REQMM：Real-Time End-User QoE Monitoring Middleware for IP-Based Commercial TV Service

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Abstract—**End-user Quality of Experience (QoE) monitoring is critical to IP-based commercial TV service. REQMM is a middleware which provides a novel video quality assessment method based on Decode Buffer probing (DBP), service failure detection and Request Response Time (RRT) calculation. DBP probes Transport Stream (TS) packet loss, overflow and underflow at decoder buffer with great accuracy, low CPU, low memory, and low storage requirements. REQMM has been integrated into over eight terminal models and will be put into large-scale commercial TV service of Shanghai Telecom.**

I. INTRODUCTION

Real-Time End-User QoE monitoring is critical to massive IP-Based Commercial TV Service. Many objective video quality assessment methods have been proposed to measure QoE. In these methods, video quality metrics are generally classified into full-reference, no-reference and reduced-reference categories [1]. Full-reference and reduced-reference models take decoded frames as the input and probe at *display buffer* which is extremely close to the end users' view, but they can't distinguish video distortion by frame content without the original video source, so they are not accurate and they need more computation resources. Recent researches have been focusing on no-reference models which probe at *network buffer* and work at packet layer or bit stream layer, but they are not accurate enough by ignoring the subsequent quality compensation, and bit-stream-based models require more computation resource and their applications are often limited to certain codecs [2]. In massive IP-Based Commercial TV system, the terminals (such as Set-top box) are provided by different manufactures and are heterogeneous, with low and limited CPU, memory and storage. Since the above QoE methods are not accurate, challenge the terminal's limited computation resources and do not consider the terminal heterogeneity, they are not suitable to assess Real-Time End-User QoE in massive IP-Based Commercial TV service. On the other hand, user perceived quality of video is not determined by video quality alone, prior work such as [3] has shown that other factors such as error messages are also important to QoE. However, there is no QoE monitoring system which considers both video quality and other factors such as system failures at the terminals of IP-based commercial TV system.

REQMM is a QoE middleware embedded in the terminals of IP-based commercial TV system. REQMM screens the heterogeneity of terminals, combines a novel video quality assessment method based on Decode-Buffer probing (DBP), service failure detection and Request-Response Time (RRT) calculation. DBP probes Transport Stream (TS) at decoder buffer with great accuracy, low computation resources.

II. REQMM MECHANISM AND ARCHITECTURE

REQMM has three main functions: DBP implement, service failure detection and Request-Response Time calculation.

A. Mechanism of DBP

To balance among accuracy, performance and trouble shooting, DBP collect data from decode buffer which is between the network buffer and display buffer. DBP monitors the TS packet loss rate and the percentage of underflow. The TS packet loss rate PLR_{ts} is: $PLR_{ts} = N_{lost}/(N_{lost} + N_{recv})$.where N_{recv} is the number of TS packets received by the decoder buffer. N_{lost} is the number of lost TS packets, it can be inferred by the continuity counter in TS heads. Suppose cc_i is the continuity counter of the ith TS packet parsed in current measurement period, then the number of lost TS packets between cc_i and cc_{i+1} is: $l_i = (cc_{i+1} + 15 - cc_i)\backslash 16 + 16k_i$.where k_i is a natural number. And when $i = 0$, cc_i stands for the continuity counter of the last TS packet in the previous measurement period. Let $N_{lost}' = \sum_{i=0}^{N_{recv}}(cc_{i+1} + 15 - cc_i)\backslash 16$, then N_{lost} of current period can be expressed by$N_{lost} = \sum_{i=0}^{N_{recv}} l_i = N_{lost}' + 16\sum_{i=0}^{N_{recv}} k_i$. DBP applies Mean Opinion Score (MOS)[4] to rate user-perceived video quality, and mapped decoder buffer parameters to it. We divided the underflow duration into thirteen sections and applied polynomial regression for TS packet loss rates within each section. The results of seven-fold cross-validation suggested that a sixth degree polynomial regression was appropriate to avoid overfit. (1) is the fitting function:

$$f_i(x) = \begin{cases} \sum_{k=0}^{6} a_{i_k} x^k, & 0 \le x \le s_i \\ 1.0, & s_i < x \le 1 \end{cases} \quad (1)$$

Here x is the TS packet loss rate, f_i is the fitting function for the ith underflow duration section, s_i is the minimum TS packet loss rate where the value of the function achieved by polynomial regression is equal to 1.0. Finally, the outputs of fitting functions range from 1.0 to 5.0.

