PC-APC Schemes in Multipath Diversity System to Get Higher Throughput

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Article Info	ABSTRACT
	This paper is studied about a new protocol of Packet combining (PC) and Aggressive Packet Combining Scheme (APC) in multipath diversity system to get higher throughput. In the proposed protocol of PC and APC schemes, two and three copies of a packet are sent in two and three paths. If either of the copies is received without any erroneous then select the correct one and discard all other copies. Again if all copies are found as erroneous then combine the erroneous copies and perform XOR operation in case of PC and bit by bit majority logic in case of APC in order to get the original copy. The paper is implemented using Mat lab and found that new proposed protocols are getting higher throughput and probability of receiving successful packet at the receiver side. Thus, performance of error prone wireless network can be improved by applying either PC or APC in multipath diversity system.

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1. INTRODUCTION

Automatic Repeat Request (ARQ) techniques are mainly implemented for error control by retransmitting duplicate copies in wireless network. Normally, the receiver discards all erroneous copies and request for retransmission. However, an erroneous packet may contain both erroneous and correct bits and hence the packet may contain useful information. Therefore, to get the correct information, it is deployed by combining multiple erroneous copies at the receiver side. S.Chakraborty et.al [1] suggested that PC is one of the simplest implementation of space diversity reception for combating fading in wireless communication system. In PC technique, only one error can be corrected and therefore, if double errors are found at same bit location of two copies then PC technique is not useful. Therefore, retransmission of duplicate packet has been occurred. Moreover, APC was introduced by Leung [2] for error correction and optimizes Backward Error Correction (BEC). Many researchers [3-14] have been studied and conclusively established that PC techniques provide higher throughput but low error correction capability to that of APC schemes. The error prone wireless network having bit error rate varies from 10^{-4} to 10^{-2} is neither reason of assuming nor any logic to apply only single path in case of conventional PC and APC techniques. Therefore, in the paper new protocol of PC and APC are introduced in order to reduce the dependency of a single path/route which gives more stable in wireless netwok.

The remaining of the paper is organized as follows. Reviews of conventional PC, APC and ELA-POR-SC are introduced in Section 2. Section 3 discusses about new protocols of PC and APC and Section 4 describes mathematical analysis of throughput and probability of error. Section 5 illustrates the simulation result using Mat lab and finally, conclusion is discussed in Section 6.

2.   PRELIMINARIES
2.1. Packet Combining Scheme (PC)
PCis proposed to locate erroneous bits received by the receiver.The technique of PC scheme are given here: let original packet be "00001111". Instead of these bits, the copy is received erroneously as "00001110".The receiver requests for duplicate copy after storing of received erroneous copy. Again, it is assumed that receiver received the copy as "00011111", which is also an erroneous. By combining erroneous copies at the receiver using XOR operation, it can identify the error location. The example is given here;

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00001110
00011111
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XOR 00010001

From the above example, 4th and 8th bit positionsfrom MSB are identified as erroneous bits. To get original packet by Chakraborty, the erroneous bits are converting received"1" to "0" or vice versa. Again, let original Packet as "11110000"

At the receiver
1st erroneous copy: 10110000 (erroneous occurs at 2nd bit position from MSB)
2nd erroneous copy: 10110000 (erroneous occurs at 2nd bit position from MSB)
…………………………………..
XORed 00000000

The operation cannot be identified erroneous bit position when erroneous occurs at same bit position. So, it is failed to correct erroneous copy.

