Adaptive Rate Control Scheme for Improving Quality of Multimedia in Broadband Wireless Networks

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Keywords: Quality Adaptation Scheme, Video Streaming, Rate Control.

Abstract: In order to improve quality of streaming services in broadband wireless networks, many researches are in progress. However, existing schemes do not guarantee a user perceived quality, because most of these schemes do not consider both wireless channel states and video characteristics. To cope with these problems, this paper proposes a NB-RC (Network and Buffer-aware Rate Control) scheme. The proposed scheme adjusts the video transmission rate according to the wireless channel states. It also controls the video quality based on buffer occupancy of clients. Through the simulation results, we prove that our scheme improves the media quality.

1 INTRODUCTION

Due to the explosive growth of the broadband wireless network technologies, there has been a significantly increasing demand for multimedia streaming applications such as mobile IPTV (Park and Jeong, 2009). Recent advances in high-speed networks have made it feasible to provide high quality of video streaming. Among the advanced wireless standards, LTE (Long Term Evolution) is an emerging wireless communication system that provides high-data rate as well as long-range converage. However, multimedia streaming service in a wireless communication network environment is largely affected by various network characteristics, such as limited channel bandwidth and variant transmission rate. The channel bandwidth variation causes the network congestion when the video transmission rate exceeds the channel bandwidth.

To solve these problems, several methods for wireless video streaming have been proposed. An end-to-end QoS-based adaptation scheme called AWMECN (Application-level Wireless Multilevel ECN) is suggested in heterogeneous wireless networks by overcoming the congestion/loss mistake problems (Karimi et al., 2010). A probing-based channel adaptive video streaming method is proposed to adjust the transmission rate to the varying throughput of wireless 3G network (Kim et al., 2006). Also, a WMSTFP (Wireless Multimedia Streaming TCP-Friendly transmission control Protocol) is proposed to effectively differentiate erroneous packet losses from congestive losses and to filter out the abnormal round-trip time values caused by the highly varying wireless channel states (Yang et al., 2004). A new single-rate multicast congestion control scheme called ASMP (Adaptive Smooth Multicast Protocol) for multimedia transmission over best-effort networks is proposed (Bouras et al., 2010). However, all of theses schemes doesn't consider the buffer states of a client and require the bandiwdth estimation of wireless network.

To cope with these problems, a new adaptive streaming scheme has been proposed (Koo and Chung, 2010). This scheme called MARC (Mobile-aware Adaptive Rate Control), which adjusts the quality of bit-stream and transmission rate of video streaming based on the wireless channel states and network states. However, the MARC scheme is sensitive to packet loss rate. It could cause the oscillation of transmission rate.

In this paper, we propose a NB-RC (Network and Buffer-aware Rate Control) scheme for improving the video quality in multimedia streaming services. The NB-RC scheme considers not only the wireless channel states but also the buffer occupancy of clients. This paper shows that the proposed NB-RC scheme can significantly improve the media quality. The rest of the paper is organized as follows. In the next section, we present the NB-RC scheme for improving quality of multimedia. Simulation

Yoon D., Kim D. and Chung K..
Adaptive Rate Control Scheme for Improving Quality of Multimedia in Broadband Wireless Networks.
DOI: 10.5220/0004020400070011
In *Proceedings of the International Conference on Signal Processing and Multimedia Applications and Wireless Information Networks and Systems* (SIGMAP-2012), pages 7-11
ISBN: 978-989-8565-25-9

results and conclusions are given in Section 3 and Section 4, respectively.

2 NB-RC SCHEME

Fig. 1 shows the architecture of the proposed NB-RC scheme. The streaming server controls the transmission rate and video quality according to the feedback information received from client. The client feedbacks its network access states and buffer occupancy to the streaming server. The main component of this architecture is the adaptation module which decides both the transmission rate and the video quality level based on wireless channel states and buffer occupancy. The wireless channel states include CINR (Carrier to Interference and Noise Ratio). In order to control the video quality smoothly, the buffer states are used in the streaming server.

