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A Novel Hybrid ARQ Algortithm for Real-Time Video Transport Over Wireless LAN

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Abstract—**In this paper, we propose a modified MAC protocol supporting real-time video traffic over the IEEE 802.11 WLAN. Investigating H.26L real-time video transmission over wireless IEEE 802.11b LANs, we present a novel hybrid Automatic Repeat request (ARQ) algorithm that efficiently combines forward error control (FEC) coding with the ARQ protocol based on multiple transmission stages. The scheme includes: (1) multiple transmission stages with corresponding ARQ feedback information that determines how many transmission stages should be activated; (2) conditional frame skipping algorithm based on accumulated feedback information. Through analysis and simulation, we show that multiple-stages based Hybrid ARQ scheme has high error recovery rate for real-time video frames. In case of severe unreliable channel which causes losing a lot of IP packets, at the cost of little end-to-end delay's increase, we obtain a peak signal-to-noise ratio improvement up to about 10dB compared to the hybrid ARQ proposed in [1].** *(Abstract)*

Keywords- QoS, ARQ forward error correction, IEEE 802.11b, H.26L video, multimedia communication, wireless local area netwoks.

I. INTRODUCTION

Wireless Local Area Networks (WLANs), especially the WLANs based on the IEEE 802.11 standards, are gaining special interest as they provide flexibility of location along with low infrastructural and maintenance costs. Accordingly, there have been a lot of efforts to evaluate, extend, revise the IEEE 802.11 protocol in order to support a wider range of applications (specially real-time traffic).

In wired networks QOS can be supported by providing more bandwidth, but this is not possible in WLANs as the radio spectrum is limited. Thus support for QOS at the MAC layer becomes necessary. To have QoS provision or guarantee for real-time video application in the current best-effort wireless LANs, beyond using effective congestion control and error control, we also introduce differentiated service to ensure that packets sent by a mobile host be differentiated [2-4]. The QoS differentiation specifies that real-time video stream has higher service priority than data traffic.

It is well known that the compressed video bit stream is extremely sensitive to transmission error due to the frame dependency. Therefore, error control techniques such as FEC and ARQ are necessary to obtain high transmission reliability required by video services [5-10]. There are two basic erro correction mechanisms, namely Automatic Repeat reques (ARQ) and Forward Error Correction (FEC). ARQ requires th receiver to explicitly (by means of negative acknowledgement or implicitly (using positive acknowledgements and timeouts request the retransmission of the lost/corrupted packets. On th other hand, FEC transmits together with original data som redundant data, called parties, to allow reconstruction o lost/corrupted packets at the receiver. Of these two errc control mechanisms, FEC has been commonly suggested fc real-time applications due to the strict delay requirements an semi-reliable nature of media streams [11]. Typical FE(schemes are stationary and must be implemented to guarantee certain QoS requirement for the worst case channc characteristics, which causes unnecessary overhead and wastc bandwidth when the channel is in a good state.

In order to overcome their individual drawbacks, th combination of these two basic classes of error control scheme calls hybrid ARQ schemes, have been developed [1,12 Though our proposed hybrid ARQ scheme based on multip! transmission stages is similar to the conventional hybr: algorithms at the point that efficiently reducing the amount (ACKs, we further consider the estimated channel condition ar real-time video encoder's ability to antagonize fluctuations i channel quality.

While the real-time video transmission over IEEE 802.1 has been studied by several researches, they have eith directly read the encoded-video from hard disk [1] or simp generated video packet which contains no real video data. other word, they intent to fine tune the IEEE 802.11 WLA performance through control of MAC layer, and didn consider the participation of application layer Our vid application adopts H.26L version JM 5.0 built in OPNET as real-time encoding&decoding traffic source. We ha translated the tremendous H.26L version JM5.0 Visual C project, which contains tens of thousands lines of code, external C file of OPNET. We final realize the real-time vid transmission in deed, which is contributed to adjusting vid encoding parameters conveniently according to feedba information. It is clear that the performance can be improved application layer can cooperate with MAC layer.

Due to the employed random backoff algorithm and syst complexity, our works toward system performance evaluat

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resort to simulation. Our simulations show that our proposed scheme can effectively reduce the number of packets errors and improve the channel utilization. In case of severe unreliable channel which causes losing a lot of IP packets, , at the cost of little end-to-end delay's increase, we obtain a peak signal-to-noise ratio improvement up to about 10dB compared to the hybrid ARQ proposed in [1].

