실시간 모바일 IPTV의 열화 컨텐츠 평가를 위한 효율적 QoE 인지형 전송 스트림 측정 스키마

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An Efficient QoE-Aware Transport Stream Assessment Schemes for Realtime Mobile IPTV's Distorting Contents Evaluation

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요 약

IPTV나 Mobile IPTV 같은 IP 기반의 방.통 융합형 멀티미디어 서비스는 사용자 인지적 QoE가 보장된 서비스를 제공하는 것이 절실하다. 본 논문에서는 실시간 Mobile IPTV 서비스시 다양한 IP망의 조건에 따라 발생하는 에러의 영향으로 열화된 컨텐츠의 손상 정도를 보다 정확하고 효율적으로 평가하기 위한 방안을 제안하였다. QoE를 고려한 실시간 전송시 측정을 위해서 손상된 프레임의 효율적 정합 및 측정 방법을 보여 주었다. 제안된 알고리즘은 실시간 전송 스트림의 각 프레임으로 부터 디지털화된 컨텐츠의 밝기 정보를 추출하여 분석하며 블러, 블록, 에지 비즈니스, 컬러 에러 등 QoE 요소들을 RR 기반의 측정 파라메터로 활용하여 평가하였다. 제안된 방안의 정확성을 증명하기 위해서 원 소스 컨텐츠와 손상된 컨텐츠를 비교 분석하였다.

Key Words : QoE, Distorting Contents, TS Matching, Measuring, VQM

ABSTRACT

Supporting user perceptual QoE-guaranteed IP-based multimedia service such as IPTV and Mobile IPTV, we represent an efficient QoE-aware transport stream assessment schemes to apply realtime mobile IPTV's contents distorted by various network errors such as bandwidth, delay, jitter, and packet loss. This paper proposes in detail an efficient matching and QoE-aware measurement methods. The brightness of the digitized contents per each frames of transport streams is used and applied to reduced-reference method. The hybrid video quality metric is designed by QoE-indicators such as blur, block, edge busyness, and color error. We compare original with processed source to evaluate them in a high precision degree of accuracy.

Ⅰ. Introduction

IPTV service through mobile networks is becoming an important application due to the explosion of the IP-based media contents and the rapid growth of mobile communication devices. Streaming digital video over the IP core and access platforms, with various networking mechanisms, has come to be called "Mobile IPTV [1]." This streaming technology considers the service transfer possible from wire to wireless / from wireless to wire over Next Generation Mobile Network (NGMN) to ensure the quality of service/quality of experience (QoS/QoE). The

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NGMN will enable Mobile Nodes (MNs) to move between heterogeneous mobile and fixed access networks and still have access to the same set of IPTV services. IPTV service continuity needs to be supported between the heterogeneous mobile and fixed access technologies. In order to evaluate IPTV quality over mobile and fixed access network environment, various measurements solutions is deployed. However, early deployments sometimes use expensive dedicated test probes. And then, these methods are unsuitable for the realtime measurement or monitoring in NGMN environment, in order to provide high quality of mobile IPTV service.

Especially, for IPTV quality measurement, both full-reference (FR) and reduced-reference (RR) methods have received a lot of attention in the literature [2]. FR methods use the entire set of pixels while RR methods extract key information from the encoder and decoder pixels. Both FR and RR require reliable transport of information to the video quality monitor from the transmitting and receiving ends. The rate of this transfer is very high for the FR methods, although they may have the greatest accuracy because they use the most information. However, the cost of maintaining a reliable alternate channel to a central facility may be prohibitive even for RR methods. Further, even RR methods are not possible if for any reason the original video is unavailable. According to use original video, both methods can not measurement and monitoring with TS in realtime. No-Reference (NR) methods do not require the original video, because they predict video quality using only measurements at either before decoder or after decoder processing. However, it may have the weak point with accuracy because it is not use original video source. For quality monitoring of video over a packet network they are use NR methods [3].

