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MODIFIED AGGRESSIVE PACKET COMBINING SCHEME

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Abstract

In this letter, a few schemes are presented to improve the performance of aggressive packet combining scheme (APC). To combat error in computer/data communication networks, ARQ (Automatic Repeat Request) techniques are used. Several modifications to improve the performance of ARQ are suggested by recent research and are found in literature. The important modifications are majority packet combining scheme (MjPC proposed by Wicker), packet combining scheme (PC proposed by Chakraborty), modified packet combining scheme (MPC proposed by Bhunia), and packet reversed packet combining (PRPC proposed by Bhunia) scheme. These modifications are appropriate for improving throughput of conventional ARQ protocols. Leung proposed an idea of APC for error control in wireless networks with the basic objective of error control in uplink wireless data network. We suggest a few modifications of APC to improve its performance in terms of higher throughput, lower delay and higher error correction capability.

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I. Introduction

In order to transfer data reliably from source to destination either BEC (Backward Error Control) or FEC (Forward Error Control) strategies are used. It is well established that BEC strategy is sufficient for wired communication, and FEC strategy is required for wireless transmission. Several researches attempted to apply BEC in wireless communication as BEC is cost effective. BEC is implemented by automatic repeat request (ARQ) protocols [1-17] in which the erroneous packet received by the receiver is corrected by the retransmission of a copy of the same packet from transmitter. BEC uses error detection code unlike FEC that is costly as it consumes higher bandwidth for using error correction code. In order to realize the best of all, it is decisively desirable to employ ARQ in modified form to control error in wireless networks. The bit error rate of wireless channels is high [18-20] in the range of 10^{-2} to 10^{-4}. To enable a reasonable performance radio link bit error rate requires to be within a range of 10^{-6} to 10^{-8} [21]. In order to achieve the desirable quality in high bit error rate wireless channels, two important modifications for applying basic ARQ are found in literature: Multiple route packet combining scheme [22] and Aggressive packet combining scheme [23]. APC does not address any issue of improving throughput rather it attempts to lower complexities of handheld device, power consumption and bandwidth utilization in the uplink. Neither does the scheme address the issues of burst error and a situation when due to repetition of same channel fading error locations in the copies remain the same. We address these issues with appropriate applications of other modified PC found in literature.

Chakraborty [24-26] suggested a very simple and elegant technique, known as the packet combining technique, for error correction using BEC strategy. The technique aims to minimize delay in correction process. Several modifications of PC are found in literature, and these are MPC [27], PRPC [28] and Error Forecasting PC [29]. However, we propose to apply these modifications in APC for better performance.

II. Review of Packet Combining Scheme (PC)

Chakraborty suggested a simple technique where the receiver will correct limited error, one or two bit error, from the received erroneous copies. The technique proposed by Chakraborty is illustrated below:

We assume the original transmitted packet to the “01010101.” The packet erroneously received by the receiver is “11010101.” The receiver requests for retransmission of the packet that was received erroneously and at the same time keeps in store the latter. The transmitter retransmits the packet, but again the packet is received by the receiver erroneously as “00010101.” Chakraborty proposed that the receiver can correct the error by using two erroneous copies. After making a bit wise XOR operation between erroneous copies, the receiver can locate the error position. In the present example the operation is as below:

First erroneous copy 11010101
Second erroneous copy 00010101

XOR 11000000

The error locations are identified as first and/or second bit from the left. Chakraborty suggested that the receiver can apply the brute method to correct error by changing received “1” to “0” or vice versa on the received copies followed by the application of error decoding method in use. In the example the average number of brute application will be 0.5, and in general 2^{n-1} if n bits are found in error.

III. Review of Modified Packet Combining Scheme (MPC)

In the MPC technique, on getting a retransmission call from the receiver the transmitter can send i (i>1) copies of the requested packet. The receiver getting i copies, can now make a pair-wise Xored to locate error positions. For example the if i=2, we have three copies of the packet (Copy-1=the stored copy in the receiver's buffer, Copy-2=one of the retransmitted copies, Copy-3=another retransmitted copy) and three pairs for XOR operation:

Copy-1 and Copy-2
Copy-2 and Copy-3

Table (I): Algorithm of MPC.

Comparing pairs	Number of bits in error (x)	Common copy in two consecutive (x)
Copy-1 and Copy-2	1	Copy-1 common in first two xs
Copy-1 and Copy-3	2	Copy-3 common in next two xs
Copy-3 and Copy-2	3	Copy-2 common in next two xs

Copy-3 and Copy-1

Assume that an actual packet 10100011 was received as:

Copy-1 = 10101011
Copy-2 = 10101111
Copy-3 = 10100001

when we have under xored operation:

Copy-1 xored Copy-2 (say, C_{12}) = 00000100 (one bit in error)
Copy-2 xored Copy-3 (C_{23}) = 00001110 (three bits in error)
Copy-3 xored Copy-1 (C_{31}) = 00001010 (two bits in error).