The rest of this paper is organized as follows. Section II depicts IEEE 802.11 WLAN Architecture and DiffServ enhancement mechanism. Section III introduces proposed hybrid ARQ algorithm based on multiple transmission stages, then explains how to overcome the problems existing in hybrid ARQ scheme proposed in paper [1] when real-time video is transmitted. Simulation results and analysis to justify the significance of our schemes will be explained in Section IV. Finally, Section V will conclude the paper.

II. IEEE 802.11 WLAN Architecture and DiffServ Enhancement Mechanism

A. *IEEE 802.11 WLAN Architecture*

In this section, we will briefly describe the IEEE 802.11 WLAN architecture and its MAC layer. There are two major architectures of the WLANs, Ad-Hoc and infrastructure networks. Traditional simulations of real-time applications are implemented in infra-structure mode of WLANs. Our research focuses on the ad hoc mode since we eventually aim at interconnected WLAN clusters where no base station is present.

Fig.1 shows our model modeled by OPNET simulation tool. It consists of a H26L video server, several interference stations and a client. The interference stations generate best-effort (BE) background traffic. The real-time video streams are produced by the H26L server, and are encapsulated into RTP/UDP/IP packets. All the packets transmitted by H26L server and interference stations are sent to H26L client. H26L video server is implemented by combining the newest video coding standard H.26L version JM5.0 with the powerful network simulation tool OPENT.

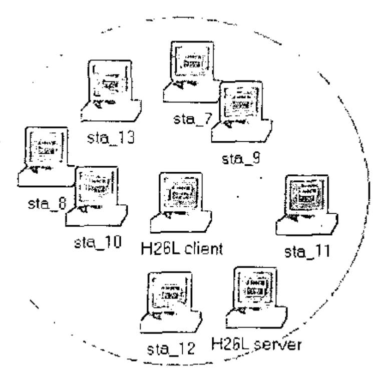

Figure 1. IEEE 802.11 WLAN Architecture

The IEEE 802.11 WLAN MAC layer coordinates the use of a shared medium. The MAC protocol specified in IEEE 802.11 is distributed coordination function (DCF) known as carrier sense multiple access with collision avoidance (CSMA/CA) [13]. CSMA/CA, which is implemented in all wireless stations and APs, is designed to reduce the collision probability when multiple stations access a medium. When using the CSMA/CA mechanism, if a station has a packet to be transmitted, it may transmit if the medium is free for greater than or equal to a DCF inter frame space (DIFS) time. If the medium is busy, it follows the backoff procedure to set a random backoff timer. The timer will decrease by one only when the medium is clear for a slot time period and will be frozen during the busy period. When the backoff timer reaches zero, the station transmits the packet. Since the probability that two stations choose the same backoff timer is very small, packet collisions are minimized.

Carrier sensing (CS) can be achieved both through physical and virtual mechanisms. The realization of physical CS mechanism is through the physical layer and is described in the IEEE 802.11 standard. We will not touch on it here. The realization of virtual CS mechanism is through the exchange of special small request-to-send (RTS) and clear-to-send (CTS) packets before the actual data packet. Usually the data transmission procedure is as follows: the source station sends RTS after DIFS or backoff procedure. After short inter frame space (SIFS), the destination station sends CTS back if it received the RTS. Both RTS and CTS contain a Network Allocation Vector (NAV) which indicates the time duration that is reserved for transmitting the actual data packet. This information is transmitted to all other stations which will stop transmission during this period to avoid collision and solve the hidden station problem. Then, after SIFS, the source station sends the data packet if it received the CTS.

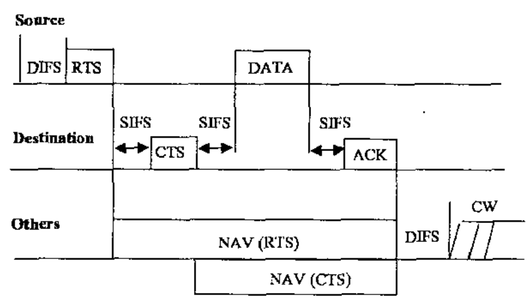

Figure 2. Successfully transmitted unicast data frame in RTS/CTS mode of the IEEE 802.11 standard.

When the packet is received successfully, as determined by the cyclic redundancy check (CRC), the destination station transmits an acknowledgment (ACK) packet to the source station after SIFS. The whole transmission mechanism is shown in Figure 2. Retransmissions happen when the source station doesn't receive CTS or ACK. The short retry limit or long retry limit is the maximum number of retransmissions of a data packet due to failure of receiving CTS or ACK.