In this paper, to solve above common problems we propose realtime video sequence matching technique which is robust method for distortion problem especially comparing reference with processed video sequences base on RR method. Hence, the proposed technique make that the method can apply to measure in realtime between TS and original video, possibly. With considering both network and video levels for mobile IPTV service, TS source is affected by packet loss, delay, jitter, etc., and then several distortions including blur, block, color error, jerkiness, edge busyness, etc., are occurred during transport times. To measure the degradation of TS quality in realtime, we design IPTV quality measuring metric using QoE-indicators and set the three monitoring points in the mobile IPTV service structure, which are head-end, transport, and customer networks. From the experimental results, with our proposed method for matching of distortion TS frames, the degradation of video quality can be measured efficiently and robustly in realtime.

The rest of this paper is organized as follows. Section 2 explains performance consideration of mobile IPTV service in NGMN environment. In Sect. 3, we describe realtime distortion frame matching scheme. Section 4 presents hybrid QoE-aware IPTV quality measurement metric. In Sect. 5, the experiments for performance evaluation of the proposed matching and measuring method are shown. Finally, we conclude with future works in Sect. 6.

Ⅱ. Next Generation Mobile Network (NGMN) Environment

In the NGMN, it is expected that a variety of the existing and new mobile/fixed access network technologies are supported, such as WLAN, Wibro, xDSL, CDMA networks etc. Each of the access networks is connected to the IP/MPLS-based core network, to provide various types of NGN services including voice, data, and multimedia services. Conceptually, a typical NGMN architecture can be viewed as many overlapping mobile/fixed access domains, as shown in Fig. 1. The main goal of NGMN is to allow users to profit services anytime and anywhere. The NGMN keeps the best features of

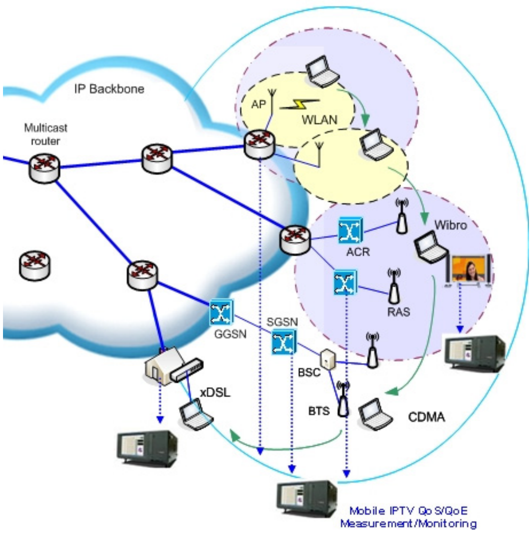


Fig. 1. Configuration of Mobile IPTV Service

the individual networks: the global coverage of CDMA networks, the wide mobility support of Wibro systems, and the high speed and low cost of WLANs. At the same time, it eliminates the weaknesses of the individual systems. For example, the low-data rate limitation of CDMA systems can be overcome when WLAN coverage is available through handover of the user to the WLAN.

When the user moves out of a WLAN coverage area, it can be handed over to CDMA system. Similarly, Wibro network can be used when neither a CDMA system nor a WLAN is available in order to use the best available network at any time [4]. In this architecture, delivery is to deliver packets to the destined MNs and paging is used to search the MNs in dormant mode [5]. Handover control is used to provide MNs with session continuity whenever they move into different network regions and change their point of attachment to the network during a session. The main objective of seamless handover is to minimize service disruption due to data loss and delay during the handover. Whenever seamless mobile IPTV media delivery desired and wherever the end-user may be, subject to any limitations imposed by the characteristics of the particular access technology (i.e. WLAN, Wibro, CDMA, xDSL, PSTN, etc.) and the terminal device being used, and with the expectation that the end user will have access to multiple terminal devices with different ranges of capabilities [6]. When an MN receiving the mobile IPTV service migrates to mobile only coverage where the access technology is not able to fully support it, the ongoing mobile IPTV services could be downgraded or disrupted. In order to prevent service disruption, mobile IPTV platform could support the storage, transcoding, conversion and relay of different types of multimedia.

To provide mobile IPTV services in NGMN, QoE is a critical issue. For example, the packet delay affects whether a decoder discards the received packet or not. Also, a lost packet in the decoder influences the decoded media quality, which affects the encode rate reallocation via RTCP (real-time transport control protocol) or other signaling[7].

