An Efficient Video Transmission Scheme in Wireless Mesh Networks

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ABSTRACT: With rapid development of wireless mesh networks, it becomes more and more important to guarantee the reliable transmission of video data in such networks. Video data requires real-time service, which presents a great challenge to provide QoS guarantee in wireless networks where the bandwidth is insufficient. In this paper, an efficient video transmission scheme is proposed, which has adopted the cross-layer dynamic queue allocation mechanism to transmit the video frame, and chosen to drop the non-critical video frame under the circumstances of heavy network load. The proposed scheme adopts H.264/SVC scalable video encoding technology and QoS guarantee mechanism of the IEEE 802.11e, which can be applied to any cross-layer encoding video transmission. We have done extensive simulation to validate our proposed scheme. The simulation results show that our scheme is effective in terms of packet loss rate and the replay quality of the received video.
KEYWORD: Wireless Mesh Networks; Video transmission; QoS

1 INTRODUCTION

Wireless mesh network [1] is a promising wireless technology for future broadband Internet access. A typical example of the network consists of wireline gateways, wireless routers, and mobile stations (MSs), organized in a three-tier architecture. The third tier is the wireless access networks, through which users access the Internet. Wireless access network includes WLANs, ad hoc networks, and cellular networks, among which the mobile users can seamlessly roam. The second tier is the wireless mesh backbone, consisting of a number of wireless routers at fixed sites. Each wireless router not only delivers traffic from the access networks in its coverage, but also forwards the traffic from and to its neighboring routers. The first tier is the mesh gateways, which connect the wireless mesh backbone to the Internet backbone. Normally a wireless mesh network covers a large geographical area. Thus, multi-hop communications are usually necessary, where a traffic flow from a source to its far away destination traverses multiple intermediate routers.

In WMNs, nodes are comprised of mesh routers and mesh clients. Each node operates not only as a host but also as a router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations. A WMN is dynamically self-organized and self-configured, with the nodes in the network automatically establishing and maintaining mesh connectivity among themselves (creating, in effect, an ad hoc network). This feature brings many advantages to WMNs such as low up-front cost, easy network maintenance, robustness, and reliable service coverage [2].

However, realtime multimedia traffic such as voice and video typically demand high data rate and more stringent service requirements, whereas wireless nodes generally cannot provide service guarantees due to the fluctuating nature of the wireless channel. It is complex and difficult to provide QoS routing in a wireless mesh network (due to the unsteadiness of wireless links) and a fixed network path from the source to the destination is often not a good choice for multimedia streaming [3].

IEEE 802.11e [4] is the supplement to the 802.11b/a/g, which makes up the shortage of the “best effort delivery” in the original algorithm and guarantees the QoS. The advantage in the IEEE802.11e is that it provides QoS support for different service types in MAC layer. 802.11e defines a channel access method, namely HCF (Hybrid Coordination Function) [5]. HCF Contains two kinds of access-mechanisms. One is based on competition EDCA access [6], and it is more flexible. The other is based on HCCA [7] polling mechanism access. The goal of this paper is to design an effective video transmission scheme to meet the growing demand for multimedia applications, in which the QoS guarantee mechanism proposed in IEEE 802.11e is included.

The rest of this paper is organized as follows. The related works is described in Section 2, and the analysis and improvement of the scheme is presented in Section 3. Section 4 is devoted to the performance evaluation of the proposed scheme, followed by concluding remarks in Section 5.

2 RELATED WORKS

So far, multimedia transmission in wireless mesh networks has made some progress, particularly on cross-layer design.

A cross-layer scheme based on priority was proposed in [8]. It follows top-down cross-layer thoughts. In this scheme, the application layer will respond the notification initiated by the data link layer and packets at the application layer will be assigned different priorities. When packet loss occurs, the algorithm can decide whether the data packet retransmits based on the assigned priority.

Another video transmission scheme based on cross-layer mapping, called static mapping mechanism, proposed in [9]. The main idea is that the video packet is identified based on its importance in the application layer. When the video packet is transmitted, the packet will be mapped to different queues according to its importance. Packet with high importance will be mapped to high-priority queue and vice versa. This scheme can be applied to MPEG-4 encoded video transmission. In this situation, frame I, frame P and frame B are mapped to AC [2], AC [1], and AC [0] respectively [10], which indicates that frame I is the most important frame.

