Adaptive QoS Framework
for Multiview 3D Streaming[*]

Jin Ryong Kim[1], Youjip Won[2], and Yuichi Iwadate[3]

[1] Digital Contents Research Division, Electronics and Telecommunications Research
Institute, Daejeon, Korea
`jessekim@etri.re.kr`
[2] Div. of Electrical and Computer Engineering, Hanyang University, Seoul, Korea
`yjwon@ece.hanyang.ac.kr`
[3] NHK Science & Technical Research Laboratories, Japan Broadcasting Corporation,
Tokyo, Japan
`iwadate.y-ja@nhk.or.jp`

Abstract. We present the adaptive QoS framework for multi-view 3D
streaming to deliver the media in time and at the same time, we provide
an optimal solution to minimize the quality variation. We dynamically
adjust the number of polygons in 3D model so that it can support
constant frame rate. We also propose to minimize the frequencies in QoS
transition to provide better user perceptive streaming. As a result, the
stable frame transmission rate is guaranteed and the quality fluctuation
becomes smoother.

Keywords: QoS, Virtual Studio, Interactive TV, Multimedia Stream-
ing, 3D Streaming

1 Introduction

When 3D media move downstream to viewers, transmission rate in the network
will be varied depending on the network traffic condition. We propose an adaptive
QoS management scheme to efficiently stream time-critical media and optimal
quality adaptation scheduling algorithm for multiview 3D streaming.

NHK[3] developed a 3D model generation system using multiple cameras with
multi-baseline stereo algorithm and the volume intersection method. It is de-
signed to generate 3D model media contents and support any viewpoint. Salehi[5]
proposed an optimal rate smoothing algorithm based on the traffic smoothing
technique to achieve minimum variability of the transmission rate. Cuetos et
al.[2] proposed to find a shortest path to minimize variability. Nelakuditi et
al.[4] accomplished the maximum reduction of quality variability for layered
CBR video using bidirectional layer selection. This paper extends NHK's multi-
ple camera system by developing the QoS architecture to develop 3D streaming
system for immersive environment. It is designed for delivering visual contents
from the studio to the consumer platform via the Internet.

2   Rate Adaptive Transmission

The idea of our scheme is to monitor the network bandwidth availability and send the 3D video having appropriate bit rate. Each time slot represents the time unit for playing a video. Let k be the time slot at t_k. C is the number of frames in a time slot and it is set to $C=20$ for every time slot to have a fixed frame rate for every time slot. We define W_k as a quantitative amount of the available network bandwidth at each time slot k. We assume that the current W_k is known. Given a maximum network bandwidth, W_k is fluctuating over a wide range. The available network bandwidth curve is divided into time slots and quantified under $\delta \geq \phi$ for $k = 1...N$ where N is the total number of time slots, ϕ_k is inner portion of network bandwidth curve, and δ_k is outer portion of network bandwidth curve. W_k is an optimal value at each time slot k from the network available bandwidth curve. QoS level at time slot k is determined as follow: if available bandwidth is greater than r_E, then QoS_k is assigned as 'E', where QoS_k is QoS level at k and r_{lv} is bit rate for QoS level lv. If available bandwidth is between r_E and r_G, then QoS_k is assigned as 'G'. If available bandwidth is between r_G and r_F, QoS_k is assigned as 'F'. If available bandwidth is between r_F and r_P, then QoS_k is assigned as 'P'. If available bandwidth is lower than r_P, then QoS_k is assigned as 'B'. Qos_k of 'E', 'G', 'F', 'P', and 'B' can be mapped into quality scale Q_k of 5, 4, 3, 2, and 1 for simplicity.

3   Optimizing Quality Variation

Fig. 1(a) illustrates the unstable video transmission if the server transmits only one quality of the video sequence and Fig. 1(b) illustrates how the video sequence is adaptively transmitted under variable network bandwidth using our existing scheme. It also illustrates the quality fluctuation in Fig. 1 (b). Each colored time slot represents the distinct quality. The basic idea of our extended scheme is that instead of changing the quality of the time slot at each point of time, we keep the same quality and raise the quality level at some point. We accomplish this scheme by prefetching some portions of the next time slot as shown in Fig. 1(c). This enables us to maximize the usage of available network bandwidth and minimize the quality variation.
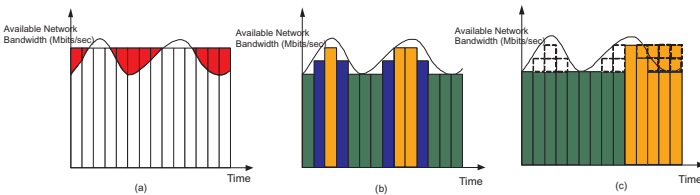
**Fig. 1.** Example of quality optimization

We forecast the future network bandwidth availability using double exponential smoothing based predictor (DESP)[1]. Using $DESP$, the future available network bandwidth can be forecasted as $P(k) = \alpha W(k) + (1-\alpha)(W(k-1) + b(k-1))$ and $b(k) = \gamma(P(k) - P(k-1)) + (1-\gamma)b(k-1)$ where $P(k)$ is smoothed value at k and $b(k)$ is a trend equation. α and γ are smoothing and trend constants, respectively, and $\alpha \in [0,1]$ and $\gamma \in [0,1]$. Forecast equation $Z(k)$ is defined as $Z(k+u) = P(k) + ub(k)$ where u denotes $u - period$ ahead forecast.

