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ERROR FORECASTING SCHEMES OF ERROR CORRECTION AT RECEIVER

Chandan T. Bhunia[1]
Haldia Institute of Technology, Haldia, West Bengal, India
and
The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.

Abstract

To combat error in computer communication networks, ARQ (Automatic Repeat Request) techniques are used. Recently Chakraborty has proposed a simple technique called the packet combining scheme in which error is corrected at the receiver from the erroneous copies. Packet Combining (PC) scheme fails: (i) when bit error locations in erroneous copies are the same and (ii) when multiple bit errors occur. Both these have been addressed recently by two schemes known as Packet Reversed Packet Combining (PRPC) Scheme, and Modified Packet Combining (MPC) Scheme respectively. In the letter, two error forecasting correction schemes are reported, which in combination with PRPC offer higher throughput.

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[1] Senior Associate of ICTP. ctbhunia@vsnl.com

I. INTRODUCTION

Packet combining (PC) scheme for correction of bit error using erroneous copies of packet at receiver was introduced by Chakraborty[1]. In the scheme two erroneous copies are XORed for locating the position of bit(s) in error of the packet, so that the receiver can correct the error rather than requesting a transmitter to retransmit the packet. The correction process proposed is the brute force bit by bit inversion of the located bit error positions and followed by FCS (frame check sequence) check. The PC scheme of Chakraborty fails: (i) when bit error locations in erroneous copies are the same and (ii) when multiple bit errors occur. A scheme called Packet Reversed Packet Combining (PRPC) has been studied[2] to tackle the first problem of PC. Modified Packet Combining (MPC)[3-6] was reported to tackle the multiple bit errors. Any error correction scheme for networks will mainly address the correction for single bit error. When bit error rate is 10^{-2} or less, the probability of higher bit error compared to single bit error in the packet is insignificant. The type of links available except very long haul wireless satellite links for networks do guarantee bit error rate of 10^{-2} or less.

We propose error forecasting correction schemes (two schemes) at the receiver in combination with PRPC. The proposed schemes can correct all single bit errors with higher throughput.

II. BASIC IDEA

Review of PRPC

The idea behind PRPC[2] is that when the receiver receives an erroneous packet and requests for retransmission of another copy without discarding the first erroneous copy, the transmitter transmits a bit reversed packet of original packet. Example:

1. Say the original packet is 00110101. Say on the first transmission the receiver receives the packet as 0011**1**101 (call it first copy) (error location is marked bold, 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 receiver gets the bit reversed copy erroneously with error at same error location (5^{th} bit from left). Thus the receiver will receive it as: 1010**0**100 (call it second copy).
2. Say the original packet is, 01. Say on first transmission the receiver receives the packet as 0**0** (call it first copy) (error location is marked bold). 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 it as: 1**1** (call it second copy). Note that to mark the bit reversed copy, we have underlined the copy.

The receiver will now perform a correction operation as follows. The receiver reverses the second copy bit wise. In the example (1), we get a second copy on reversing as 0011**0**101. Now the receiver does the correction as in PC with reversed second copy and first copy. In the example, XOR of 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 the example (2), XOR operation will result 11. The brute force bit inversion scheme will be employed to correct. The PRPC scheme will be able to correct single bit errors by using two consecutive erroneous packets when error occurs at the same location, because the packet reversing changes the bit position.

PROPOSED BASIC IDEA Scheme I

We propose that the receiver operates in the PRPC scheme for correcting a first few packets $m \leq k$ where k is the packet size in bits. When the receiver corrects bit errors of these m packets by PRPC, it maintains a record of frequency of correction done at different bit locations. The receiver then prepares a set of bit locations in error in order of descending frequency. We call the set an error forecasting set. When any packet in the next slots of m packets received erroneously, the receiver applies the bit inversion scheme for correcting on the bit locations in the set as per order. At the same time, the receiver keeps the record of corrections for new m packets. The correction by this scheme may be called an error forecasting correction at the receiver. If for any packet, correction fails by the forecasting process, the receiver requests for retransmission by sending negative acknowledgements. The transmitter then operates in PRPC scheme. The protocol of the proposed scheme is shown in fig 1.

