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Table of Contents

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A Leader-Based Reliable Multicast MAC Protocol for MPEG-4 Traffic

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Abstract. Multicasting is an efficient way for group communications because one sender can transmit data to multiple receivers only by one transmission. Multimedia applications are expected to become more prevalent over mobile ad-hoc networks in the near future. Therefore, reliability in multimedia communication is an important task. However, IEEE 802.11 standard does not provide any reliable multicast. In MPEG-4, the losses of different frames have different impact on video quality. In this paper, the effects of different frame types losses on Peak Signal to Noise Ratio (PSNR) are shown, and a reliable multicast MAC layer protocol for MPEG-4 traffic is proposed to enhance video quality and reduce the probability of a collision when the traffic volume exceed the network capacity.

Keywords: MPEG-4, Multicast, Reliability, PSNR.

1 Introduction

Recently, group-oriented services have appeared as one of the primary applications i.e. video conferencing, online gaming, and video streaming. Multicasting [1][2] is the transmission of data to a group of multicast members identified by single destination address. Moving Picture Expert Group version 4 (MPEG-4) gives the better performances in terms of video streaming applications as compared to MPEG-1 and MPEG-2. While MPEG-4 makes the use of video codes to reduce the bit rate and the amount of data transmitted, it provides the same video quality as MPEG-1 and MPEG-2 does. MPEG-4 video stream consists of three types of frames; I-frame (Intra-coded frame), P-frame (Predicted frame), and B-frame (Bi-directional frame). I-frames are independently encoded from the other frames. P-frames are encoded with a reference frame, which is I-frame or P-frame. P-frames consider the closest time-preceding frames. B-frames are coded with a reference frame, which is I or P frames and are the time adjacent frames [3]. An example of the sequence of frames is shown in Figure 1.

There are a few proposals for reliable multicast [5][6][7]. However, still there is no proposal that specifically addresses MPEG-4 multimedia streaming. The higher throughput does not always mean the better quality of MPEG-4 as shown in [4]. The transmission losses on the different types of frames have a different impact on video quality. In this paper, at first, we show the effect of different frames on Peak Signal to

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Noise Ratio (PSNR) and then proposed a Leader-based reliable multicast Medium Access Control (MAC) layer protocol for MPEG4 traffic.

The rest of the paper is organized as follows. In section 2, we provide some of the research efforts carried out in the perspective related to our works. Section 3 discusses problem statement in detail. After, problem statement, loss of different frames on video quality is described in section 4. Section 5 presents proposed protocol, and finally, conclusions and future works are given in Section 6.

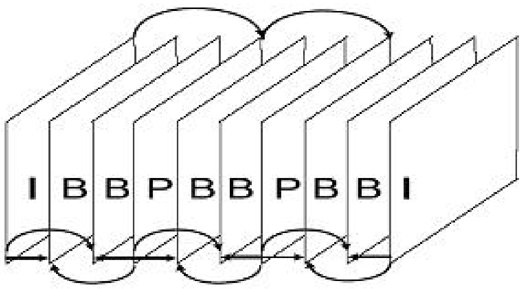

Fig. 1. I, P and B frames

2 Related Work

Kuri and Kasera [5], propose a Leader-based Protocol (LBP) to improve the reliability of multicast traffic in wireless LAN. This protocol chooses one of multicast receivers for the exchange of Clear to Send (CTS), Ready to Send (RTS), and Acknowledgement (ACK) frames. However, proposed protocol does not consider the numerous parameters associated with MPEG-4 traffic i.e. frame types, frame size.

Authors in [6] propose an extension to the IEEE 802.11 standard-based MAC, called 802.11MX, to improve link-level reliability for multicast data. They use a tone-based mechanism for the signal of negative acknowledgement (NAK) frame, so there is no collision in NAK frames. Authors further propose a dual busy tone to reduce packet collisions due to node mobility. However, the higher data throughput and reliability of 802.11MX comes at the cost of additional transceivers.

Choi at al [7], propose a Reliable multicast MAC protocol (RBMAC) by using a busy tone that improves the data throughput while guaranteeing the transmission reliability. The simulation results show that the proposed RBMAC improves the throughput up to 20 % and the receiving rate up to 49 %. To provide reliability RBMAC uses two busy tones (BTC) channels and one control tone channel (CTC) which requires extra time to monitor the status of channels.