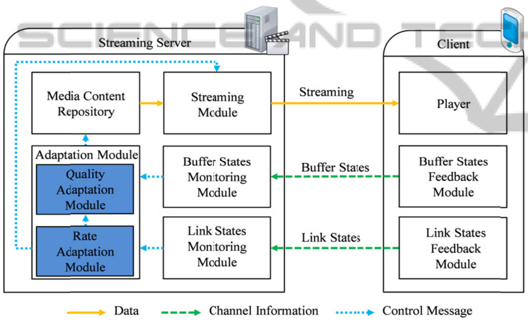

Figure 1: Architecture of a multimedia streaming system.

2.1 Adaptive Rate Control

The rate adaptation module computes an initial transmission rate when CINR has changed. The physical data rate, R_{PHY}, is calculated with Eq. (1), where D_{rate} is the data subcarrier rate, m_{gain} denotes the modulation gain that m_{gain} = 2 for QPSK, m_{gain} = 4 for 16-QAM, and m_{gain} = 6 for 64-QAM. The c_{rate} represents the coding rate (bits/subcarrier). For example, if the current MCS (Modulation and Coding Scheme) level is 5/6 64-QAM, then the physical data rate, R_{PHY}, for downlink is equal to 18.432 (=3.6864·(5/6)·$\log_2$64)Mbps. The MCS level according to the CINR and the corresponding R_{PHY} is summarized in Table 1 (Kim et al., 2008). By setting the initial transmission rate, R_{init}, to R_{PHY} as shown in Eq. (2), we can reflect the network physical states.

$$R_{PHY} = D_{rate} \cdot m_{gain} \cdot c_{rate} \quad (1)$$

$$R_{init} = R_{PHY} \quad (2)$$

Table 1: Physical data rate with CINR level.

CINR (dB)	Modulation	Coding Rate	R_{PHY} (Mbps)
26	64-QAM	5/6	18.43
23	64-QAM	3/4	16.59
20	64-QAM	2/3	14.74
18	16-QAM	5/6	12.29
16	16-QAM	3/4	11.05
14	16-QAM	2/3	9.83
12	16-QAM	1/2	7.37
10	QPSK	2/3	4.91
6	QPSK	1/2	3.69
3	QPSK	1/3	2.46
1	QPSK	1/6	1.23
-1	QPSK	1/12	0.61

After setting up the initial transmission rate, the rate adaptation module calculates the transmission rate, R, based on wireless channel states. In this paper, we define a new matric, M_{DL}, to determine the wireless channel states, which consider the downlink data rate, R_{DL}, as shown in Eq. (3), where R_t is a target bit rate for video decoding. The streaming server decides the network states by M_{DL}.

$$M_{DL} = \frac{R_t}{R_{DL}} - 1 \quad (3)$$

The video transmission rate is calcualted with Eq. (4) and (5), where α represents a rate control ratio. The choice of α has directly impact on responsiveness of network channel states. In highly dynamic network states, the proposed rate control with different α has a different response pattern to transient changes of network resources. For example, since large α is very sensitive to bandwidth variation, its instantaneous transmission rate changes rapidly. Such behaviour may cause frequent interruptions on video playback. The video decoding rates for the largest level, R_{LL}, and a base layer, R_{BL}, are transmission rate limits.

$$R = R + \alpha \cdot M_{DL} \quad (4)$$

$$R = \begin{cases} \min(R_{LL}, R), & M_{DL} > 0 \\ \max(R_{BL}, R), & M_{DL} < 0 \end{cases} \quad (5)$$

The rate adaptation algorithm is described in Fig. 2. The initial transmission rate is calculated when CINR has changed. After that, the transmission rate is computed based on the M_{DL}.

```
WHILE
    IF CINR has changed
    THEN
        R_init = R_PHY
    ELSE
        R = R + α·M_DL
    END IF
END WHILE
```

Figure 2: Algorithm for the rate adaptation.