Now we have to define with which copy the bit inversion will start and how to proceed thereafter. We define an algorithm for the purpose as below. Make a table (see Table (I)) in ascending order of number of bits in error as indicated by the xor operation. The bit inversion and the FCS checking process shall begin with the common copy indicated in the last column of the table so prepared, and proceed down the table if required. If all the inversions do not yield any result, the receiver has to request further retransmission. As per table(I) in this example, the detection of error location and consequent bit inversion will start with Copy-1 and if required will be followed by Copy-3 and then by Copy-2.

IV. Review of Packet Reversed Packet Combining Scheme (PRPC)

The idea behind PRPC is that the receiver when receives an erroneous packet and it requests for retransmission of another copy without discarding the first erroneous copy, the transmitter transmits a bit reversed packet of original packet. The idea and operation of PRPC is illustrated with several examples below.

Example: 1. Say the original packet is, 00110101. Then say on the first transmission the receiver receives the packet as 0011**1**101 (call it first copy) (error location is marked in boldface, 5^{th} bit from left). Receiver requests for retransmission. Transmitter retransmits a copy with bit reversed as: 10101100 (bit wise reversed copy of original packet, LSB of original packet is now MSB of bit reversed packet and vice versa). Say the receiver gets the bit reversed copy erroneously with error at the same error location (5^{th} bit from left). Thus the receiver will receive as: 1010**0**100 (call it second copy).

2. Say the original packet is, 01. Then say on the first transmission the receiver receives the packet as 0**0** (call it first copy) (error location is marked in boldface). Receiver requests for retransmission. Transmitter retransmits a bit reversed copy as: 10 (bit wise reversed copy). Say the receiver gets the bit reversed copy erroneously with the same error location. Thus the receiver will receive as: 1**1** (call it second copy).

3. Say the original packet is, 111111111. Then say on first transmission the receiver receives the packet as 1111**0**1111 (call it first copy) (error location is marked in boldface). Receiver requests for retransmission. Transmitter retransmits a bit reversed copy as: 111111111 (bit wise reversed copy). Say the receiver gets the bit reversed copy erroneously with the same error location. Thus the receiver will receive as: 1111**0**1111 (call it second copy).

[NOTE: To mark the bit reversed copy, we have underlined the copy. This is for illustration purposes.]

The receiver will now perform the correction operation as below:

I. The receiver reverses the second copy bit wise. In example (1), we get the second copy on reversing as 0011**0**101. Now the receiver does the correction as in PC with a reversed second copy and first copy. In the example, XOR of the first and reversed second copy will result in 00011000. Thus, now, the application of brute force bit inversion on 4^{th} & 5^{th} bit will correct the error and it will require on average 2 trails only. In example (2), the XOR operation will result 11. Brute force bit inversion scheme be employed to correct.

II. In example (3) correction is not possible. This is because error is exactly at the middle bit of the packet. (In examples 1 and 2, each of the packets is of 8 bits. In example 3, the packet is of 9 bits. Middle bit is the 5^{th} bit from both ends.) Bit reversion does not change its position. Thus so long as the packet is not of an odd number of bits, the proposed technique will certainly work.

All packets of networks are in size of multiple of several bytes, and thus always of an even number of bits. This authenticates the no-failure case of correcting bit errors by the PRPC scheme.

Unlike PC, the PRPC scheme will be able to correct all single bit errors by using two consecutive erroneous packets even when error occurs at the same location, because the packet reversing changes the bit position as:

i^{th} bit from the right of original packet of k bits to $(k-i+1)^{th}$ bit in reversed packet for i=1 to k.

V. Review of Aggressive Packet Combining Scheme (APC)

APC is a modification of MjPC[30] so as to apply APC in wireless networks. APC is best illustrated as in [23].

i. ORIGINAL PACKET=11111, and it sent from the sender. Sender sends three copies of the packet.

ii. All the packets reached the receiver with errors as: FIRST COPY: 11011, SECOND COPY: 11110 and THIRD COPY: 11011.

iii. Receiver applies majority logic bit by bit on the received three erroneous copies:
11011
11110
11011, and thus gets a generated copy as 11011.

iv. Receiver applies error detection scheme to find whether generated copy is correct or not. As it is not correct in this case, the receiver chooses least reliable bit from majority logic. In this case these are the third and fifth bit from the left side.

v. Receiver applies brute force correction as in PC to the third and fifth bits, followed by error detection. By the process it may get a correct copy. If it fails it requests for retransmission when the sender will repeat three copies of retransmission.