For the measurement and monitoring mobile IPTV service, network performance can be monitored directly to ensure video service delivery in NGMN. Some necessary performance metrics for mobile IPTV surveillance can be collected from element management systems, including network traffic loss/delay/jitter statistics. Furthermore, mobile IPTV system can be classified by three main factors: head-end system, transport network, and customer network. We define head-end system which is including until process before muxing of TS source. IP-core and access network can be defined as transport networks. Finally, customer network include full processing after access network which is included set-top box, lab-top, handheld devices, etc. On the head-end area, we can assess at the points which are before/after encoder processing and before muxing. At the measuring points, block distortion and blurring effects mainly happen on the TS source. From the transport area, we can assess at the points which are before/after IP network and before/after access network. Color error, jerkiness, edge busyness, etc., in TS source is affected by packet loss, delay, jitter, etc. Set-top box in customer network area which is after final access network measures all of QoE-indicators which can be mainly affected by channel zapping time.

The current issue in the area is to measure in realtime with face value which service providers really want the greatest accuracy. Thus, our focus is on the distorted TS matching in realtime basically, and then the proposed method is useful for applying to estimation of network-considered video-QoE indicators based on proposed RR video measurement method.

Ⅲ. Accurate Transport Stream Frames Matching Scheme

The content-based video retrieval systems normally use color histogram-based matching methods [8]. However, they are not suitable for distorted TS of mobile IPTV service and have problem with color distribution between original and processed TS especially since the color histogram does not preserve information about the spatial distribution of colors. Also, in the cases of dynamic motion and various shot changing for short time, there are usually occurred serious distortion problem on TS.

For applying to various distortion frames of TS without above problem, we use partition based [9] ordinary measuring approach method. The proposed scheme uses color classification in necessary for training of realtime matching using digitized TS source, first of all. Second, the proposed scheme is also robustness to matching and measuring in accuracy with even serious distortion frames on TS source by several reasons such as delay, jitter, packet loss, encoding/decoding processes, etc. The color classification based training of current TS is investigated in RGB/HSV. Colors are specified in terms of the three primary colors: red (R), green (G), blue (B), basically. We analyze colors which are specified in terms of hue (H), saturation (S), and intensity value (IV) and show the relationship with RGB in order to match and measure in realtime considering various distortion errors. We consider distortion of all or a portion of the final characterized by the appearance of unnatural or unexpected hues or saturation levels which were not present in the original source on mobile IPTV service.

We assign H bins for hue channel, S for saturation channel, and IV for intensity value channel. We set 64, 64, and 256 to H, S, and IV, respectively. We define accumulated histograms HUE, SATURATION, INTENSITY_VALUE, in which the values in each bin is accumulated for the first 30 TS frames per second.

$$\begin{aligned} HUE[k] &= \sum_{i=0}^{29} Hue_i[k] \\ SATURATION[k] &= \sum_{i=0}^{29} Saturation_i[k] \\ INTENSITY\_VALUE[k] &= \sum_{i=0}^{29} IntensityValue_i[k] \end{aligned} \quad (1)$$

The equations to compute saturation S and intensity value IV in HSV color space from R, G, B values in RGB space.

$$\begin{aligned} S &= \tfrac{Max(R,G,B)-Min(R,G,B)}{Max(R,G,B)} \, for(0.0 \le S \le 1.0) \\ IV &= Max(R,G,B) \, for(0.0 \le IV \le 1.0) \end{aligned} \quad (2)$$

where R,G,B are all normalized values from 0 to 1.

For the computation of partition based ordinary measuring, since the considering mobile IPTV resolution, each TS video frame is partitioned into 8*8 images. That is, each frame is partitioned as the same 64 blocks. After partition the TS source, the mean brightness of color is expressed as

$$M_i = \frac{1}{HW} \sum_{x,y \in B_i} I(x,y), \quad i = 1,2,...,64 \quad (3)$$

where B is block, H*W are height * width of blocks from the partitioned TS sources. I(x, y) is brightness degree values, respectively. From Eq. (3), M which is mean brightness value, is saved as 8 * 8 rank maps to measure distance between original source frame and TS source frame.

$$d_{n,m} = \frac{1}{64}|TM_i^n - OM_i^{n+m}|, i=1,...,64,\ m=0,1,..,L-P \quad (4)$$

where TM is processed TS source, OM is original source. L is length of TS source, and P is length of original source. After the processing of each frame as Fig.2, distance value D is measured from Eq. (5), respectively.

$$D = \frac{1}{P}\sum_{n=1}^{P} d_{n,m}, \quad m = 0,1,\dots,L-P \quad (5)$$

With dynamic motion shots such as dancing, sports, etc., there are usually occurred serious distortion problem on current TS. For the case of serious distortion areas happen, to detect more closely, the video sources are partitioned again into (8 * 8) * n times to matching in accuracy and check distance until the value is less than threshold values which is less than 3. Finally, we match the distortion frames of current TS in realtime to support QoE indicators errors. After the processing procedures, all of the QoE indicators are measured by the proposed RR-based realtime video measurement methods.