Lee and Cho [8], proposed a multiple access collision avoidance protocol for multicast services in mobile ad hoc network. In this protocol, a sender sends a single multicast RTS frame to all the neighbors and waits for the CTS frame. The RTS frame is overloaded to contain the addresses of all multicast next hop neighbors. Thus, the RTS frame size is larger than the size of the frame in IEEE 802.11standard making the RTS frame itself prone to collision due to hidden terminals. CTS frames are transmitted in a time-based priority schedule like the ACK frames. Jain and Das [9], propose an extension to 802.11-based MAC protocol. Authors modify the RTS frame to include, at-most, four multicast next hop neighbor addresses which helps to keep the RTS frame size within bounds. However, proposed protocols are not suitable for MPEG-4 traffic because different frames require different reliability.

The works in [10] propose a reliable multicast MAC protocol (RAMP) for multi-hop networks. RAMP ensures high packet delivery ratio as well as reduce control overheads. To maintain the control overhead low, RAMP limits the use of multicast RTS and multicast CTS frames to the first packet of a multicast data flow. There is no handshaking for the following packets. The unreliable and error-prone nature of the wireless channel can cause severe degradation in performance due to such hand-shaking process.

Multimedia communication over wireless devices is increasing day-by-day and multicasting is an efficient way of multimedia group communication. Reliability is issue in multicast communication because IEEE 802.11 standard does not provide reliability. This motivates us to propose a reliable multicast MAC protocol for MPEG-4. Furthermore, in this paper we analyze the impact of losses of different types of MPEG-4 frames on PSNR.

3 Problem Statement

Xiao et al [4] present simulation result shows that the higher throughput does not always mean a better quality of MPEG-4 video. Losses from different frames have different effects on the video quality. During their analysis in [4], authors observed that I, P and B frames are in a decreasing order of importance. If I frames of MPEG-4 video are lost, the next N-1 frames (all P and B frames) are useless, where N is the total number of frames contained in one Group of Picture (GOP). In the case of I frame loss, the transmission of N-1 frames would also be a waste of network resources i.e. bandwidth. During our experiments, for example, we have a GOP size of 9 with one I frame, 2 P and 6 B frames, then the average bandwidth waste for 2 P and 6 B frames will be:

$$(Average\,size\,of\;P\;frames \times 2\;\; + \;Average\,size\,of\;B\;frames \times 6) =$$
$$(765 \times 2 + 490 \times 6)\,bytes = \;4470\,bytes = \;4.36\,KBytes$$

I frame is used as a starting point for the sequence of the frames (P and B frames). I frame is also used for resynchronization of the entire scene. Because the loss of I frames affects so many later P and B frames, the reliability of I frames is very important.

The 802.11 specifications [11] do not offer any MAC layer recovery on multicast and broadcast frames. There is no handshaking mechanism, such as Request-to-Send/Clear-to-Send (RTS/CTS) frames or acknowledgement (ACKS). To overcome the shortcoming of IEEE 802.11 and enhance the video quality we proposed a Leader-based reliable multicast MAC layer protocol for MPEG-4.

4 Effect of Different Frame on Video Quality

In order to test the effect of a different frame loss on video quality, we conduct simulations using video framework Evalvid [12]. Evalvid is a complete framework and tool-set for evaluating the quality of video transmitted over a real or simulated communication networks. Simulations are performed in Network Simulator 2 (NS2) version 2.35[13] over multicast-based network environments. The simulation parameters are shown in table 1. To measure the video quality on multicast receiver, PSNR is calculated with different frame loss rates. PSNR is one of the most widespread objective metrics to assess the application-level QoS of video transmissions. Such objective methods are described by ITU [14] [15], MPEG [16], and ANSI [17][18].

