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THE STUDY OF TRANSMISSION PERFORMANCES FOR INTEGRATED TFRC AND ARQ OVER WLANS

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ABSTRACT
With technology advances in current wireless network and broadband Internet, multimedia communications over wireless network are dramatically boosted. During the delivery process, a robust transmission rate control scheme plays the key role to the received picture quality. However, a wireless network with many non-congestion losses may bring huge performance reduction to convenient TFRC rate control mechanisms. This paper first proposes a Loss Differentiation Algorithm (LDA) for TFRC in WLAN environment. LDA can effectively avoid treating wireless bit errors as congestive leading to unnecessary rate reduction and poor delivery performance. Moreover, this study further evaluates influences of Automatic Repeat Request (ARQ) operations to the performance of TFRC. Simulation results show that, the received data rate of WLAN using LDA is obviously higher than that without LDA. Moreover, when the ARQ is activated, this work finds that the congestion loss rate and delay time of video packets can be effectively reduced if the TFRC mechanism properly includes the packet loss due to wireless bit error in the determination of available network bandwidth.

KEY WORDS
ARQ, TCP Friendly rate control, WLAN.

1. Introduction

With the advances of wireless network technology and video compression technology, rich multimedia services have dramatically boosted to wireless clients. However, current network cannot provide sufficient QoS guarantees to video data. To smooth the negative affect occurred with congestion events, the rate control mechanism plays a key role for streaming videos over both wired and wireless networks. TCP is a conventional congestion control protocol which adapts its sending rate to current network condition. However, TCP is not suitable for real-time applications because of its long response time. Another scheme called TCP Friendly Rate Control (TFRC) [1] is then proposed. TFRC is an equation-based algorithm, which is fair to TCP connection and suitable for multimedia applications with a smoother fluctuation in sending rate. However, conventional TFRC methods assume that all packet losses are due to congestion events. This assumption results in significant perform degradation in wireless network since the packet losses due to bit errors are included to the packet losses due to congestion. Transmission errors would falsely trigger end-to-end congestion control, which cause underestimation of available bandwidth and reduce application performance.

Performance improvement for TFRC over WLANs can be achieved by extending TFRC with a packet loss differentiation operation, that is, congestion losses due to congestion events are distinguished from the wireless packet losses due to bit errors. There are many efforts to improve the TFRC performance over wireless networks. Pyun et al. [2] added a Wireless Adaptation Layer (WAL) between IP and MAC layers, which monitors the incoming traffic of all video sessions for differentiating various packet loss events. Chaudhary et al. [3] proposed an ECN-based TFRC, where the method used ECN marking rate instead of packet loss event rate. Cen et al. [4] proposed a hybrid end-to-end loss differentiation method to switch dynamically its algorithms according to current network condition. Biaz et al. [5] and Tobe et al. [6] used inter-arrival time and Relative One-Way Trip Time (ROTT) of each packet to discriminate loss type, respectively. Tong et al. [7] proposed a non-loss-differentiation algorithm called Loss Event Rate Discounting (LERD) scheme, which increases the discounting level of the loss event rate when the wireless bandwidth is underutilized and decreases it when the wireless bandwidth is overestimated. Yang et al. [8] used the control messages in link layer of 3G system to differentiate packet losses.

In contrast to [2] and [3], this paper intends to differentiate packet losses by standard control messages of data link layer and physical layer of WLAN. Moreover, this paper focuses on the transmission performance for integrated TFRC and ARQ (Automatic Repeat Request) over WLANs. Regarding multimedia delivery system over wireless network, the ARQ mechanism is widely used for wireless error control of wireless networks because it is simple and effective. This work first implements a Loss Differentiation Algorithm (LDA) for IEEE 802.11 WLAN and describes its detailed procedure in Section 2. In Section 3, this study introduces a modified LDA to discover its impact under ARQ-on wireless network. Sufficient experimental results are also discussed. Finally, Section 4 concludes this paper.

2. Loss Differentiation for 802.11 WLAN

2.1 Implement LDA in WLAN

This work intends to exploit inherent control messages defined in data link and physical layers of 802.11 WLAN standards [9] to our LDA mechanism. In the normal operation of MAC layer, frames are reported to LLC layer only if they are validly formatted at the MAC layer, received without error, received with valid (or null) WEP encryption, and designated their destination address with the local MAC layer entity. This study finds that the standard defines a signaling message called PHY-DATA.indication (RXERROR) in PHY layer, which indicates the transfer of data from the PHY sublayer to the local MAC entity. Sufficient error condition information is already included in the RXERROR control message, as listed below.