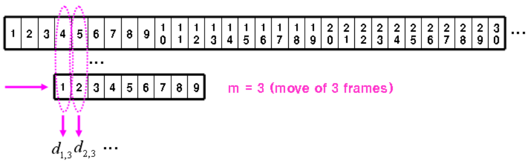


Fig. 2. Distance measure of each frame

Ⅳ. QoE-Aware Quality Assessment Metric

Differences in quality of video between head-end and receiving-end are due to loss compression/decompression as well as transmission errors, which lead to artifacts in the received viewing contents. The amount of artifacts and visibility of these distortions strongly depend on the video contents. There are two types of quality to measure and to verify digital video quality which is delivered to the end user to identify content quality degradation: objective and subjective quality. Both of these are to develop Video Quality Metrics (VQM) which is intended to provide calculated values that are strongly correlated with a viewers' assessment [10]. In this research, we mention above five QoE-indicators which include blurring, block distortion, edge busyness, color error, and jerkiness according to the whole transmission process which can produce artifacts to digital video QoE. We design hybrid VQM model which is efficient in combining those indicators.

$$VQM = a\times E_{edge} + b\times E_{block} + c\times E_{blur} + d\times E_{color} - E_{jerky} + C \quad (6)$$

As mentioned in the introduction, the main drawback of the objective quality tests is that they do not correlate well with human perception. To evaluate the quality of video systems, a subjective quality test is generally used. In this kind of test, a group of human subjects is invited to judge the quality of the video sequence under different system conditions (distortions). There are several recommendations [11, 12] that specify strict conditions to be followed in order to carry out subjective tests in the ITU recommendations. We use the main subjective quality methods which are Double-Stimulus Continuous Quality-Scale (DSCQS) to design accurate objective metrics. In the DSCQS subjective quality test, a pair of video sequences is presented to each observer, one after the other. The observer is asked to assess the overall quality of the distorted sequence with respect to the non distorted one (the reference sequence), using a grade scale from one to five, corresponding to his/her mental measure of the quality associated with. It should be noted that there several quality scales exist. We chose this five-grade scale as a tradeoff between precision and dispersion of the subjective evaluations. Following the ITU-R recommendations, subjective tests are to be divided into multiple sessions overall; each session should not last more than 30 min. This is done to calculate the final mean opinion score (MOS) that we will use to design the hybrid VQM and testing phases. In our method, what we mean by a test condition is the resulting sample or sequence after distorting the original one (reference) by a selected set of values for the quality-affecting parameters. We use four different image frames consisting of various contents such as Product Advertising, Documentary, Dancer and News video. As shown in Fig. 3, test video frames are printed in pairs to

$$\Pi = \sum_{i=1}^{n}[y_i - f(x_i)]^2 = \sum_{i=1}^{n}[y_i - (a + bx_i)]^2$$

accommodate the double presentation of each test sequence. Each video frame is shown for 10s and gray video frame present for 3s after reference and processed frame. The 20 evaluators vote after repeat twice. It is divided into five equal lengths which correspond to the normal ITU five-point quality scale.

In order to map the result with subjective MOS (1~5 grading scales) per QoE indicators (0.0 ~ 1.0 grading scales), we define the limitation equation as follows,

$$Limit_j^i = \frac{1}{N}\sum_{n=1}^{N}\max(S_{n,j}^i), \quad where\ i = \{Block,\ Blur,\ Color,\ Edge\} \quad j = \{1,\ 2,\ 3,\ 4,\ 5\} \tag{7}$$

where ***i*** is each QoE-indicator, ***j*** is MOS value, ***N*** is number of evaluator (20 in this case), and S is result of each QoE-indicators.

