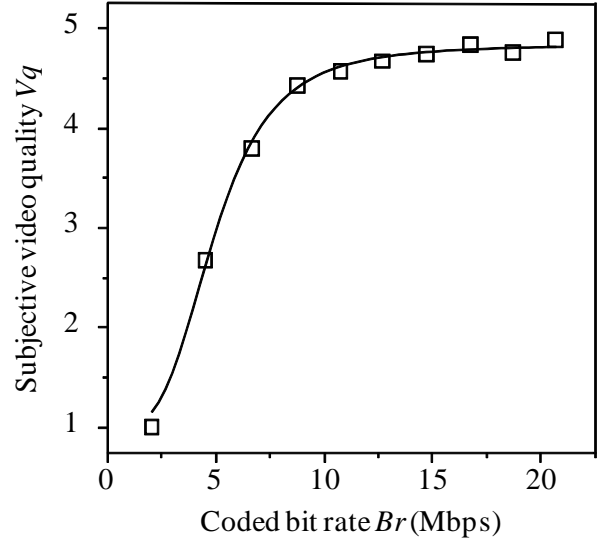


Fig. 2. Coded-distortion characteristics.

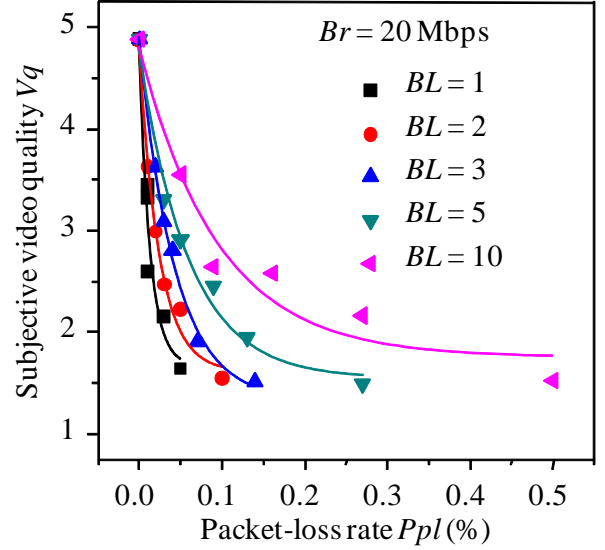


Fig. 3. Packet-loss degradation characteristics.

rate are almost the same, as shown in Fig 5. Therefore, the degree of degradation with respect to packet-loss frequency is constant regardless of coded bit rate.

#### V. PARAMETRIC PACKET-LAYER MODEL

From the experimental results, we developed a model for assessing coded distortion and packet-loss degradation. Then, we applied our proposed model to an H.264 CODEC and evaluated its validity.

##### A. Quality-estimation unit for coded distortion

We developed a quality-estimation unit for estimating video quality affected by coded distortion from the relationship between video quality,  $Vq$ , and coded bit rate,  $Br$ . As the coded

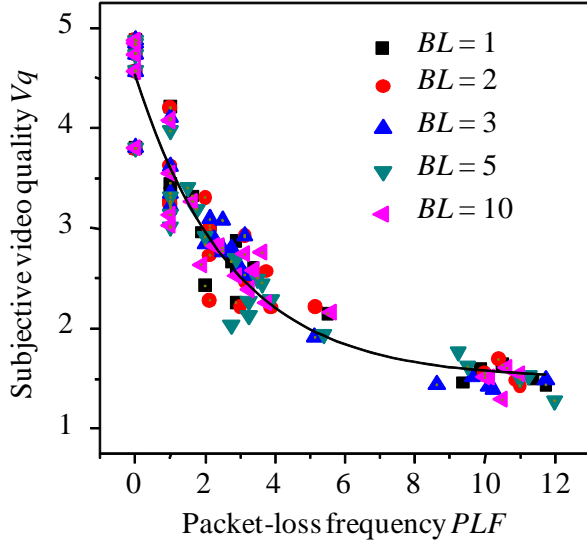


Fig. 4. Subjective video quality vs. packet-loss frequency.