- NoError: The value is used to indicate that no error occurred during the receiving process in the PLCP.
- FormatViolation: The value is used to indicate that the format of the received PLCPPDU was in error.
- CarrierLost: The value is used to indicate that the carrier was lost and no further processing of the MPDU can be accomplished during the reception of the incoming MPDU.
- UnsupportedRate: The value is used to indicate that a nonsupported date rate was detected during the reception of the incoming PLCPPDU.

Therefore, our system utilizes the useful RXERROR control message directly and consists of two parts: the Monitor Module and the LDA Module. The Monitor Module resides in MAC layer and traces the information reported from RXERROR. The Monitor Module will send a wireless loss warning to LDA Module while detecting transmission error. LDA Module resides in transport layer and manages the overall receiving packet status to mitigate the negative effect of wireless losses. The major responsibility of LDA Module is to distinguish the congestion losses due to congestion events from the wireless packet losses due to bit errors. Though the data transmitting over WLAN is broadcasted to all users, we can still determine the damaged packets belonging to the local host correctly when RTS/CTS procedure is turned on.

While receiving a successful packet, LDA Module marks it as "RECIEVED", "UNKNOWN" otherwise. When receiving a transmission error message from MAC layer, LDA Module would assume the sequence number of the lost packet is the smallest one with unknown status and refreshes its status from "UNKNOWN" to "RECIEVED". TFRC Module will detect if there exits a new congestion loss event by checking UNKNOWN-status packets and calculate the loss event rate periodically. Therefore, the wireless losses could be excluded out of TFRC procedure.

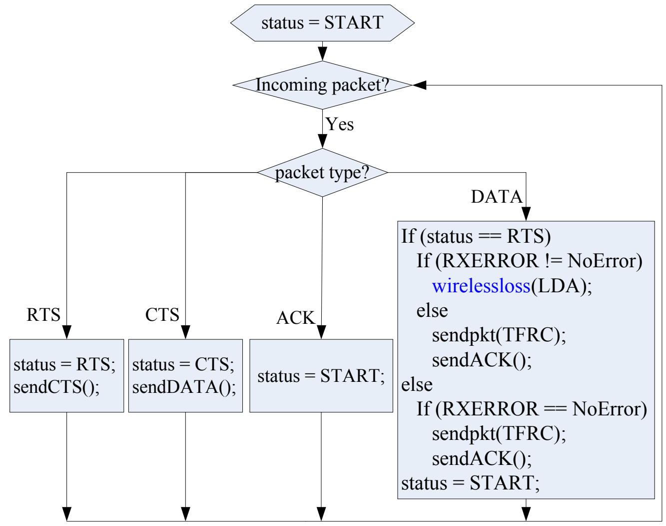

Fig.1 Algorithm of Monitor Module

The detailed algorithms of Monitor Module and LDA Module are shown in Figs 1 and 2, respectively.

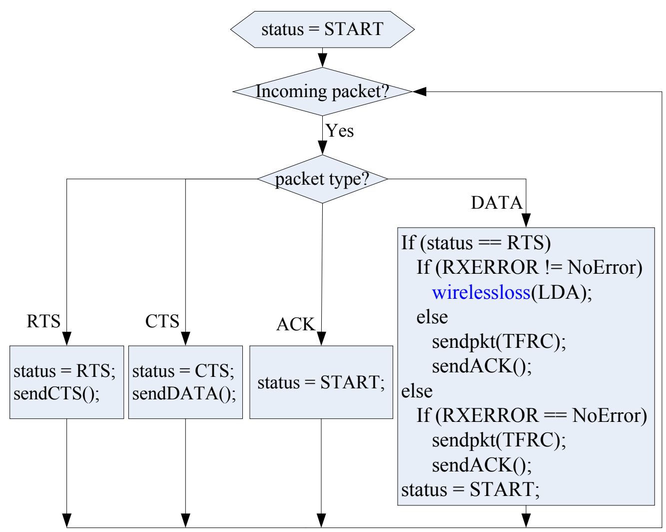

Fig.2 Algorithm of LDA Module

2.2. Simulations

A. Simulation Environment Settings

To demonstrate the performance, this work implements the proposed scheme by the Network Simulator version 2 (NS-2.28) [10]. The network simulation topology is shown in Fig. 3. The bottleneck link is the wireless connection at last hop (indicated by dash lines), which is configured by IEEE 802.11g parameters. This study employs a two-state Gilbert error model to simulate the wireless link [11]. The sending rate of CBR connection varies from 1Mbps to 5Mbps in increments of 2Mbps. For reacting different network conditions, the packet loss rate (PLR) is set to 0.16 and 0.26, respectively. Both TCP and TFRC are implemented with original settings. The connection using the proposed LDA is named as "*wirelessTFRC*". Each simulation runs for 1000 seconds.