2.2 Quality Adaptation

The quality adaptation module controls the video quality according to the transmission rate calculated and buffer states feedback from client. Fig. 3 shows the algorithm of the quality adaptation scheme.

```
WHILE
    IF (R ≤ B_CQ) & (BO < TH_min)
        THEN
        CQ = CQ - 1
    END IF
    ELSE IF (R > B_CQ+1) & (BO > TH_max)
        THEN
        CQ = CQ + 1
    END IF
END WHILE
```

Figure 3: Algorithm for the quality adaptation.

In Fig. 3 B_{CQ} denotes bandwidth of current video quality level, *CQ*. *BO* represents the current buffer occupancy. TH_{min} and TH_{max} are the minimum and the maximum threshold of buffer occupancy, respectively. If the transmission rate is lower than bandwidth of current video quality level and current buffer occupancy is lower than the minimum threshold, the current quality level is decreased. On the other hand, if transmission rate is higher than bandwidth of *CQ+1* and current buffer occupancy is higher than the maximum threshold, the current quality level is increased. Through this operation, the quality adaptation algorithm can prevent a client buffer overflow or underflow.

3 SIMULATION RESULTS

In this section, the performance of the proposed NB-RC scheme is evaluated using NS2 (Network Simulator) of LBML (Lawrence Berkeley National Laboratory). The simulation topology is shown in Fig.4. In this simulation, the streaming server transmits video streams via router. The video receivers are connected using wireless links. There are two background traffic flows in the simulation. One is the Pareto traffic flow transmitted by using UDP packets. Another is a FTP traffic flow transmitted by using TCP packets. The transmission rates for both traffic flows are 1.5Mbps; burst and idle time are both set to 0.5ms. The link between the BS (Base Station) and the router is set at 10Mbps. The link between traffic sources and the router is set at 2Mbps. For the experiments, SOCCER_352x288 _30.yuv video clip was encoded into SVC profile layers using the reference software, JSVM (Joint Scalable Video Mode), as shown in Table 2.

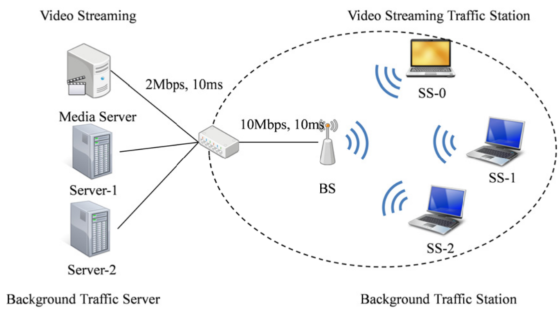

Figure 4: Network configuration to evaluate the performance of the proposed rate control.

Table 2: Characteristics of the video streams.

Quality Level	Resolution	Frame Rate (fps)	Bitrate (kbps)
0	352x288	30	503.4
1	352x288	30	735.4
2	352x288	30	1037.9
3	352x288	30	1794.3
4	352x288	30	2265.5

Fig. 5 shows packet loss rate of both the NB-RC scheme and TFRC under three cases with different loads. Two schemes compared have similar packet loss rate in various environments. However, the NB-RC scheme controls the transmission rate smoothly, because it is robust to packet loss.

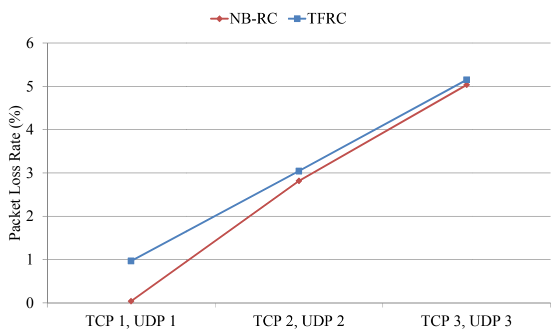

Figure 5: Average packet loss rate of the NB-RC scheme and TFRC under different loads.