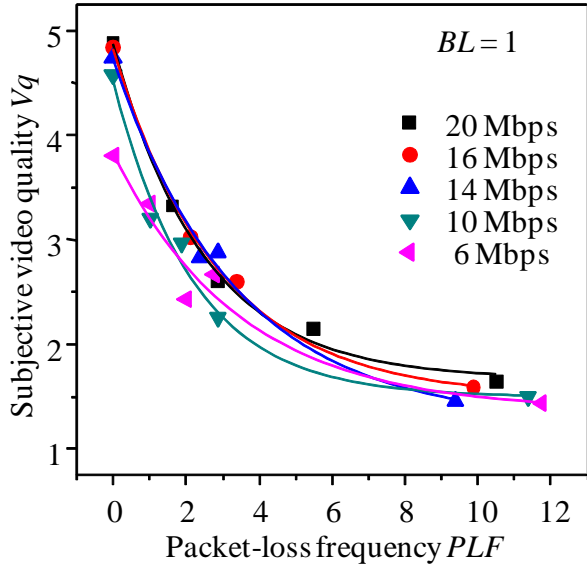


Fig. 5. Subjective video quality vs. packet-loss frequency at various coded bit rates.

bit rate,  $Br$ , increased, the video quality,  $Vq$ , increased and saturated, as mentioned in Section IV-A. Thus, that situation could be approximated by a logistic function as follows:

$$Vq \Big|_{Pl=0} = 1 + Ic \quad (1)$$

and

$$Ic = v_1 - \frac{v_1}{1 + \left(\frac{Br}{v_2}\right)^{v_3}}, \quad (2)$$

where  $v_1$ ,  $v_2$ , and  $v_3$  are constants that are determined from the subjective data obtained from each CODEC implementation.

We calculated the coefficient table of the parametric packet-layer model for the H.264 CODEC based on the least-square

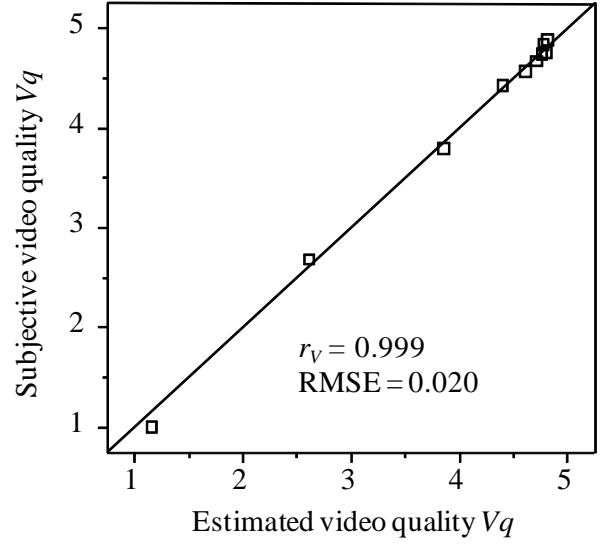


Fig. 6. Subjective vs. estimated video quality: accuracy of estimating coded distortion.

approximation (LSA). Then, using these coefficients, we estimated the subjective video qualities. The accuracy of our model is shown in Fig. 6. The cross-correlation ( $r_V$ ) and the root mean square error (RMSE) are also shown in Fig. 6. The mean of the 99% confidence interval (MCI) of the subjective score of each video sequence was 0.34.

We used two criteria to determine that the accuracy of the model was sufficient, as follows:

- 1)  $r_V \geq 0.9$  was used as one of the criteria.
- 2)  $RMSE \leq 0.34$  (which is MCI) was used as another criterion because MCI indicates the statistical reliability of the subjective-quality evaluation.

In this experiment,  $r_V$  was larger than 0.9 and RMSE was smaller than MCI. Therefore, we concluded that the video quality can be formulated by Eqs. 1 and 2 with sufficient accuracy.