In [11], a dynamic channel allocation scheme was proposed. But it did not fully consider network load, in which the probability for frames sent into AC[0] or AC[1] is independent of the network load. In this paper, we propose to improve the scheme in [11] for video transmission.

3 THE ANALYSIS AND IMPROVEMENT OF THE DYNAMIC ALLOCATION ALGORITHM

In [11], a dynamic allocation scheme was proposed. This scheme dynamically assigns different ACs (Access Category) to different video frames according to the importance of video frames and network traffic situations. It defines three kinds of Frame. Frame I has the highest priority and the biggest opportunity to connect to channels. Frame P follows frame I and frame B is the lowest. This scheme defines the probability that the specific TYPE of video sub frame needs to be degraded to the lower priority queue for transmission as Prob_TYPE (0 <= Prob_TYPE <= 1). In order to let more important video sub frames get into high priority ACs in MAC layer, the scheme gives the video sub frames different mapping probability: Prob_B> Prob_P>Prob_I. But this scheme still has some problems: it needs to artificially define the original probability of frame I, frame B and frame P. The different values have a great effect on the performance of the network. Under this mechanism, the probability of frame P and frame B sent to AC(0) or AC(1) is totally defined by users. It has nothing to do with the network load.

Based on the importance degree of the video sub frame and the network situation, we propose a new mechanism, in which the probability of video sub frames sent to ACs always satisfies Prob_I<=Prob_P<=Prob_B at any time.

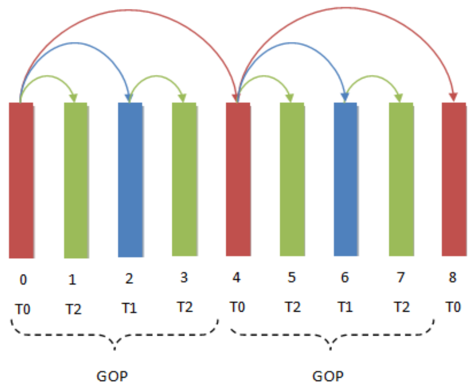

Figure 1 The SVC temporal scalability

Since the MPEG4 encoding compression ratio is lower than the H.264/SVC video encoding format, the H.264/SVC video encoding format is more suitable for transmission in wireless networks than MPEG4. We adopt the SVC video encoding format to describe our algorithm which is also suitable for other video encoding formats such as MPEG video encoding format. We use the temporal scalable technology to differentiate the importance level of the video sub frames (see Figure 1 and define that the GOP (Group of Pictures) includes four frames.

We assume that the probability of video sub frames not getting into AC(2) is P. We propose that when the length of AC(2) is between threshold_min and threshold_max, the probability of video sub frames to be degraded is the same at first. We define that Frame T1 can be degraded only when Frame T2 is degraded. After Frame T2 degraded, it still has the probability P to be degraded to AC(0) whose queue priority is the lowest; Similarly, only when Frame T2 is degraded to AC(0), Frame T1 can be degraded to AC(0). Because of the greatest importance of Frame T0, we have to guarantee that it can get into AC(2) preferentially. So in this paper, we define the probability of Frame T0 entering AC(2) is 1. Based on this mechanism, we calculate the probabilities of each sub frame entering each queue and make sure that the degrading probability of Frame T1 and Frame T2 continuously goes up with the queue saturation level increasing. Note that the probability of Frame T2 to be degraded is greater than Frame T1. Formula 1 and 2 stand for the queuing probability of Frame T1 and Frame T2 respectively.

$$\text{Frame T1:} \begin{cases} 1-P^2 & \text{get into AC(2)} \\ P^2-P^4 & \text{get into AC(1)} \\ P^4 & \text{get into AC(0)} \end{cases} \tag{1}$$

$$\text{Frame T2:} \begin{cases} 1-P & \text{get into AC(2)} \\ P-P^2 & \text{get into AC(1)} \\ P^2 & \text{get into AC(0)} \end{cases} \tag{2}$$