Example: A simple example is taken to illustrate the idea. Say the packet size is 32 bits, the receiver assumes m=16. Say, the first m packets, when delivered under PRPC scheme, the receiver gets a record of bit correcting locations as in table I. The receiver generates error forecasting set. In the example, the set is [8, 5, 3, 12, 16]. The scientific reason for this is that the probability of future packets having error at locations 8, 5, 3, 12 and 16 are respectively 6/13, 5/13, 3/13, 1/13 and 1/13, if the channel remains static in generating error vectors. The dynamic or time variant situation will be tackled by the continuously upgraded error forecasting set of the receiver on each block of m packets.

Table I: Example of bit errors in locations.

Bit locations	Frequency of error correction at different locations
1	
2	
3	2
4	
5	3
6	
7	
8	6
9	
10	
11	
12	1
13	
14	
15	
16	1

PROPOSED BASIC IDEA Scheme II

We propose that the receiver will calculate a weighted average, w with frequencies of error occurred at different bit locations in first slot of m packets:

$$w = \frac{\sum frequencies}{number\ \ of\ \ locations\ \ that\ \ got\ \ in\ \ error}$$

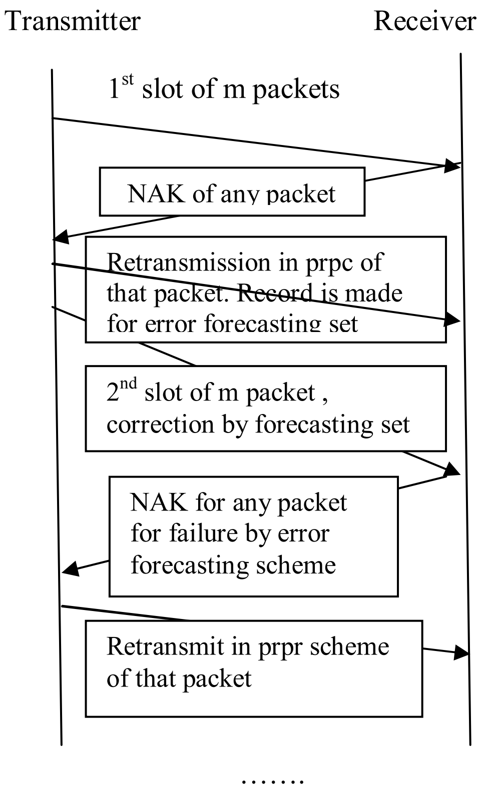

Fig. 1: MPC with PRPC in stop and wait ARQ operation

Unlike scheme I, in scheme II the receiver will make an error forecasting set with the locations having frequency ≥w. For the next slots of m packets, the receiver will apply for correction with location in the set, and at the same time will record and calculate w for the next slot. In the example considered for scheme I, when applied in scheme II, w becomes =13/5=2.6. The error forecasting set is then [8,5]. Bit inversion correction will then apply to location 8 and then to 5 followed by PRPC if required. Note that scheme II applies bit inversion only to locations having error occurrence frequency greater than w. This makes scheme II to realize correction with probability in the considered example, such as {6/13 + 5/13} unlike full probability 1 {=6/13 + 5/13 + 3/13 + 1/13 + 1/13} of scheme I.

III. ANALYSIS

The throughput of all ARQ techniques depends on the average number (n) of times a packet needs transmission (including retransmission) for successful reception by the receiver. As n decreases, the throughput increases, and when n=1 the throughput is 100%. We propose to study the gain of the proposed scheme over that of PRPC and if gain is achieved, it will be equally true for other ARQ schemes[1-7], as PRPC offers higher throughput over ARQ protocols[7]. The gain will be measured by the parameter, n as defined. In normal stop and wait ARQ:

$$n_{sw} = \frac{1}{1-P} \tag{1}$$

where P=packet error probability,

$$= 1-(1-\alpha)^k$$

and α = bit error rate and k is the packet size in bits.

PRPC

In PRPC, all single bit errors will be corrected. The probability that a packet is with single bit error is

$$P_1 = C_1^k \alpha^1 (1-\alpha)^{k-1} \tag{2}$$

Thus the probability of packet in error except single bit error is:

$$P - P_1 \tag{3}$$

In PRPC, for correction of single bit error, a packet is transmitted twice: first the original and then the reversed. Thus in PRPC when stop and wait ARQ protocol is implemented, the average number of times, n_{prpc} a packet needs transmission (including retransmission) for successful delivery is:

$$n_{prpc} = \frac{1-P_1}{1-(P-P_1)} + 2.P_1 \tag{4}$$

The first part of the right-hand side of eq.(4) is for correction in normal stop and wait ARQ for bit errors other than single bit error, and the second part is for PRPC in correcting single bit error.
Simple Proof: i) when $P=P_1=0$ (no error case, the result must be 1 packet per success) we got that as $n_{prpc} = 1$; ii) when $P=P_1=1$(all single bit error, the result must be 2 packets per success as in PRPC), we got that as $n_{prpc} = 2$ and iii) when P=1 and $P_1 \neq 1$ (always packet is in error but error is not always single bit error, the result must be towards infinite packets per success), we got that as $n_{prpc} \rightarrow \propto$.

