CHANNEL-ADAPTIVE HYBRID ARQ/FEC FOR ROBUST VIDEO TRANSMISSION OVER 3G

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ABSTRACT

This paper addresses the important issues of error control for video transmission over 3G. Based on the time-varying wireless channel conditions and the essential defects of the traditional hybrid ARQ for real-time service, the architecture of the channel-adaptive hybrid ARQ/FEC is presented, moreover an algorithm for encoder is given to automatically adjust the parity data length and the maximum number of retransmissions. The experimental studies show that the transmission efficiency of the proposed algorithm increased 13% than the traditional hybrid ARQ.

1. INTRODUCTION

The explosive development of the video coding technique and the wireless communications, especially the third generation (3G) wireless network with up to 384 kbps outdoor and 2 Mbps indoor bandwidth for multimedia services, makes it reasonable for delivering video over the wireless channel [1].

Video transmission in wireless network is limited by the bandwidth in network, the capability of the battery in the mobile device, and particularly the high error rate. To cope with the errors during the multimedia transmission, lots of approaches are proposed. As is known, automatic retransmission request (ARQ) and forward error correction (FEC) are two basic error control mechanisms. For real-time applications with strict delay requirements, FEC recovers lost information by adding redundant information. ARQ, the closed-loop error control technique has been shown to be more effective than FEC, however, introduces additional delay. A hybrid ARQ scheme proposed in [2] can achieve both delay bound and rate effectiveness by limiting the number of retransmissions. However, wireless channel is dynamically time varying caused by fading, interference, shadowing, path loss and so forth. These widely varying error conditions limit the effectiveness of classic FEC, since a worst-case design would lead to a prohibitive amount of redundancy [3]. An adaptive technique was proposed in [4], to adapt the parity data length according to the wireless channel condition. However, there are several essential fatal disadvantages in this method so that it doesn't work well for the time varying wireless channel.

To address the aforementioned issues, this paper proposed a novel error control scheme of the channel-adaptive hybrid ARQ/FEC for video transmission over 3G network, which based on the received simple feedback messages negative acknowledgment (NACK) and positive acknowledgment (ACK) from the decoder, statistically estimates the bit error rate for wireless channel, and adaptive optimizes the parity data length to get the tradeoff between the error correction and network traffic efficiency.

The rest of this paper is organized as follows. Next section explains traditional hybrid ARQ/FEC and its defects. Section III gives the proposed algorithms in detail and conducts theoretical performance analysis. Simulation experiments are explained in section IV. Section V concludes the paper and suggests future works.

2. TRADITIONAL HYBRID ARQ/FEC

Video transmission in wireless environments is a challenging task. The bit-error rate is high and varies with the wireless environments. In order to deal with high error rate in wireless networks, error control techniques has been employed in many ways [5]. Two basic approaches FEC and ARQ are considered.

For the popular FEC techniques, if the original message length is K, then after adding extra parity data of length R, the codeword is of length N. Obviously, when N is given, the larger the value of R, the more errors it would correct. On the other hand, parity data introduces more traffic to the limited network bandwidth. So choosing an appropriated R to trade-off error correction and network traffic should be

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considered carefully.

In order to decrease the packet error rate, the ARQ mechanism is combined with FEC together. For the real-time streaming and conversational services, the number of retransmission times is limited. The bigger the maximum number of retransmissions is, the smaller the packet error rate is, but the more power the mobile device uses for the same fragment of video, vice versa. So the ideal number of retransmissions should be a value fit for the capability of the user in the delay bound.

For applications, when the wireless environments are relatively stable, the bit-error rate is also close to some given value in some interval. For every given value, there is an optimized value of R for the error control coding. At the mean time, the maximum number of retransmission times is related to the round-trip time (RTT) and the playback delay, and the RTT between the server and the mobile device is time-varying with the user location and other wireless environments. So the maximum number of retransmission times is also different with time varying. However, the general hybrid ARQ/FEC techniques designs the value of R and the maximum number of retransmission times for the worst case and doesn't change any more so that exists several essential fatal disadvantages:

- The value of R is fixed and designed for the worst wireless environments. If the wireless channel conditions are better than the worst case for a relatively long interval, there would be a waste for the limited bandwidth.
- The maximum number of retransmission times is fixed a priori, and furthermore the average number of retransmissions is not controllable.