We model the quality adaptation for CBR video by replacing re-scheduled time slots to maintain a uniform quality scale. In formulating optimal quality adaptation, we consider a discrete-time model. We assume that there are 5 seconds of buffers in the client. The time slots are scheduled in the server based on $DESP$. We set u as 4 to have 4 time slots in the server. We consider the future available network bandwidth trend as a reference quality scale for every point of time. Let i be the index and N be the number of time slots in the server. Then, the mean quality scale of the time slots in the server is $Q_{avg} = \lfloor \frac{\sum_{i=k+1}^{N+k} Q_i}{N} \rfloor$. We define a majority quality scale in the system for selecting optimal quality scale. Let $f_R(r,k)$ denotes a set of frequencies of quality scales where $r \in \{E, G, F, P, B\}$. Then, the majority quality scale is $Q_{majority} = max\{f_R(r,k)\}$. We now introduce our prefetching algorithm. The time slots are divided into layers with the same size and it is represented as granules. When the server transmits the time slot with rescheduled quality scale, some vacant granules become available. Then, we take advantage of using these empty spots to prefetch some granules from the next time slot. We keep track of residual bandwidth $RB(k)$ and it is defined as $RB(k) = RB(k-1) + W_k - r_{lv}$. $L(k)$ denotes the depth of layer at k and it is defined as $L(k) = \frac{r_{lv}}{l}$ where l denotes the size of granule. $e(k)$ denotes the number of empty granules and it is $e(k) = \frac{RB(k)}{l}$. Using $L(k)$ and $e(k)$, we prefetch granules in $k+1$ as $Prefetch = \sum_{j=L(k+1)-e(k)+1}^{L(k+1)} Q_{k+1}^j$ where j denotes the layer index.

4 Performance Experiment

We examine the effectiveness of rate adaptive transmission. To measure the smoothness of the quality scale, we use average run length(ARL) metric proposed by [4]. ARL is the metric to measure a sequence of consecutive frames in a layer. This metric attempts to measure the smoothness in the perceived quality of a layered video. It is defined by $ARL = \frac{1}{L} \sum_{i=1}^{L} \frac{\sum_{j=1}^{k_i} n_j}{k_i}$ where k_i is the number of runs in the ith layer, and n_j is the length of the jth run. Fig. 2 illustrates the performance of rate adaptation transmission scheme between normal and optimal transmission. Fig. 2(a) illustrates the quality fluctuation with the traffic interferences at 5 Mbps in normal rate adaptive transmission. In Fig. 2(a), the majority quality scale in this figure is 'F' and some transitions are occurred between 'G' and 'F'. ARL is 1.263, which is very small run length. As a result, the quality fluctuation and degradation of perceptual quality is highly occurred.

(a) UDP Traffic = 5 Mbits/sec   (b) UDP Traffic = 5 Mbits/sec
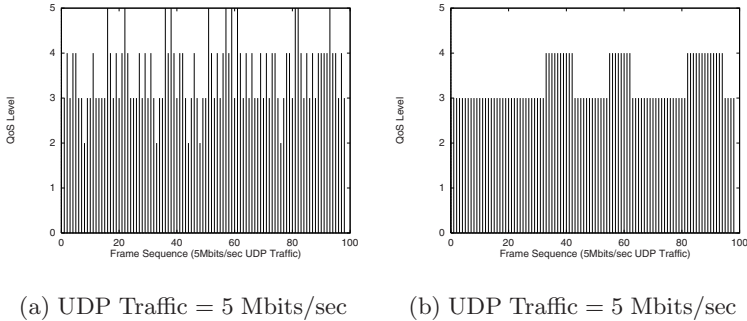
Fig. 2. Performance of Normal and Optimal Rate Adaptive Transmission

Fig. 2(b) is the performance of optimal rate transmission with the traffic interferences at 5 Mbps. In Fig. 2(b), *ARL* is 14.286. Note that *ARL* is longer in optimal rate transmission than normal rate adaptation scheme. It is also noticed that only two quality scales are used and an extremely smoothed result is accomplished. Overall, the results show that the optimal rate transmission algorithm exhibits smoother quality fluctuation compared to the normal rate adaptive transmission scheme.

5   Conclusion

In this paper, we proposed adaptive QoS management to reduce time delay and guarantee the constant playback rate in delivering high-quality, 3D contents. We also provided optimal quality adaptation scheme to minimize the quality fluctuation. Our results show that proposed QoS architecture can effectively utilize the available network bandwidth and minimize the quality variation.

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