PROPOSED SCHEME I

We assume in the proposed scheme, the average number of times a packet needs transmission (including retransmission) for successful delivery is $n_{proposed}$.

Single bit error occurs in packets of k bits at any of the k locations with different k error vectors. With a choice of block of m packets, single bit error may maximum occur with m different vectors in maximum m different locations. Therefore, the scientific justification of error forecasting has success and failure probability respectively $\frac{m}{k}$ and $(1-\frac{m}{k})$. In case of success probability, the $n_{proposed}$ =1 whereas in case of failure it will be equal to that of PRPC. Hence,

$$n_{prposed} = 1 \times \frac{m}{k} + (1-\frac{m}{k})[\ \frac{1-P_1}{1-P-P_1} + 2.P_1\ ] \tag{5}$$

Based on eqs.(4) and (5), the Gain% of the proposed scheme over PRPC becomes:

$$gain\% = \frac{n_{prpc} - n_{proposed}}{n_{prpc}} \times 100\%$$

$$= (\frac{m}{k})\left(\frac{P + 2P_1^2 - 2PP_1}{1 - P - P_1}\right) \times 100\% \qquad (6)$$

That shows that gain is obtained when:

$$P > 2PP_1 - 2P_1^2 \qquad (7)$$

The inequality (7) meets as both P and P_1 are less than 1. The numerical results of eq.(6) is plotted in fig 2. We find:

i) gain% increases with packet size. This is due to increasingly probability of packet error with increased packet size

ii) gain% increases with BER. This is because packet error probability increases with increased BER.

Analysis and results indicate the superiority of the proposed error forecasting scheme to PRPC.

<u>PROPOSED SCHEME II</u>

In the scheme:

$$n_{prposed} = 1 \times \frac{m}{k} \times L + (1 - \frac{m}{k})(1 - L)\left[\frac{1 - P_1}{1 - P - P_1} + 2.P_1\right] \qquad (8)$$

where:

$$L = \frac{\sum frequencies \geq w}{number\ \ of\ \ locations\ \ that\ \ got\ \ in\ \ error}$$

Scheme II will offer higher a throughput compared to PRPC as well compared to scheme I depending on w. If error locations repeat too much, scheme II will be superior to scheme I.

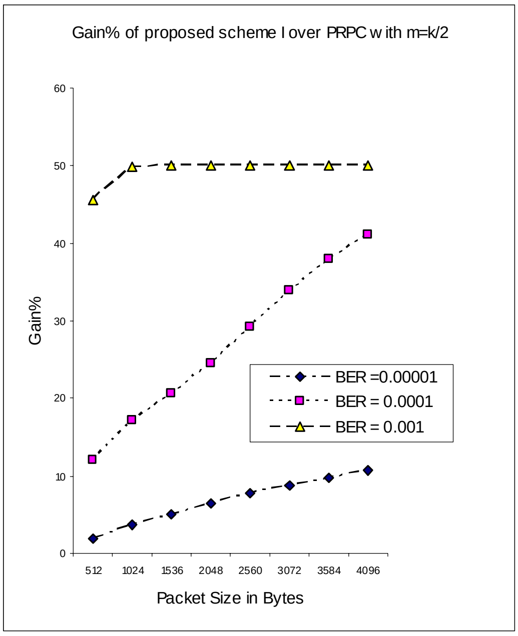

Fig 2: Gain% of proposed scheme I over PRPC

IV. CONCLUSION

In this paper we have proposed error forecasting error correction schemes at the receiver. Our studies indicate a higher throughput of proposed schemes than that of PRPC schemes. In an earlier study[7] it was shown that PRPC offers a higher throughput than that of Stop & Wait and hence GBN ARQ protocols. Thus, proposed error forecasting schemes offer higher throughput than that of conventional ARQ schemes.

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