B. *Differentiation mechanisms for IEEE 802.11*

As can be observed from papers [2-4], service differentiation priority in IEEE 802.11 per station can be introduced into 802.11 by modifying the following parameters: 1) Backoff increase function, 2) Backoff decrease function, 3)

Maximum Frame length, and 4) DIFS. Each priority level has a different parameter setting.

We choose to modify AIFS parameter in the standard IEEE 802.11b radio MAC algorithm to ensure that packets sent by a mobile host are differentiated. And specify real-time video stream has smaller AIFS than data traffic.

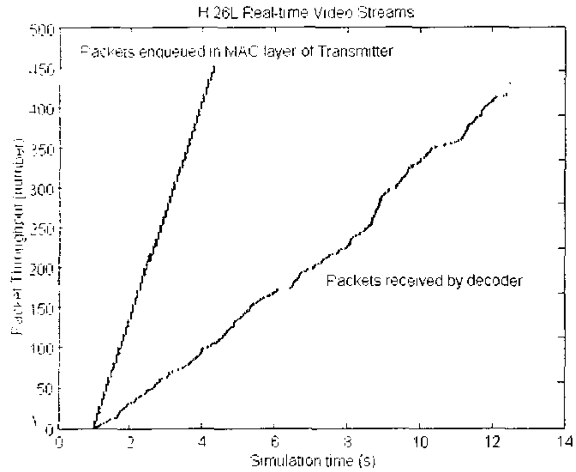

Figure 3. Packet Throughput without QoS Differentiation

The MAC protocol specified in IEEE 802.11 is distributed coordination function (DCF) known as carrier sense multiple access with collision avoidance (CSMA/CA) which is similar to stop-and-wait (SW) ARQ protocol. CSMA/CA is designed to reduce the collision probability, but also increases too much ETE delay when multiple stations with heavy load access a medium. To verify this point, we transmit H.26L real-time video over WLAN. The configuration of BE traffic is demonstrated in Table II. The simulation result of packet throughput is showed in Fig.3 where the horizontal distance between two curves represents ETE packet delay. Transmitter spends 3.3 seconds in encoding and enqueue fifty video frames, but receiver spends 11.3 seconds in receiving them, which can't achieve the requirements for real-time service at all.

To alleviate this disadvantage, we introduce QoS differentiation by adjusting *AIFS_slot_num* which is indicated in Table I. further can calculate *AIFS_time* according to (1). Under the same traffic condition, the result of packet throughput is showed in Fig.4 where the performance of ETE packet delay has much improvement, since receiver spends 5.8 seconds in receiving all the video frames. But these efforts still can't achieve the requirements of real-time service which should provide ETE delay less than 150ms. In following sections, we will introduce our hybrid ARQ scheme which can achieve this goal.

$$AIFS\_time = SIFS\_time + AIFS\_slot\_num \times slot\_time \quad (1)$$

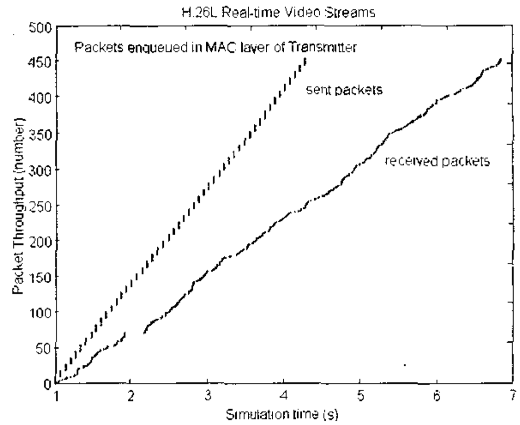

Figure 4. Packet Throughput with QoS Differentiation

TABLE I. QoS DIFFERENTIATION SPECIFICATION

QoS Differentiation Specification	Traffic Type	
	BE traffic	***H.26L video***
SIFS_time(μs)	16	
Slot_time (μs)	9	
AIFS_slot_num	5	2
AIFS (μs)	61	34

III. HYBRID ARQ BASED ON MULTI TRANSMISSION STAGES

Though FEC scheme can improve the performance for reliability, this improvement is achieved at the expense of additional bandwidth. Typical FEC schemes are stationary and must be implemented to guarantee a certain QoS requirement for the worst case channel characteristics, which causes unnecessary overhead and wastes bandwidth when the channel is in a good state. In order to overcome this drawback, hybrid ARQ schemes have been developed [1,12].