2.2. Aggressive Packet Combining Scheme (APC)
APC is a modified version of Majority Packet Combining. This technique isused for obtaining high error correction capability in wireless networks. Examples of APC are given here:
a. "00111" is assumed as original packet which is sent form sender to receiver. It is also assumed that the original packet is received as erroneous.Therefore, the receiver request for duplicate copies from sender. Let all the copies are received with error as: 1^{st}erroneous copy: 00011, 2nd erroneous copy : 00110 and 3rd erroneous copy:00011.
b. 00011 are generated at the receiver side after performing bit by bit majority logic on three erroneous copies.
c. Error detection scheme is applied at receiver to check the generated copy is original or not. If it is not actual packet, least reliable bits will be chosen from majority logic. Therefore, in the example the 3rd and 5th bit from the MSB is chosen.
Brute force correction method is applied as in PC technique to the 3rd and 5th bits, followed by error correction method. This process may lead to get actual packet. If actual packet is not generated in the above process then it will discard all erroneous copiesandrequests for duplicate copies.

2.3. Error Location Algorithm-POR-SC
Liang et.al [5] introduced Error Location Algorithm (ELA) which is an enhanced version of Automatic Repeat Request-POR-SC. The scheme operates as follow: if any one of the received copies is correct, then it is accepted. However, if all copies are erroneous then in order to get correct copy, it performed ELA-POR-SC. In this scheme, three copies are sent from transmitter to receiver. At least one copy is found as correct then proceed for the next packet otherwise performing ELA-POR-SC. It is assumed that A, B, C are the three received of erroneous copies of the same transmitted packet from transmitter over three diversity channels, then:
AA=(A xored C).(A xored B)
BB=(A xored B).(B xored C)
CC=(A xored C).(B xored C)
In AA, BB, and CC, every '1' indicates an error in the copy of A, B and C respectively. In this case, the original packet can be retrieved by using
S=AA xored A (=BB xored B = CC xored C)
However, the retrieval process fails when it is found as double, triple error and so on. In this time, erroneous copies are discarded and request for next duplicate copies by sending NAK.

Table 1. Examples of ELA-POR-SC.

Original Packet at Sender	Receiver (Erroneous bits are underlined)	
1. 11100011	A-111<u>10</u>011	AA=00010000,
	B-<u>0</u>1100011	S=11100011 (Original
	C-1110001<u>0</u>	packet)
2. 00001111	A-0<u>1</u>001111	BB=10000000,
	B-<u>1</u>0001111	S=00001111(Original
	C-00001<u>1</u>0<u>1</u>	packet)
3. 10101010	A-1010<u>10</u>00	CC=00001000,
	B-1<u>1</u>101010	S=10101010(Original
	C-1010<u>0</u>010	packet)

3.   PROPOSED PROTOCOLS

3.1. Proposed Protocols of PC Scheme

In this new PC scheme, duplicate copies of a same packet are transferredfrom sender to receiver by using two paths (branches). The step wise procedures are illustrated below:

a. The first copy is sent original as "11100011" in first path but erroneously received as 10100011.

b. As in PC scheme, duplicate copy will be sent in second path by shifting three bits from LSB to MSB as 01111100. It is assumed that the copy has been found error at 2^{nd}bit position from MSB as 01111100. In order to get the original bit sequence, the received copy will be shifted back from MSB to LSB by three bits at the receiver side as 11100011.

c. The two erroneous copies are stored and performed XOR operation to locate the erroneous bit position and apply brute force method as conventional PC scheme (erroneous bits are underlined). The example is given below:

Original packet as "11100011"
1st erroneous copy-1<u>0</u>100011
2nd erroneous copy-111000<u>11</u>
…………………………………..
XORed 01000010

This technique overcomes the limitation of conventional PC as receiver will be detected same bit error location in two erroneous copies.

3.2. Proposed protocol of APC

In this protocol, triplicate copies of same packet are sent in three paths from sender to receiver. The stepwise procedures are illustrated below:

a. The first copy is sent in first path as original packet.

b. The second copy will be sent after three bits shifting from LSB to MSB in second path. The receiver will perform three bits shifting from MSB to LSB.

c. The third copy will be sent in third path after six bits shifting from LSB to MSB and at receiver side the six bits will be shifted back from MSB to LSB in order to get the original sequence of bits position.

d. The three copies are stored in receiver and perform Aggressive Packet Combining Scheme to get the original packet.The examples of proposed protocols are illustrated as below:

Table 2. Erroneous may happen at any two bits position

Original Packet	Sender	Receiver (Erroneous bits are underlined)
1. 11110011	1st copy -11110011	1st copy -<u>00</u>110011
	2nd copy -01111110	2nd copy-11110<u>101</u>
	3rd copy -11001111	3rd copy -11<u>000</u>011
		…………………
		11110011 (original packet after majority packet combining)
2. 11110000	1st copy -11110000	1st copy-<u>0</u>111000<u>1</u>
	2nd copy -00011110	2nd copy-1111<u>1</u>100
	3rd copy -11000011	3rd copy-1<u>00</u>10000
		………………………
		11110000 (original packet after majority packet combining)
3. 00001111	1st copy -00001111	1st copy -000<u>10</u>111
	2nd copy -11100001	2nd copy -<u>11</u>001111
	3rd copy -00111100	3rd copy -<u>00</u>001111
		…………………..
		00001111 (original packet after majority packet combining)

4.   ANALYSIS

It is assumed that the sender sends bit 1 to receiver using single path and receiver receives bit 0 instead of 1. Let 'μ' be the probability of receiving bit error (received 0 instead of 1 and vice versa) and therefore, 1- μ be the probability of correction bit at the receiver side. For 'n' packet size, the probability of error correction is given by Equation 1.

$$PC = (1-\mu)^n \tag{1}$$

And Probability of error is given by Equation (2)

$$PE = [1-(1-\mu)^n] \tag{2}$$

It is assumed that in proposed PC and APC the sender sends two and three copies of n packet size in two and three paths then the probability of receiving at least one correct copy [5] is given by Equation 3 and 4.

$$X = 1-[1-(1-\mu)^n]^2 \tag{3}$$

$$Y = 1-[1-(1-\mu)^n]^3 \tag{4}$$

Throughput [19] of proposed PC and Proposed APC will be given by Equations (5) and (6)

$$TH_{pc} = (1-\pi_{pc})/(2+\pi_{pc}) \tag{5}$$

$$TH_{apc} = (1-\pi_{apc})/(3+\pi_{apc}) \tag{6}$$

Where $\pi_{pc} = [(1-(1-\mu)^n)+(1-(1-\mu)^n)]/2$, $\pi_{apc} = [(1-(1-\mu)^n)+(1-(1-\mu)^n)+(1-(1-\mu)^n)]/3$

4.   RESULTS

4.1. Comparisons of proposed APC and PC Schemes in Term of Probability of Successful Packet Received at the Receiver Side
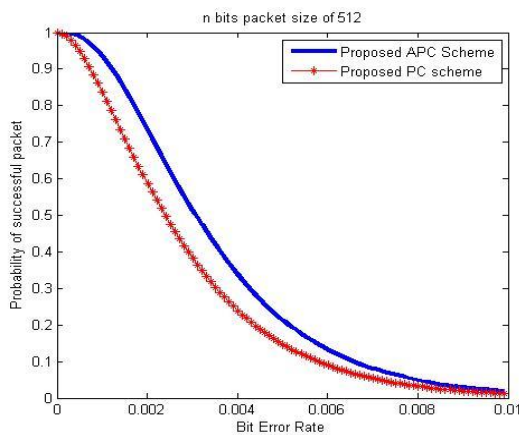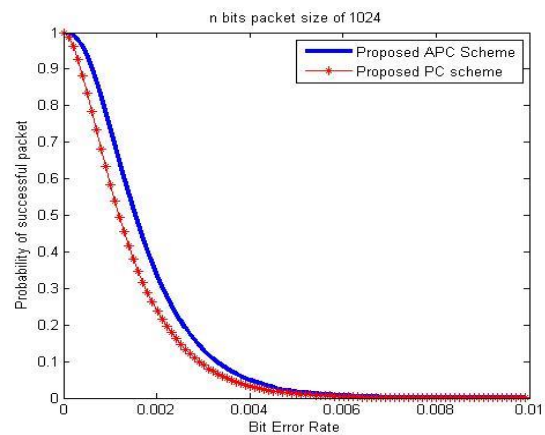