On the other hand, there are some potential information in the feedback messages, which haven't been used. Those are, the statistical packet error rate in the feedback message series of ACK and NACK, and the round-trip time of some feedback message at that time. To cope with the above issue, we introduce a channel-adaptive hybrid ARQ/FEC error control scheme as follows.

3. CHANNEL-ADAPTIVE HYBRID ARQ/FEC

For video transmission over 3G, there is no agreeable standard model for the underlying wireless link, mainly due to the highly time-varying and non-stationary nature of wireless networks. It involves fast channel fading and slow channel fading, as well as the mobility pattern, the location of the mobile node, and so on. But in all cases, the wireless link can just be modeled as an error generator, so the bit error rate (BER) is the main parameter we considered for the wireless channel. For a general video service, there are three parts should be take into account, which are the encoder, the channel and the decoder. Fig. 1 shows the block diagram of a channel-adaptive hybrid ARQ/FEC. The main work is focus on the encoder. The decoder doesn't have to change much and just send the simple feedback messages ACK and NACK identifying if the packet received recently has an error.

3.1. Architecture of the error control scheme

In encoder, if the newest RTT is appropriate, the scheme is going to work.

First, statistically calculate the PER. The PER is a statistical average value in this case, shows that how many packets have an error in transmission in a period of time. Because the PER should be close to reflect it as much as possible, two kinds of cases should be treated differently. One is the stable state, the other is the temporary state.

In stable state, the wireless environment is relatively stable, and then the PER is relatively stable, thereby the feedback messages of much more packets can be used to calculate the PER. A general method is that whenever receive a new feedback message then put it into the calculation to get a new PER. However, when the total number of the messages is too huge, it would get to memory saturation so that any new message would not work for the statistical average value of PER. So the hits for Stat. must be limited to some finite quantity, which is the so-called finite memory method. When a new message is received, it replaces the oldest one to get the newest PER. How to set the hits, that depends, such as the mobile pattern.

In temporary state, the method mentioned above doesn't work well, just because the new message that comes recently bring up the new information of the wireless channel, and so it should be given a bigger weight to play a more important role in the calculation of the PER. An iterative forgot factor is used to cope with that issue in this algorithm.

In order to switch the state between the two given conditions fluently, a predictive mechanism is badly needed. It is an available way that uses the local statistic value of the PER as a threshold value. When the local statistic value is abnormal, it shows that the wireless environment has varied because of some factors outside, and then it would switch the current state to change the error control strategy. Furthermore, there are two temporary states according to the different threshold value, one is the up-temporary state that shows the wireless channel is getting worse and the PER becomes bigger, and the other is the down-temporary state that shows the channel is getting better and the PER becomes smaller. For these two temporary states, the threshold values to switch the temporary state to the stable state are also different.

Second, estimate the BER. The statistical average value of the PER has been got, however what the BER needed