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B. Service Failures Monitoring

To monitor the service failures in the network, a state machine driven by the network packets is maintained. The network packets are classified into four categories: IGMP Packet, RTSP Packet, RTP packets, HTTP packets, they have different interactive processes, and the state machine can eliminate non-playing period during video quality assessment. Besides streaming service, other more complicated business processes require multiple interactive steps in IP-based commercial service, such as authentication; when any error occurs, the following steps are aborted and authentication operation fails. For this kind of procedure, a state machine can record its progress.

C. Calculate Total Request-Response Time

The total RRT for video streams: $RRT_{total} = t_d - t_q$, where t_d is the time when the first data packet is received and t_q is the time when the first request of video control is sent. The result RRT_{total} is recorded in millimeters (ms).

D. Architecture of REQMM

As Fig 1, REQMM is mainly composed of three modules: Embedded Module, Network Monitoring Module and Analysis Module. The *embedded module* includes two

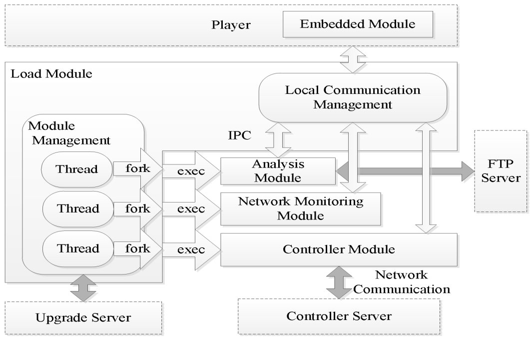

Fig. 1. The architecture of REQMM middleware

interfaces for the main thread of video player to report TS information and buffer underflow or overflow, with multithread mechanism to minimize the impact on the performance of original system. *Network Monitoring Module* opens a raw socket to capture network packets and maintains a state machine of video player. If a captured packet is one of the four required packet categories, it is taken as input by the state machine. When a service failure is detected, it is reported to analysis module instantly. QoS parameters are reported only at each end of a calculation cycle in a separate thread. *Analysis Module* periodically summarizes all the collected data and sends reports to server; it merges data of the same calculation cycle and calculates MOS for each playing cycle and writes the monitoring results of all calculation cycles into a log file, uploads it to FTP server and then deletes the local copy.

REQMM has been integrated into over eight Set-Top Box(STB) models produced by different terminal manufacturers including Huawei, ZTE, Daya, Coship Electronics and Dare Technology, and works well through detail tests which play High Definition (HD) Live TV streams from Shanghai Telecom IPTV service to obtain the results of video quality assessment. REQMM will be put into large-scale use on the Internet Protocol Television (IPTV) service of Shanghai Telecom soon.

III. REQMM DEMO SETTING

We will demonstrate REQMM using Daya4900 STB (CPU 400MHz, Memory 128M, Available Storage 8M) and Huawei STB EC5108 STBs (CPU 400MHz, Memory 128M, Available Storage 53.7M) and two laptops. Both STBs were embedded with our REQMM middleware; one of them has implemented Automatic Repeat-reQuest (ARQ). Laptop One will work as a proxy, introducing packet loss and jitter to media traffic. Laptop Two will display statistics of active STBs, showing their status information including video quality, detected failures and workload. All the calculation interval of the monitoring system was set to 5 seconds and the report interval was 300 seconds. We played a VoD stream from Shanghai Telecom IPTV service with 1.6Mbps bitrate on these set-top boxes with and without REQMM running, and compared their use of CPU, memory, and the available storage. During the demonstration we will set the impairment parameters on Laptop One so that there will be no visible video quality degradation on STB with ARQ, while the other STB will suffer quality problems. The users are asked to tune those parameters and examine corresponding analysis results as well. They are able to see that logs and figures displayed on Laptop Two which reflect network condition and QoE in time

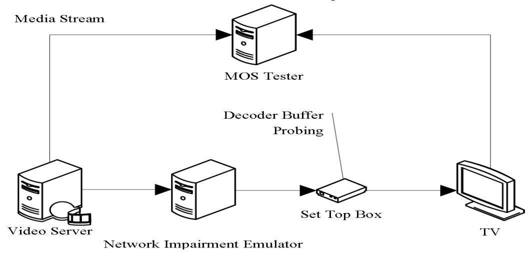

Fig.2. The experiment environment for MOS testing.

Figure 2 is the demo environment to test relationship between decoder buffer parameters and MOS, The input was actual video streams from Shanghai Telecom IPTV service. The demo system will generate the comparison result of outputs from MOS tester and our model, shows the accuracy of REQMM.

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