Table 1. Simulation Parameters

Parameter	Value
Radio Channel	802.11 a
Data rate	6 Mbps
Wmin	31
Wmax	1023
SIFS time	16µs
DIFS time	34µs
Slot time	9µs
Phy header	46bits
Mac header	24 Bytes
UDP + IP header	28 bytes
Application layer Traffic	MPEG-4
Average GOP size	3989 bytes
Average Frame sizes	I=2734 bytes, P=765 bytes, and B=490
Error Probability	0.05
Number of Nodes	5

$$PSNR(n)_{db} = 20\log_{10}\left\{\frac{V_{peak}}{\sqrt{MSE}}\right\}, \tag{1}$$

$$V_{peak} = 2^k - 1, \tag{2}$$

where V_{peak} is the maximum possible pixel value of the image, and k is number of bits per pixel i.e. when pixel are represented using 8 bits per sample, this peak value will be 255. Mean Square Error (MSE) is referred to the estimate of error variance and the value of MSE is given as:

$$MSE = \frac{\sum_{i=1}^{N_{Col}}\sum_{j=1}^{N_{row}}[Y_S(n,i,j) - Y_D(n,i,j)]^2}{N_{Col}\,N_{row}}, \tag{3}$$

where N_{Col} and N_{row} are the total number of columns and rows in input images, respectively, i and j indicate the current columns and rows position, and n is current frame number. Y_S is the luminous component of source image, and Y_D is the luminous component of destination image as defined in [12].

The other measure is known as subjective quality metrics. This metric of the human quality impression is usually given on a scale that ranges from 1 (worst) to 5 (best) known as Mean Opinion Score, shown in table 2.

Table 2. PSNR to MOS conversion

PSNR(db)	MOS
> 37	5 (Excellent)
31 ~ 37	4 (Good)
25 ~ 31	3 (Fair)
20 ~ 25	2 (poor)
< 20	1(bad)

The impact of I frame loss on video quality can be viewed in Fig 2. Fig. 2(a) represents the frame number 287 in the original video file and the type of frame is I frame. Fig. 2(b) shows the received video I frame, which is not fully decoded due to a missing of MAC frame delivering parts of the frame. There is multiple MAC segments for one I frame because and I frame are the bigger in size as compared to P and B frames. Fig. 2(c) and Fig. 2(d) show the propagation effect on the following P and B frames in one GOP due to a missing a I frame.

The propagation effect due can also be observed in Fig. 3. In Fig. 3, Frame number 287 (I-frame) is not decoded since some MAC frames are lost, so the following P and B frames also show lower PSNR values. The same effect can also be observed for the frame number 305 (I-frame) and 341(I-frame).

Fig. 3 also shows the effect of the losses of P and B frames on PSNR. In the case of the loss of P frame, there is less PSNR. However, there is no effect of propagation. On the other hand, in the case of the B frame, the PSNR value is acceptable.

5 Proposed Method

Our proposed method is an extension of a Leader-based protocol in which there will be one or more receivers of from the multicast group that have been chosen to be the leader for the purpose of supplying CTS packet and ACK packet in response to RTS packet and data packets. There may be some nodes that are not ready for receiving multicast data, and the nodes will send NCTS (Not Clear to Send) packet. On the successful reception of CTS packet from the leader, the sender /base station will send data and wait for the ACK packet. Only the leader will send ACK and the nodes that are not ready will reply with NACK packet. There will be a backup leader, which will take the responsibilities of the leader in case of the leader’s mobility, or the leader leaves the group.

Fig. 2(a). I Frame No:287 from "Carphone_qcif" [Transmitted frame]

Fig. 2(b). I Frame No: 287 from "Carphone_qcif" [Received frame]