VI. Modified APC: Why and How

A. *Enhancing throughput:* The APC, as proposed by Leung [23], has a very low throughput. One basic parameter of measuring throughput is the average number of times (n) a packet is transmitted/retransmitted for successful receiving at the receiver. In APC, n>=3, making throughput less or at best equal to (1/3) X100%. If S/W ARQ is employed with APC, n=[3/(1-p)] where p is the probability that a packet is in error. P= $1-(1-\alpha)^N$ when α is bit error rate(BER). For GBN ARQ with APC, n=3[{1+(L-1)p}/(1-p)] where L is the window size in GBN. Such a low throughput of APC does not guarantee the claim of bandwidth savings in APC. Logically, original APC with three copies of transmission is as if sending a packet with 3-bit prepetition code. We suggest that rather than sending three copies of a packet in an aggressive scheme as repetition code, we may send one copy as it is and one more copy (second copy, no third copy) with simple (7,4) hamming code. Assume a packet is made of N bits. For the suggested technique, the total of bits to be transmitted is N(first packet) + (3N/4)(check bits)+N (second copy)=2.75N in lieu of 3N in APC. This technique will 1) enhance throughput; 2) provide better correction capability as one bit error correction under each 4 bits block of the second copy will be possible by the hamming code followed by PC; 3) take care of error occurrence at the same locations in both copies more effectively.

B. *Tackling situations of bit error in the same location of all erroneous copies:* In the stated example of APC, if the received erroneous copies would have been: 11011, 11010, 11011 (notice that 3rd location is repetitively in error in all copies), there was no scheme in APC to identify the least reliable bit for error correction. To tackle such a situation it is proposed that APC, if applied in any network, may do with the bit interleaving scheme.

The bit interleaving scheme is proposed as follows. We assign bits of three different copies as:

First Copy: b_{00}, b_{o1}, b_{o2}, b_{o3}, b_{o4}
Second Copy: b_{10},b_{11}, b_{12}, b_{13}, b_{14}
Third Copy: b_{20}, b_{21}, b_{22}, b_{23}, b_{24}

We propose to send bits of three copies in aggressive mode column wise in a circular fashion rather than row wise in a block fashion, as in APC. Thus if error happens always in the third location, errors will be distributed now in b_{24}, b_{12}, b_{00}. This eliminates the problem of identifying least reliable bit in APC. Bit interleaving will correct burst error too unlike in APC that may not correct the burst error when burst size is high.

C. *Tackling situations of bit error in the same location of all erroneous copies in APC with PRPC*: The situation, as stated in interleaving scheme, may be equally dealt with the application of PRPC. Out of three copies, the second copy may be sent in reversed (bit wise) mode, in which case error location will be not same while the receiver will apply the majority rule. In fact, rather than sending three copies as in the original APC, we propose to send a single copy with 3-bit repletion code that may tackle both problems of burst error and error happening in a single location in all the three copies.

D. *Adopting APC to variable error rate channel*: There is no justification of sending three copies of the packet as suggested in AOPC when the channel is a variable rate channel. The wireless channels are variable error rate channels. We may like to consider the channel matrix as: The transition matrix of the forward path is as per common equivalent two state Gilbert model [33]

$$\mathbf{P} = \begin{matrix} p_{00} & p_{01} \\ p_{10} & p_{11} \end{matrix}$$

where 0 and 1, respectively, denote successful and erroneous transmission. At the probability states of p_{00}, p_{01} /p_{10} and p_{11}, APC may be adopted to send respectively one copy, three copies and five copies of packets to equivalently tackle the variable rate condition of the channel. Assuming that all the states are equi probable, n=(1+3+3+5)/4=3 that is, equal to that of the original APC. In fact in reality, n will be less than 3, as accurate n= $[p_{00}X1+p_{01}X3+p_{10}X3+p_{11}X4]/4$, and as $p_{11} < p_{01}/p_{10} < p_{00}$. Besides, the advantage of the proposed scheme of sending variable copies lies in better correction capabilities when the channel is in the p_{11} state, as then APC will apply majority logic on five copies. Similarly, when a link is in p_{00}, there is no need to send more than one copy.

E. Applying multipath routing in APC: A mobile ad-hoc network (MANET) is a self-configuring network of mobile routers (and associated hosts) connected by wireless links—the union of which form an arbitrary topology. The routers are free to move randomly and organise themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Thus it will be logical to send different copies (three copies as in the original APC) in different paths by dynamically reserving more than one path between source and destination [34]. In the original APC, one of the selected paths is in state p_{11}, all the copies received may be completely erroneous. In multipath scenario, it is unlikely that the entire chosen paths will be at p_{11} state at one time. This gives more confidence in applying majority logic for error correction.

VII. Conclusion and future research

We have proposed a few suggestions and modification of APC for performance improvement. All these modifications require to be compared with simulation studies to arrive at some definite conclusions. Analytical comparisons of the techniques suggested may be made in light with studies made elsewhere [31,32].

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