We use the multiple linear regression analysis. If we suppose as $y = a + bx$,it can be described by the results of QoE-indicators and subjective MOS as in $(x_1, y_1), (x_2, y_2), \cdots, (x_n, y_n)$, and then to get linear coefficient a, b, the procedure is as follows,

$$\Pi = \sum_{i=1}^{n}[y_i - f(x_i)]^2 = \sum_{i=1}^{n}[y_i - (a + bx_i)]^2 \tag{8}$$

By differentiation of a, b, as follows, and then define by x, y

$$\frac{\partial \Pi}{\partial a} = 2\sum_{i=1}^{n}[y_i - (a + bx_i)] = 0$$
$$\frac{\partial \Pi}{\partial b} = 2\sum_{i=1}^{n}x_i[y_i - (a + bx_i)] = 0 \tag{9}$$

$$\sum_{i=1}^{n} y_i = a\sum_{i=1}^{n} 1 + b\sum_{i=1}^{n} x_i$$
$$\sum_{i=1}^{n} x_i y_i = a\sum_{i=1}^{n} x_i + b\sum_{i=1}^{n} x_i^2 \tag{10}$$

Finally, linear coefficient a, and b are as follows, and then from the equation, coefficients a, b, c, d, C for the hybrid VQM is a = -17.809, b = -3.352, c = 5.340, d = 32.191, C = 4.424 from equation (6).

$$a = \frac{(\sum_{i=1}^{n} y_i)(\sum_{i=1}^{n} x_i^2) - (\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} x_i y_i)}{n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2},$$
$$b = \frac{n\sum_{i=1}^{n} x_i y_i - (\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} y_i)}{n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2} \tag{11}$$

Finally, we design the hybrid VQM model as

Fig. 3. Frames for block distortion testing

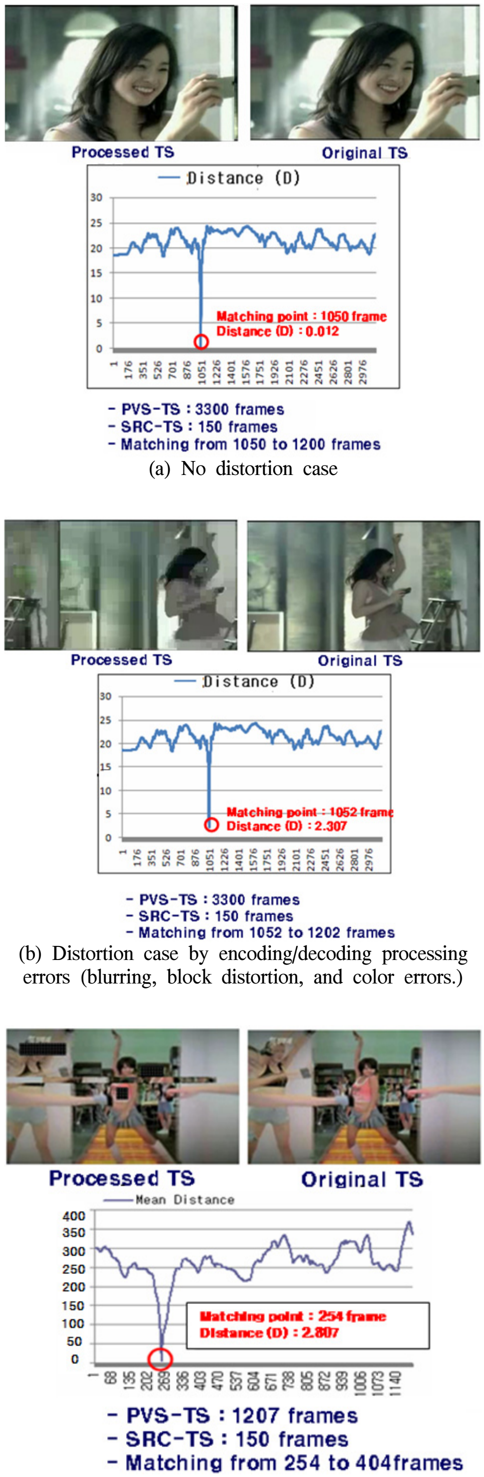
follows,

$$VQM = -17.809E_{edge} - 3.352E_{block} + 5.340E_{blur} + 32.191E_{color} - E_{jerky} + 4.424 \quad (12)$$