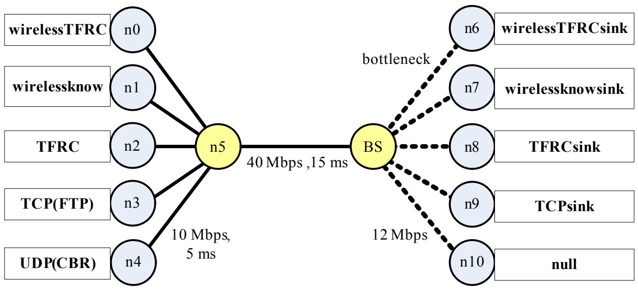

Fig. 3 The Simulation Topology

B. Simulation Results

Table 1 first compares the receiving rate of each connection under the congested condition, that is, UDP = 5Mbps and wireless PLR = 0.16. When the sending rate of CBR connection is 5Mbps, the bandwidth of the wireless link is almost occupied by CBR connection. In such a situation, we find that the receiving rate of wirelessTFRC is higher than original TFRC up to 9 times.

Table 1 Receiving Rate of Each Connection

Flow	Receiving rate (Kbps)
wirelessTFRC	398.51
TFRC	46.36
TCP	9.87
UDP	4097.02

3. Modified LDA for ARQ-ON Networks

3.1 Modified LDA

ARQ is a link layer approach to improve the wireless link performance and is adopted in current IEEE 802.11 standard. It retransmits lost packets in response to ARQ messages to reduce the wireless error rate. However, retransmission may increase congestion loss rate, leading to a worse congested network condition. To discover the impact of LDA under ARQ-on wireless network, this work slightly modifies the proposed LDA Module by adding a separation ratio (TH) on the LDA Module. TH is the ratio that the wireless packet losses are considered in the TFRC Module. In Section 2, TH is set to 0, that is, no wireless packet loss is considered in the TFRC Module. The case that TH=0 was used in traditional researches for TFRC over ARQ-ON wireless networks. In this section, we try to observe the relationship among the TH value, the receiving rate, and the congestion loss in following simulation scenarios.

3.2 Simulations

A. Simulation Environment Settings

The network environment of Fig. 4 is similar to the previous experiment shown in Fig. 3. There are three retransmission cases: noARQ, ARQ1 and ARQ2 that represent no retransmission, one retry and two retry opportunities, respectively. The TH value of LDA Module varies from 0 to 1 in increments of 0.05.

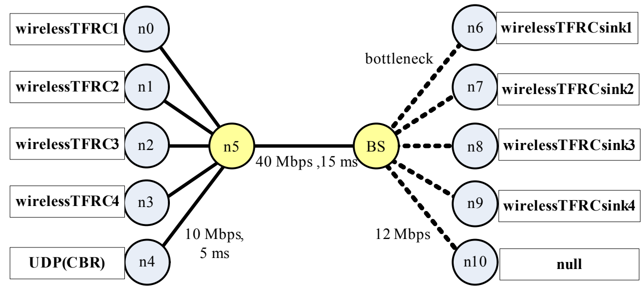

Fig. 4 The Simulation Topology for Modified LDA Solution

B. Simulation Results

Fig. 5 presents average congestion loss rates and receiving rates of four *wirelessTFRC* connections using different TH values. The sending rate of CBR connection is set to 1Mbps and PLR is set to 0.16 in this simulation. Each figure shows the results of three retransmission cases, where the bars of each case represent the results using various TH values that gradually increase from left (TH=0) to right in increments of 0.05 at each case. Fig. 5(a) illustrates that the congestion loss rate gradually decreases when augmenting the TH value in all three cases. At each case of Fig. 5(a), we define the number of bars that their corresponding congestion loss rates are not zero as *convergence range*. A large *convergence range* means that a large TH value is needed to reduce significantly the congestion loss rate while affecting the receiving rate slightly. We find that the *convergence ranges* of noARQ, ARQ1 and ARQ2 are 1, 11 and 20, respectively. We then map the same width of *convergence ranges* of Fig. 5(a) to Fig. 5(b) and find that, the average receiving rates decrease slightly in the respective *convergence ranges*. In summary, we can properly increase the TH value of LDA to improve the overall performance of *wirelessTFRC*, obtaining low congestion loss rate with small impact of receiving rate behaviours.