Fig. 6 shows the comparisons of the video transmission rate between the proposed NB-RC scheme and TFRC (TCP-Friendly Rate Control). The average transmission rate of the NB-RC scheme is larger than that of the TFRC scheme by 572.6 kbps. Then the standard deviation of NB-RC transmission rate is smaller than that of the TFRC by 222.8. Because the proposed scheme sets up the initial transmission rate by physical data rate, it controls a transmission rate faster than the existing scheme by 2 second.

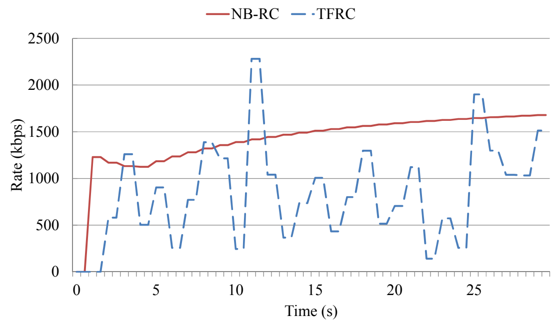

Figure 6: Comparison of the transmission rate between the NB-RC scheme and TFRC.

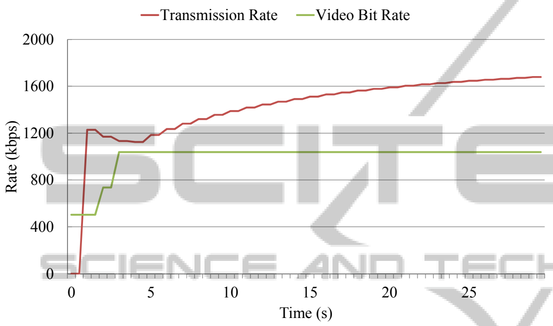

Figure 7: Transmission rate and video quality adaptation of NB-RC scheme.

These results mean that the proposed NB-RC scheme controls transmission rate smoothly and quickly by utilizing the available bandwidth. Since the transmission rate of the NB-RC changes smoothly as shown in Fig. 7, it does not control the video quality level frequently.

Fig. 8 shows a comparison of the PSNR (Peak Signal to Noise Ratio) between the NB-RC scheme and TFRC. The PSNR of NB-RC scheme is higher than that of TFRC as our scheme is robust to packet loss. The NB-RC scheme controls the data transmission rate smoothly, because it utilizes M_{DL}.

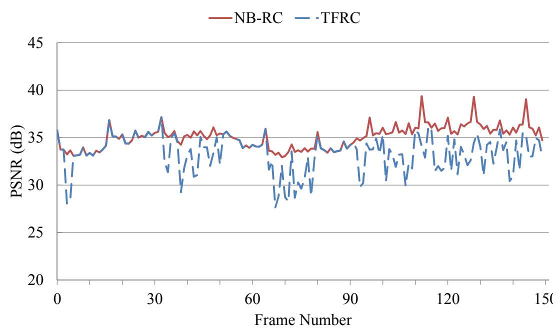

Figure 8: Comparison of the PSNR between the NB-RC scheme and TFRC.

4 CONCLUSIONS

To improve the video quality in multimedia streaming services, we propose a NB-RC scheme that considers not only network conditions but also buffer states. The NB-RC scheme consists of the rate adaptation method and the quality adaptation method. The rate adaptation algorithm decides the initial transmission rate by physical data rate. After that, it calculates transmission rate based on M_{DL} which is a matric using downlink data rate to determine if the network is congested. The quality adaptation algorithm controls the level of video quality according to the transmission rate and the occupancy of client's buffer. Our simulation results show that the proposed scheme can provide quickly utilizing the available bandwidth and smooth playback. It can also significantly improve the media quality in terms of PSNR.

ACKNOWLEDGEMENTS

This research was financially supported by Knowledge Economy Technology Innovation Programs - International Collaborative R&D Programs.

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