Ⅴ. Simulation Results

We have used a MPEG-2 TS with 3300 frames wherein this sequence has a variety of sub-sequences including news, advertising, sport, drama, etc. In figure 4, the captured image frame of the advertising which has dynamic motion and several shot changing is used to test the proposed algorithm. We examine various distortion cases of the processed TS by the affections of packet loss, jitter, delay, out of order, encoding/decoding processing errors, etc. For the matching examination, SRC (original video source)-TS which is composed by 150 frames length, use to compare with PVS (processed video source)-TS of about 3300 frames length. After applying the proposed scheme with average threshold distance 3 for PVS-TS which has no distortion errors, we get matching period from 1050th to 1200th frames that is measured at 0.012 mean distance between SRC-TS and PVS-TS as Fig.4 (a). For the distortion cases by transport and encoding/decoding processing errors (blurring, block distortion, and color errors.), our proposed method finds the matching in accuracy with 2.307 mean distances for displaying on system in realtime as Fig.4 (b). For the serious distortion case by packet loss, out of order, jitter, and encoding/decoding processing errors, our proposed method finds the matching in accuracy with 2.807 mean distances for displaying on system in realtime as Fig.4 (c), which is processed in condition of that SRC (original video source)-TS which is composed by 150 frames length, use to compare with PVS (processed video source)-TS of about 1207 frames length.

After matching the distorted frames, we evaluate IPTV quality using the proposed hybrid objective VQM. Table 1 shows the relationship between four QoE-indicators and subjective MOS



(a) No distortion case

(b) Distortion case by encoding/decoding processing errors (blurring, block distortion, and color errors.)

(c) Distortion case by packet loss, out of order, jitter, encoding/decoding processing errors (blurring block distortion, edge busyness, jerkiness, color errors, etc.)

Fig. 4. Distance matching results

Table 1. Decision of MOS values per QoE-indicators

MOS	Block distortion	Blurring	Color error	Edge busyness	Jerkiness
5	0~ 0.045	0 ~ 0.028	0 ~ 0.036	0 ~ 0.158	0.0
4	0.045~ 0.224	0.028~ 0.124	0.036~ 0.066	0.158~ 0.398	0.0
3	0.224~ 0.458	0.124~ 0.241	0.066~ 0.088	0.398~ 0.678	0.0
2	0.458~ 0.811	0.241~ 0.341	0.088~ 0.094	0.678~ 0.928	0.0
1	0.811~	0.341~	0.094~	0.928~	1.0

result by the decision of limitation from Eq. (7). Especially for jerkiness, if it is caused, it is 1. Otherwise, it is 0.0 (MOS=5).

Table 2 shows the results of each QoE-indicator from object tests and VMOS results from subject test using 10 different video sources. The results of each indicators use to get VQMs for Eq. (12) and then we compare it with VMOS using the method.

Table 2. QoE-indicators : VMOS

Video No.	E_{edge}	E_{block}	E_{blur}	E_{color}	E_{jerky}	VM-OS (avg.)
1	0.035418	0.491012	0.038312	0.026424	0.0	3.3
2	0.041433	0.082635	0.016618	0.002723	0.0	2.6
3	0.061732	0.012096	0.099532	0.000777	0.0	4
4	0.051893	0.066658	0	0.008998	0.0	3.9
5	0.100438	0.38334	0.062724	0.011724	1.0	1.9
6	0.411201	0.601793	0	0.187385	1.0	1.1
7	0.015523	0.026087	0.008097	0.022293	0.0	4.8
8	0.144709	0.079513	0	0.004151	1.0	1.8
9	0	0	0	0	0.0	4.7
10	0.090711	0.324119	0.03081	0.008727	0.0	2.4

Ⅵ. Conclusions

In this paper, we propose the realtime TS frames matching and measuring schemes between original and processed source, which are designed robustly for so much as distortion frames of TS. The proposed method gives much useful advantage to service provider as the processing in accuracy and in realtime to provide QoE-guaranteed mobile IPTV service. As evidenced in the experimental matching results after applying to points over headend system, transport network, and customer network areas over NGMN environment, the presented scheme is very effective for measuring in accuracy and monitoring in realtime. Furthermore, we propose hybrid QoE-aware mobile IPTV contents quality measurement method considering QoE-indicators.

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