Fig. 6 illustrates average congestion loss rates and receiving rates when the sending rate of CBR connection increases to 3Mbps. Fig. 6 (a) shows that the *convergence ranges* of noARQ and ARQ1 are 4 and 20, respectively. The width of *convergence ranges* in all cases is larger than that of the previous experiment (UDP =1Mbps). When mapping the same *convergence ranges* of Fig. 6(a) to Fig. 6 (b), we notice that increasing properly the TH value of LDA still brings some improvements for *wirelessTFRC* even in the ARQ1 case that the *convergence range* is wide. So we can choose a larger TH to smooth the impact of ARQ to congestion loss in such a contention environment.

Fig. 7 shows average congestion loss rates and receiving rates when the sending rate of CBR connection increases to 5Mbps. Figs. 7 (a) and (b) show that the *convergence ranges* of ARQ1 and ARQ2 cases are very wide due to the extremely severe contention network environment. In ARQ1 and ARQ2 cases, there is no improvement to *wirelessTFRC* on either congestion loss rate or receiving rate items even tuning TH up to 1.

Finally, this work sets the sending rate of CBR connection to 1Mbps and increases the wireless PLR to 0.26. Fig. 8 (a) shows that the *convergence ranges* of noARQ, ARQ1 and ARQ2 are about 1, 8 and 14, respectively. We find that the *convergence ranges* of ARQ1 and ARQ2 are smaller that that of Fig. 5. This work then maps the three *convergence ranges* to Fig. 8 (b) and find that the required TH value for obtaining similar effect of Fig. 5 would be getting smaller while wireless channel condition is getting worse. So we can pick up a smaller TH value to smooth the impacts of ARQ method under such an environment.

In summary, the decision of a proper TH value would depend on network contention and wireless channel condition level; a larger TH value would be chosen when the network contention is severer and a smaller TH value would be selected when the wireless channel condition is worse.

4. Conclusion

In this paper, we propose an effective LDA by exploiting inherent signaling messages defined in 802.11 WLAN standards to improve the TFRC performance in the environment of both wireless and wired networks. The receiving rate of WLAN with the proposed LDA is nine times of that without LDA in the simulation scenarios used in this study. When ARQ is activated in wireless networks, retransmission may put the packets of AP to be dropped due to buffer overflow. However, retransmission also decreases the PER at the same time. While wireless packet losses are properly included to the calculation of TFRC Model, we find that the receiving rate was affected slightly but improves congestion loss rate significantly. In the future, we will focus on the optimal determination of the TH value for various network conditions

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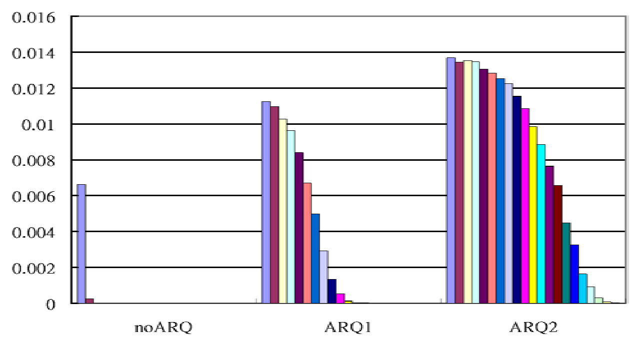
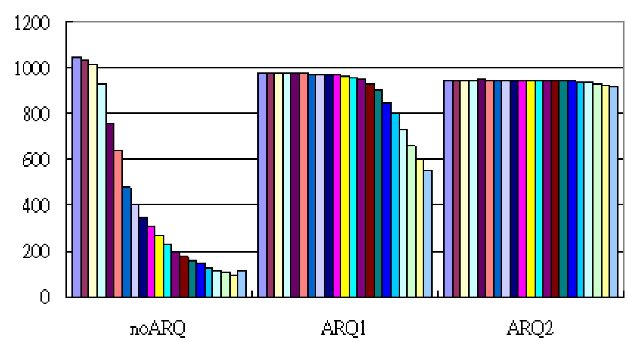
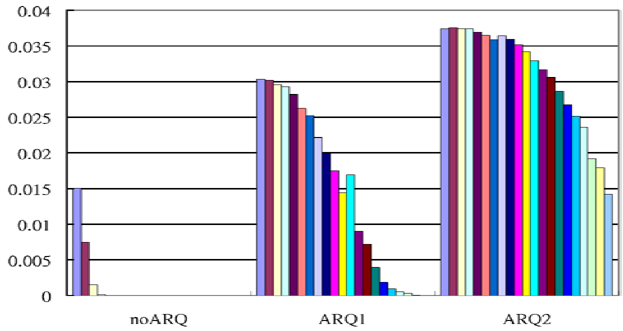