Now we consider the case when the length of AC(2) is greater than the threshold_max(which means AC(2) is full) and the length of AC(1) is between the threshold_min and threshold_max. We assume that the probability of video sub frames not getting into AC (1) is P. We define that only when frame T2 is degraded, T1 can get the chance to be degraded. After Frame T2 is degraded to AC(0), it may be discarded with probability P. Furthermore, only when Frame T2 is discarded, Frame T1 can get the chance to be discarded. Because of the greatest importance of the Frame T0, we have to guarantee that it can get into AC(1) preferentially. So in this paper, we define the probability of Frame T0 entering AC(1) is 1. Based on this mechanism, we calculate the probabilities of each sub frame entering each queue and make sure that the degrading probability of Frame T1 and Frame T2 continuously goes up with the queue saturation level increasing. Formula 3 and 4 stand for the queuing probability of Frame T1 and Frame T2 respectively.

$$\text{Frame T1:} \begin{cases} 1-P^2 & \text{get into AC(1)} \\ P^2-P^4 & \text{get into AC(0)} \\ P^4 & \text{be discarded} \end{cases} \tag{3}$$

$$\text{Frame T2:} \begin{cases} 1-P & \text{get into AC(1)} \\ P-P^2 & \text{get into AC(0)} \\ P^2 & \text{be discarded} \end{cases} \tag{4}$$

When the length of AC(1) is greater than the threshold_max which means the level of network load is high, in order to ensure more frame T0 getting into AC(0), we directly discard frame T1 and frame T2.

The following formula is used to calculate P. P equals to the queue saturation level. N is 1 or 2, which means AC(1) or AC(2).

$$P = \frac{\text{QlenAC(N)} - \text{threshold\_min}}{\text{threshold\_max} - \text{threshold\_min}} \tag{5}$$

Our proposed scheme (see Figure 2) overcome the disadvantages in [11], which include artificially defining the probability and that the probability for frames sent into AC(0) or AC(1) is independent of the network load. In our scheme, the probability to entered high priority queue for frame T1 and frame T2 will rapidly decrease when the saturation level of the queue is increasing. We also add the mechanism of discarding frame T1 and frame T2 so that it can decrease the quantity of the package which is sent into the lower queue before the highest priority queue is full, thus bring more opportunities to transmit more important video frames.

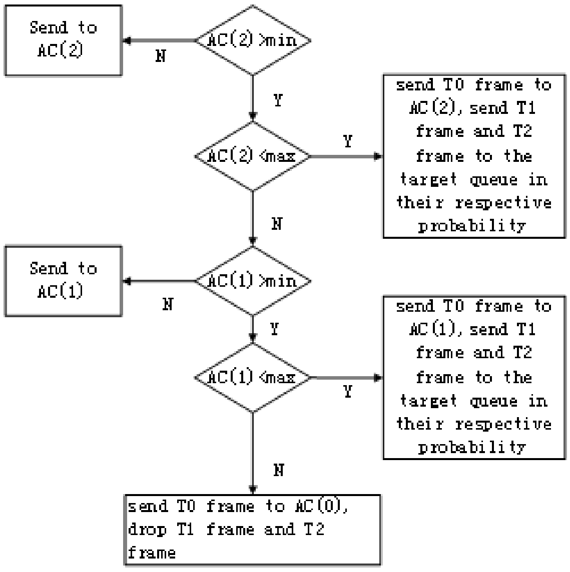

Figure 2 Proposed dynamic queue allocation process

4 PERFORMANCE EVALUATION

We have done extensive simulation to validate our scheme. The simulation environment is based on NS2. We adopt the same experiment scenario in [11] for performance comparison. There are 2 nodes in this experiment scenario: node0 and node1. In order to test and verify the performances under the environment of the light load and heavy load, node0 sends an audio stream (AC3) and three video streams (AC2), a CBR (AC1) and a TCP link (AC0) to node1 respectively. The video is encoded by H.264, and it has 400 frames and QCIF resolutions (refer to Table 1). Packet size is 1500 and the speed of the wireless link is 1Mbps. The audio is transferred after 5 seconds, and video is transferred after 10 seconds, CBR is transferred after 20 seconds, and the TCP is transferred after 15 seconds. The threshold of the queue length (i.e. threshold_min and threshold_max) is initialized with 10 and 40 respectively. The performance comparison between two schemes is done under the heavy load network environment. Table 2 shows the comparison of the packet loss rate. Table 3 shows the numbers of the incorrectly decoded frames.