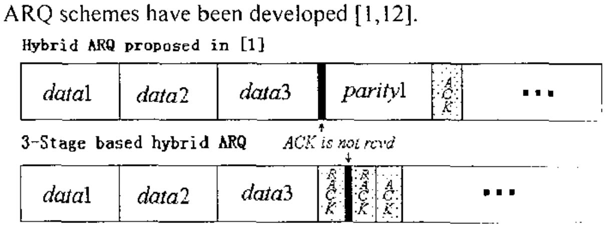

Figure 5. Comparison of two schemes handling ACK loss

By numerical experiments, we find some ARQ frames will be corrupted or lost in a bad channel state. Under this situation conventional hybrid ARQ scheme will cause transmitter to send useless FEC packets to receiver, which wastes limited bandwidth. As can be seen from Fig.5, all the packets are received successfully, but transmitter doesn't know it because the ARQ frame is lost. To solve the problem, we introduce a RACK (RequestACK) control frame by modifying IEEE

802.11b MAC algorithm. Transmitter uses RACK to request receiver to feed back ACK immediately after all the packets are transmitted. If ACK is lost or corrupted, only a RACK frame will be retransmitted in our scheme. Since that the size of control frame (RACK or ACK) is much smaller than that of data frame (data packet or FEC packet) and that SIFS is shorter than DIFS in IEEE802.11 MAC protocol, the introducing of RACK can decrease ETE packet delay and overhead of channel bandwidth in the case mentioned above.

Paper [1] proposed a novel hybrid ARQ algorithm which efficiently reduces the amount of ACKs to achieve high channel utilization. But receiver must know how many data packets in Transmission Group (TG) in advance, which limits the scheme only suitable for the TG where packets number is fixed. We packetize H.26L video frame into k data packets forming a TG. Since different TG will have different packet quantities, for example, intra video frame has more data than inter one, under this situation, hybrid ARQ algorithm in [1] is not suitable.

We also find another problem. Considering a burst bad channel state arrives, only a few packets are received when the deadline of TG comes. Maybe the same thing happens to the next TG. It is well known that many corrupted video frames are not as good as few intact frames if their payloads are the same. So it would be better to terminate current TG if we can early foresee its destiny of failure, and save the bandwidth for another TG.

To solve the two problems mentioned above, transmitter uses RACK to request receiver to feed back information at receiver side. By the way, receiver also knows how many packets should be received in current TG. In multi-stages based hybrid ARQ algorithm, RACK is mainly used to collect information by which transmitter can decide whether or not the next transmission stage is needed, whether or not current transmission should be terminated and declared failure, and whether or not encoder should perform frame skipping.

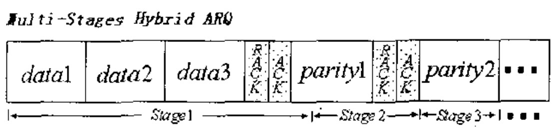

Figure 6. Schematic representation multi-stage Hybrid ARQ

Proposed mechanism traces the transmission condition, and acts differently during each transmission stage according to current feedback information. It is schematically shown in Fig.6. If the end of stage three implies the end of current TG, the feedback information is no use in stage three, so RACK is only used in the end of stage one or stage two. The multi-stages processing is divided into five steps, namely "Step 1.Transmitter high layer handle H.26L video streams", "Step 2.Transmitter MAC layer handle H.26L video streams", "Step 3.Receiver handle H.26L packets", "Step 4.Transmitter MAC layer handle H.26L ACK" and "Step 5.Receiver decode H.26L video" according to time flow.

IV. SIMULATION AND ANALYSIS

In this paper, simulations are made by modeling the IEEE 802.11 infrastructure network closely and carefully. The simulations are programmed in OPNET language which is based on C language.

An ON/OFF model is implemented in application layer to represent the burst background traffic model. State ON represents the interference user (all the users expect for H.26L server and client are regarded as interference users) is in a "active" state. State OFF represents the interference user is in a "close" state. The duration of these two states are assumed to be exponentially distributed with parameters 10ms and 10ms, respectively, as showed in Table II. Other traffic parameters of the simulation are shown therein. The traffic load can be calculated by these parameters. Note that traffic load is 100% higher than channel bandwidth, because the simulation can intensively demonstrate effectiveness of our proposed scheme in case of severe unreliable channel which causes losing a lot of IP packets.