(a) Congestion Loss Rate (%)

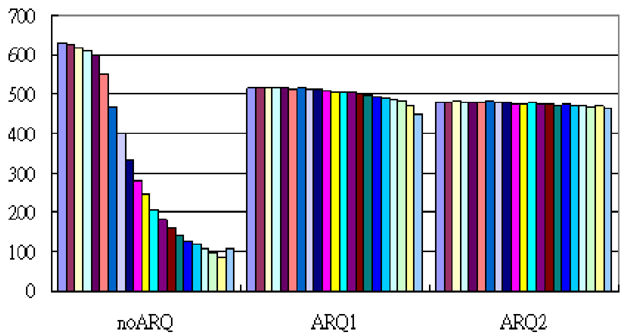


(b) Receiving Rate (kbps)

Fig. 5 Average Statistics of WirelessTFRC (UDP = 1Mbps, PLR = 0.16)

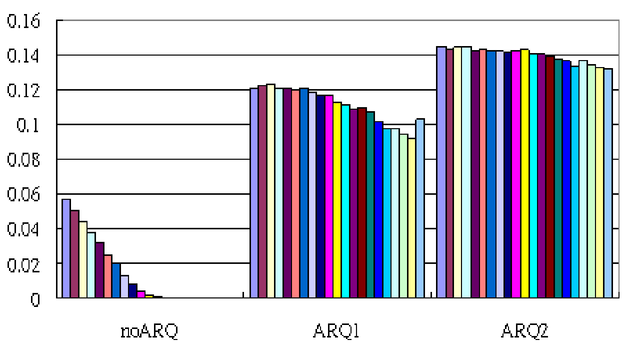


(a) Congestion Loss Rate (%)

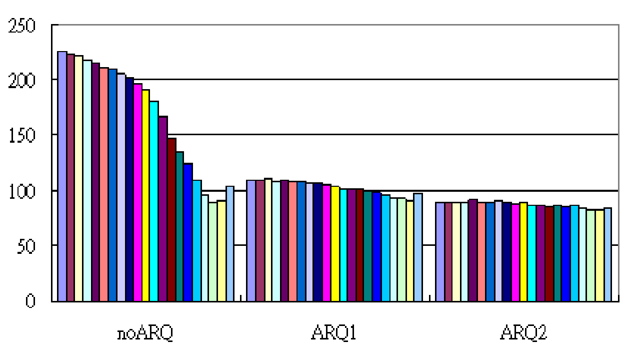


(b) Receiving Rate (kbps)

Fig. 6 Average Statistics of WirelessTFRC (UDP = 3Mbps, PLR = 0.16)

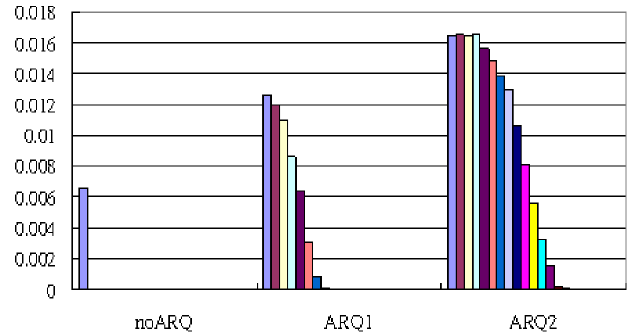


(a) Congestion Loss Rate (%)

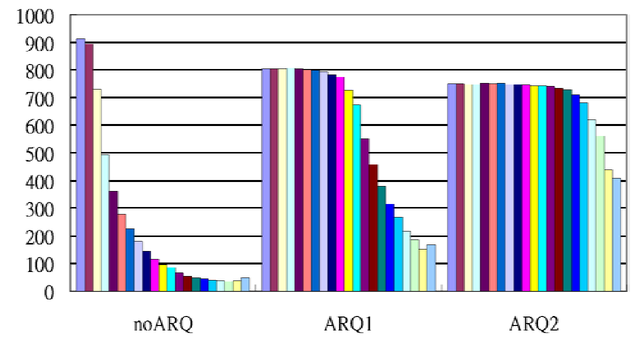


(b) Receiving Rate (kbps)

Fig. 7 Average Statistics of WirelessTFRC (UDP = 5Mbps, PLR = 0.16)



(a) Congestion Loss Rate (%)



(b) Receiving Rate (kbps)

Fig. 8 Average Statistics of WirelessTFRC (UDP = 1Mbps, PLR = 0.26)