Table 1 Video data

resolution	Number of Frame			Total	Number of Package			Total
	T0	T1	T2		T0	T1	T2	
QCIF	45	89	266	400	237	149	273	659

Table 2 The comparison of the packet loss rate

	Packet loss rate of the original scheme	**Packet loss rate of the proposed scheme**
Video 1	0.16	0.03
Video 2	0.18	0.06
Video 3	0.25	0.15

Table 3 The numbers of the incorrectly decoded frames

	Average PSNR (dB) (original/proposed)	incorrect number (original/proposed)			
		T0	T1	T2	Total
Video1	32.21/33.36	0/0	55/0	231/103	286/103
Video2	31.51/32.38	3/7	51/14	227/127	281/148
Video3	29.97/30.58	10/17	53/35	227/162	290/214

We can find from Table 4 that the proposed scheme is better than the original scheme in the packet loss rate and as well as the replay quality of the received video.

Table 4 Performance comparison

	the original scheme	**the proposed scheme**
Average PSNR	31.23	32.11
Average Packet loss rate	0.20	0.083
Average frame loss rate	0.71	0.38

5 CONCLUSION

In this paper we have proposed an efficient scheme to improve the transmission quality of H.264 video data. The proposed scheme has adopted the cross-layer mechanism to transport the critical information of the video frame, and chosen to drop the non-critical video frame in the case of heavy network load. Furthermore, the proposed scheme can be applied to any cross-layer encoding video transmission. However, there are still some problems to be considered and addressed in the future. Firstly, the threshold of the queue length which is regarded as the basis should be variable when the data frame goes into the queue .There is a certain proportion of threshold’s relationship with the total size of the I frame, P Frame and B frame. According to the feature that different data frame has different sizes, the threshold of the queue length should be computed dynamically in order to reach an optimal performance. Secondly, when the network congestion control mechanism is based on EDCA parameter adjustment, the influences brought by the AIFSN change need be investigated.

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REFERENCES

[1] Ping Wang, Member, IEEE, and Weihua Zhuang, Fellow, IEEE. A Collision-Free MAC Scheme for Multimedia Wireless Mesh Backbone.IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 8, NO. 7, JULY 2009 3577.

[2] Akyildiza, Xudong Wangb, Weilin Wangb. Wireless mesh networks: a surveyIan F. Computer Networks Volume 47, Issue 4, 15 March 2005, Pages 445–487.

[3] Chungui Liu, Yantai Shu and Lianfang Zhang. Backup Routing for Multimedia Transmissions over Mesh Networks. IEEE Communications Society 2007.

[4] Deep Kaur ,Kirandeep kaur. QoS in WLAN using IEEE802.11e (Survey of QoS in MAC Layer Protocols). 2012 Second International Conference on Advanced Computing & Communication Technologies.

[5] Madhar Saheb, Bhattacharjee, Dharmasa, Kar. Enhanced hybrid coordination function controlled channel access-based adaptive scheduler for delay sensitive traffic in ieee 802.11e networks. Networks, IET Volume 1, Issue: 4, 2012 , 281- 288.

[6] Nilsson, Farooq. A Novel MAC scheme for solving the QoS parameter adjustment problem in IEEE 802.11e EDCA. World of Wireless, Mobile and Multimedia Networks, 2008, Page(s): 1- 9.

[7] Byung Joon Oh, Chang Wen Chen. A cross-layer adaptation HCCA MAC for QoS-aware H.264 video communications over Wireless Mesh Networks. Circuits and Systems (ISCAS), 2010 , 2259- 2262.

[8] Jinh ZhouTonghai Wu, Zhiling Li. Cross-layer Qos for Video based on Priority-ARQ. Wireless Communications Networking and Mobile Computing (WiCOM). 2010: 1-4.

[9] I.Amonou, N.Cammas, S.Kewadec et al Optimized rate-distortion extraction with quality layeis in the scalable extension of H 264/AVC. IEEE Transactions on Circuits and Systems for Video Technology, 2007,17(9):1186-1193.

[10] LIN C H, SHIEH C K, KE C H, et al. An Adaptive Cross-layer Mapping Algorithm for MPEG-4 Video Transmission over IEEE 802. 11e EDCA. Telecommunication Systems, 2010, 42(3-4): 223-234.

[11] D.Singh, H.Rathore, Chih-Heng Ke. “Dynamic Adative Cross Layer Mapping Mechanism for Video Transmission over Wireless Networks. Emerging Trends in Networks and Computer Communications”,in 2011 International Conference on, 2011, 205-208. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.