In all the tested cases, the first frame was intra-coded and the remaining frames were inter-coded. The testing video sequence is *Forman* format (176× 144 pixels/frame) that was coded in QCIF at a temporal resolution of 15 fps.

TABLE II. TRAFFIC PARAMETERS CONFIGURATION

Number of interference stations	3
AIFS (us)	85
ON (s)	0.01
OFF (s)	0.01
Average Packet Inter-arrival time (s)	0.006
Packet length (bytes)	1024
Data Rate (Mbps)	1
Short Retry Limit (slots)	7
Long Retry Limit (slots)	4
Total load of BE traffic (Mbps)	2.048

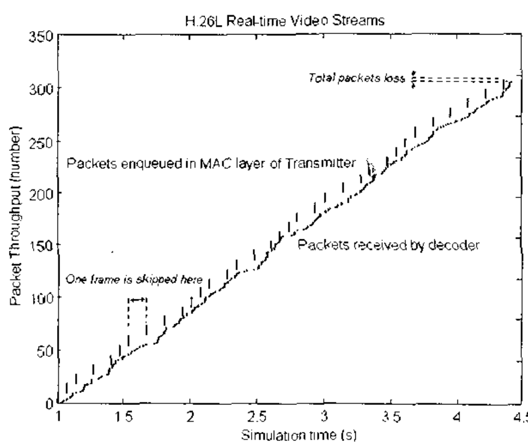

Figure 7. Packet Throughput using our scheme

Fig.7 shows packet throughput using our scheme. The horizontal distance of Fig.3, Fig.4 and Fig.7 between two curves represents end-to-end delay. In addition, the vertical distance between two arrived and departed curves denotes the amount of bits backlogged in the queue of transmitter MAC layer. Clearly, our scheme can achieve both guaranteeing real-time service and reducing the buffer occupancy.

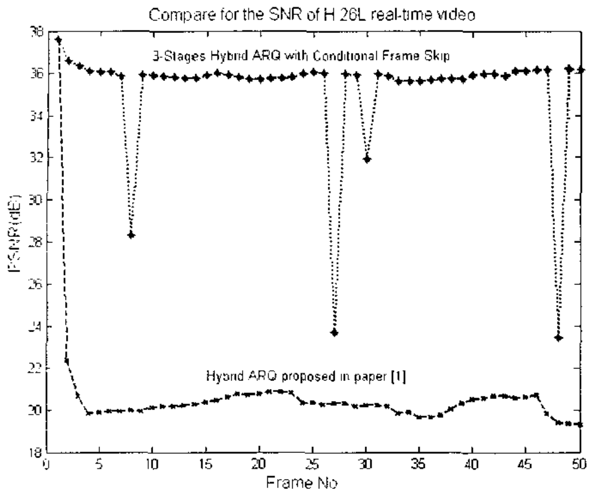

Figure 8. Comparison of PSNR

Fig.8 shows the comparison results of PSNR for the test sequence Foreman. Our scheme achieves an improvement of about 10dB compared to hybrid ARQ scheme proposed in [1] under the same condition. The improvement is due to three points: 1) the saved bits by reducing the useless amount of FEC packets using RACK; 2) conditional frame skipping strategy to adapt video coding rate to fluctuations of channel bandwidth; and 3) keep transmitted video frame as intact as possible by having to compromise little delay boundaries.

V. CONLUSION AND FUTURE WORK

In this paper, we presented a new network-adaptive congestion control scheme with conditional frame skipping for real-time video streaming over wireless LANs. Specifically, we investigate H.26L real-time video transmission over wireless IEEE 802.11b LANs. A QoS differentiation is achieved by modifying the standard IEEE 802.11b MAC protocol. By modified the MAC protocol, we also realize the real-time video coding and transmission over the WLAN. Using the simulation system, the error resilient methods mentioned above have been studied.

Future work will emphasize on real-time video application layer to adjust other encoding parameters or/and algorithms based on accumulated information during multi-stages transmission. This idea can further improve the performance of our proposed scheme.

In wireless IEEE 802.11 LANs, packets are lost due to both congestion and random bit error caused by fading or multi-path effect. Next we also are concerned with FEC scheme by combining packet-level and bytes-level to antagonize congestion and random bit error respectively, then discover optimal allocation between packet-level and byte-level FEC to achieve maximum video quality.

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