#### B. Quality-estimation unit for packet-loss degradation

We developed a quality-estimation unit for estimating packet-loss degradation. Video quality,  $Vq$ , decreased exponentially as the  $PLF$  increased, as mentioned in Section IV-B. That is, video quality,  $Vq$ , was approximated by an exponential function as follows:

$$Vq = 1 + Ic \exp\left(-\frac{PLF}{v_4}\right), \quad (3)$$

where  $1 + Ic$  indicates the video quality when the packet-loss frequency,  $PLF$ , is 0, and  $v_4$  indicates the degree of video-quality degradation due to the packet loss.

The degree of degradation for packet-loss frequency is constant for coded bit rate, as mentioned in Section IV-B. Therefore, we define  $v_4$  as follows:

$$v_4 \stackrel{def}{\longleftrightarrow} v_4 \Big|_{Br=Br_{Max}}, \quad (4)$$

TABLE IV  
TABLE OF COEFFICIENTS OF OUR MODEL FOR H.264 CODEC

	$v_1$	$v_2$	$v_3$	$v_4$
Value	3.8	4.9	3.6	3.5

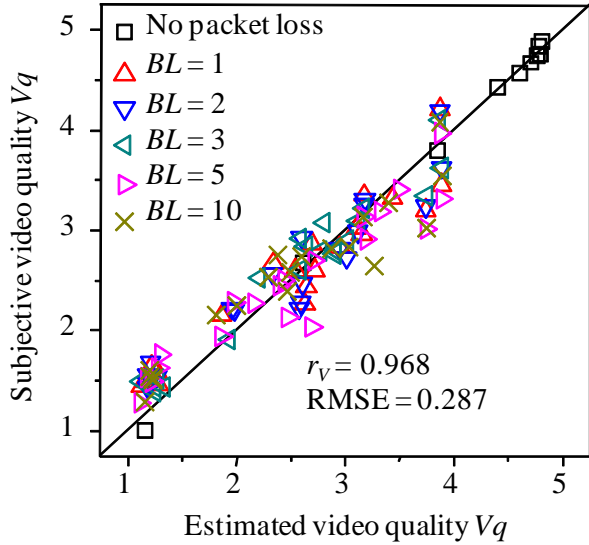


Fig. 7. Subjective vs. estimated video quality: accuracy of estimating packet-loss distortion.

where coefficient  $v_4$  is constant and determined from the subjective data obtained for each CODEC implementation, and  $Br_{Max}$  denotes the maximum coded bit rate that was used in the experiment.

We calculated the table of coefficients of the parametric packet-layer model for the H.264 CODEC based on the LSA, as shown in Table IV. Then, using these coefficients, we estimated the subjective video qualities. The relationship between subjective  $Vq$  and estimated  $Vq$  is shown in Fig. 7. The values of  $r_V$  and RMSE are also shown in Fig. 7.

In this experiment,  $r_V$  was larger than 0.9 and RMSE was smaller than MCI. Therefore, we concluded that the model could be applied to the estimation of video quality degraded by coded distortion and/or packet-loss degradation.

## VI. CONCLUSION

We proposed the framework of the parametric packet-layer model for estimating video quality of IPTV services, and then, we developed our proposed model for assessing coded distortion and packet-loss degradation. The quality-estimation unit for coded distortion can be used to monitor whether the coded bit rate satisfies a QoE requirement. The quality-estimation unit for packet-loss degradation can be used to monitor whether the video quality affected by packet loss satisfies a QoE requirement. By using these models, we can estimate video quality because the RMSE of the estimated quality obtained by our proposed model was smaller than the statistical uncertainty of the subjective quality evaluation. Our

proposed model provides a method of monitoring information about the QoE of IPTV services, so it will be a powerful monitoring tool.

The following issues call for further study. First, we will verify that our proposed model can be applied to other CODECs and the packet-loss concealment algorithm. Then, using other types of video sequences, which were not used in this experiment, we will confirm that our proposed model can estimate the quality of other video sequences. After that, using unknown experimental data sets, which include variable burst packet-loss lengths, we will verify the validity of our model's coefficients.

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