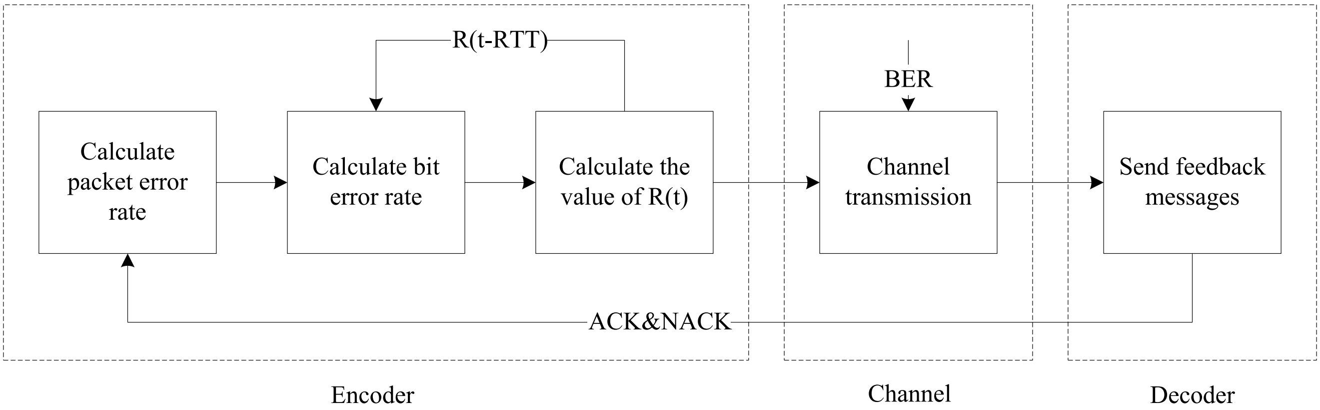


Fig. 1. A functional block diagram for channel-adaptive hybrid ARQ/FEC.

here is an instantaneous value. We can only get the approximate value of the BER in the wireless channel through their relation at that time and the accuracy depends on the strategy that the PER is calculated. And because of the round trip time all the data used are the past time, there is also a delay for the BER.

Third, Optimize R. Based on the BER, the optimized value of R is got easily, which is the smallest one that meets the demand of the object PER. However, sometimes the optimized R is not the real R what we want because of the delay. The method of the predictive control is used to adjust R to the optimized value at that time.

3.2. Formulation of the Algorithm and Performance Analysis

In order to explains the above algorithm in detail and analyze it clearly, the formulation expressions would be given in this subsection. Let ber and per represent the bit error probability in the channel and the packet error probability separately, let N represents the number of the length in the packet, and let r represents the length of the parity data in one packet. Then it is thought the packet has an error when the number of the error bits in one packet is bigger than $r/2$, and then sends the NACK message to the encoder. If the number of retransmissions is not exceed the maximum retransmission limit the decoder would wait for the retransmission, else some error concealment would be done in the decoder, which is not took into account in this paper. When the ber is given, the per would be got by the following equation.

$$per = 1 - \sum_{i=0}^{r/2} C_N^i ber^i (1 - ber)^{N-i} \tag{1}$$

And then, the optimized r_{opt} could be gained through the relations (2).

$$r_{opt} = min\{r|per \leq perobj\} \tag{2}$$

where $perobj$ represents the expected value of the system depended on the capability of the mobile terminal, which could be used to control the average number of retransmissions.

During the video transmission over 3G, the encoder calculates the statistical average value of the packet error rate based on the feedback messages from the decoder, which is represented by $perobs$. For the stable state, the finite memory method is adopted to observe the $perobs$

$$perobs(n - rttn) = \frac{1}{S} \sum_{i=0}^{S-1} m(n - rttn - i) \tag{3}$$

where n represents the current moment of the packet being compressed, $rttn$ represents the number of packets transmitted within the round trip time, S represents the total number of the sampled packets, and $m(i)$ represents the feedback message of the packet transmitted at the ith moment, the value of 1 and 0 represent the message NACK and ACK. And the equation (3) is also used as the state switcher where S is replaced by much smaller number s, which indicates the sensitivity to the channel conditions variety. When the local statistical value is out of the range that set before, the state would be switched. Let tsh_{su}, tsh_{us}, tsh_{sd} and tsh_{ds} represent the threshold value of different states separately.