Fig. 2(c). B Frame No: 288 from "Carphone_qcif" showing Propagation effect

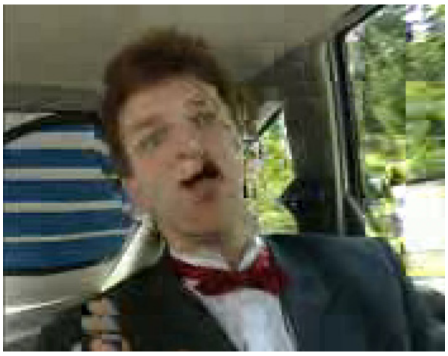

Fig 2(d). B Frame No: 294 from "Carphone_qcif" showing Propagation effect

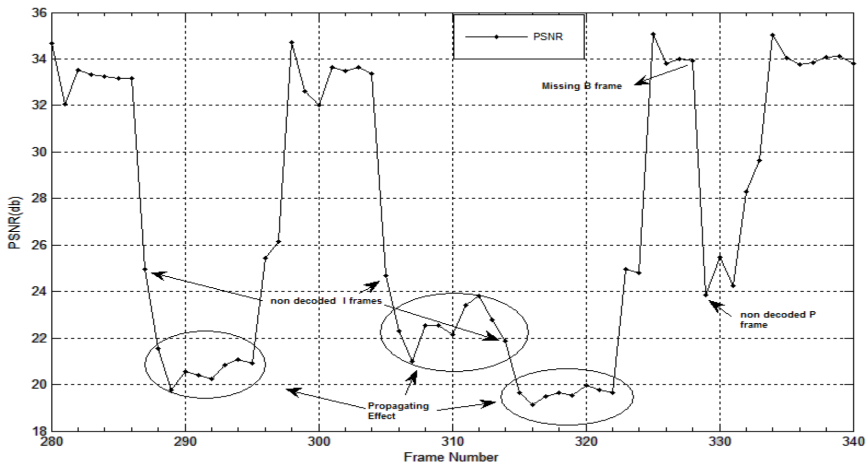

Fig. 3. Loss and Propagation effect of I, P and B frames

Our proposed Leader-based protocol for MPEG-4 multicasting is specified as follow:

1. Sender→ Receivers
   Send RTS packet
2. Receivers→ Sender
   Leader: If ready to receive data, send CTS packet
   If not ready to receive data, do nothing
   If move or leaves group, inform to backup leader
   Others: If ready to receive data, do nothing
   If not ready to receive data, send NCTS packet
3. Sender→ Receiver
   If CTS packet is heard, start multicast transmission
   If no CTS packet is heard, back off and go to step 1

.Receivers→Sender
   Leader: If I frames is received without error, send ACK packet
   If P and B frames received without error, no ACK packet
   If I frames received with error send NACK packet

   Others: If I, P and B frames are received without error, do nothing
   If I frames are not received, send NACK packet.

4. Sender→Receiver
   If ACK packet is not received for I frames, retransmit I frame.
   If NACK packet is received for I frames, retransmit I frames

The proposed protocol reduces the number of retransmissions as compared to LBP, because only the missing I frames will be retransmitted, and there is no retransmission for P and B frames. Chan et al [19] experimental results show that when the traffic load is near or exceed the network capacity, retransmissions cause erratic video quality and tremendously increase the end-to-end delay. They also show that, when the best-effort traffic coexists, increasing the number of retransmissions degrades the good-put of best-effort traffic and increases the end-to-end delay of video streaming. Retransmissions add reliability and increase the video streaming quality only when the traffic volume is far below the network capacity limit. We have already showed that P and B frames are less important than I frames are, and wireless channels are mostly suffering from low bandwidth and high bit error rates due to the noise, interference, and multipath fading channels[20]. Therefore, when traffic volume is very high, retransmissions of P and B frames can significantly reduce the throughput and have less impact on video quality.

The proposed protocol also reduces the number of RTS/CTS and ACK packets comparing to LBP, so the probability of collision is less. Only a leader will transmit ACK packet on successful reception of I frames, there will be no ACK packet for P and B frames. MPEG-4 traffic is generated as shown by Fig. 1. GOP pattern can varied with different values of P and B frames. However, in one GOP, the first frame is always an I frame called a reference frame, and there is only one I frames in one GOP followed by B and P frames. We can consider that an error in the I frame will affect N (distance of I frames) frames in the actual GOP and M-1 frames in the previous one. Therefore, the distortion level is the highest when I frame is damaged. If I frame is dropped, then following B and P frames are useless, so the retransmission of I frame can enhance the video quality.

6 Conclusion

We have two main contributions in this paper. Firstly, we analyze the impact of different frame losses on PSNR values. Our simulations results show that, I frames are more important that P and B frames and have significant impact on video quality. Secondly, we propose an extension to the leader-based protocol for reliable multimedia multicasting over mobile ad-hoc networks. The proposed protocol reduces the number of retransmission as compared to leader-based protocol, and increased the system throughput when the traffic volume exceeds the network capacity. Implementation of proposed idea is as future work to provide detail results.

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