For the temporary state, the technique of the iterative forgot factor would be used to calculate the $perobs$

$$\begin{aligned} perobs(n - rttn) = (perobs(n - rttn - 1) \times \beta + \\ \tfrac{1}{s} m(n - rttn)) \times \tfrac{1}{1+\beta} \end{aligned} \tag{4}$$

And the first value would be set as

$$\begin{aligned} perobs(n - rttn) = (perobs(n - rttn - s) \times \beta^s + \\ \tfrac{1}{s} \sum_{i=0}^{s-1} m(n - rttn - i)\beta^i) \times \tfrac{1-\beta}{1-\beta^{s+1}} \end{aligned} \tag{5}$$

where β is a decay factor within 0.95 1, and the value of β decides the pace of tracing the varied $berobs$ in the channel.

Based on the $perobs$ that has been observed, we can get the $berobs$ by using numerical technique through the equation (1). Furthermore, we can get the optimized $r_{opt}(n - rttn)$ of the packet transmitted at the $(n - rttn)$th moment through the equation (2).

For the stable state, the ber is relatively stable, and then it could be thought that the $r_{opt}(n - rttn)$ is still the optimized value of r at the current time. However, for the temporary state with the varied ber , the delay has to be taken into account, so an adjustment should be added into the value of $r(n)$.

$$r(n) = r_{opt}(n - rttn) + (r_{opt}(n - rttn) - r(n - rttn))/2 \quad (6)$$

In order to reflect the effect of retransmission on the system, we define a transmission efficiency parameter for radio unit as the ratio unit as the ratio of the actual useful data and the total number of data transmitted.

$$\gamma = \frac{\sum_{i=1, t_i \le t_{max}}^{n_p} (N - R_i)}{N n_p + N \sum_{i=1} n_p t_i} \quad (7)$$

where n_p represents the total number of the packets that need transmit, t_i represents the number of retransmissions for the ith packet, $t_m ax$ represents the maximum number of retransmissions, N represents the data length in one packet, and R_i represents the parity data length in the ith packet.

4. SIMULATION

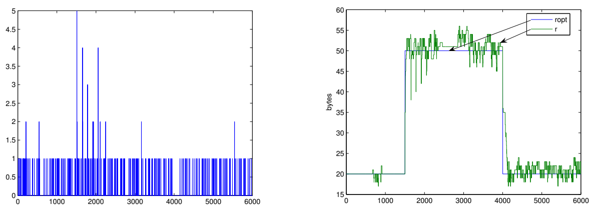
Some common test conditions for wireless video services have been presented in [6]. Two of them for packet-switched streaming services over 3G are given in Table I. It is assumed that the wireless environment varied between the pattern 1 and the pattern 2. So the ber changes the value between 2.9e-3 and 9.3e-3.

Table 1. Bit-error patterns

No.	Bit rate	Length	BER	Mobile Speed
1	64 kbit/s	60 s	9.3e-3	3 km/h
2	64 kbit/s	60 s	2.9e-3	3 km/h

We simulated the proposed algorithm and choose the parameters as follows. $N = 255$bytes, $n_p = 6000$, $t_{max} = 5$, $S = 1000$, $s = 100$, $\beta = 0.95$, $perobj = 0.05$, $tsh_{su} = 2.5perobj$, $tsh_{us} = perobj$, $tsh_{sd} = 0$, $tsh_{ds} = 2perobj$.

According to the given varied trend of BER and the definition in this paper, the actual optimized value of R would change between 20bytes and 50bytes.



(a)The number of retransmissions (b)The parity data length

Fig. 2. The number of retransmissions and The parity data length for every packet.

The number of retransmissions and the parity data length for every packet is shown in Fig. 2(a), (b), separately. The average value of R is 34.96, the average times for retransmission is 0.043 and the transmission efficiency γ is 0.8670. While the γ for traditional hybrid ARQ is 0.7656.

5. CONCLUSION

We proposed an error resilient video transmission architecture of channel-adaptive hybrid ARQ/FEC over 3G network. Theoretical performance analysis and simulation results demonstrate the effectiveness of the proposed algorithm. Future research is needed with issues such as more accurate error models for wireless channel and predictive control techniques for delay.

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