Figure 1. 512 Bits Packet Size

Figure 2. 1024 Bits Packet Size

4.2. Comparison of Proposed PC and Conventional PC Schemes in Term of Throughput
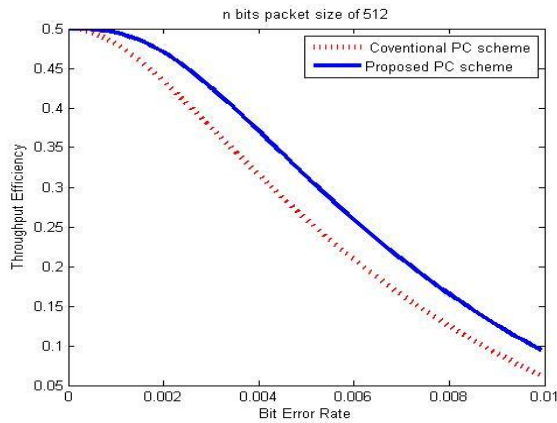

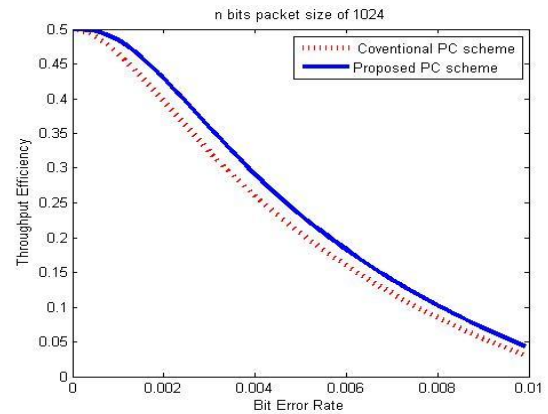Figure 3. 512 bits packet size   Figure 4. 1024 bits packet size

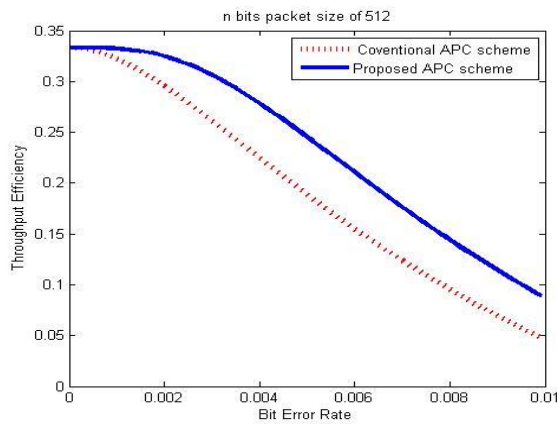### 4.3. Comparison of Proposed APC and Conventional APC Schemes in Term of Throughput
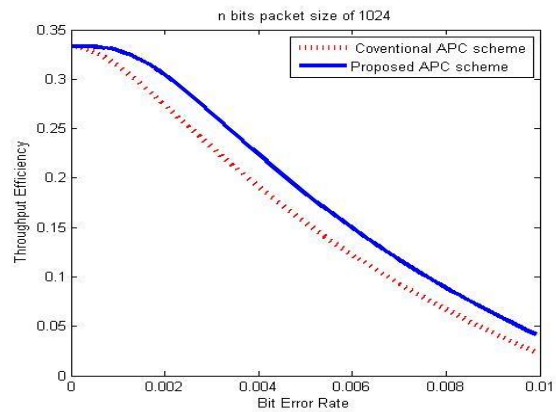

Figure 5. 512 bits packet size   Figure 6. 1024 bits packet size

5.   CONCLUSION

In wireless networks, data transmission is high chance to get failured and thus, retransmission of duplicate copies from sender to receiver may drastically reduce the throughput. In orderto reduce retransmission of duplicate copies, erroneous copies are combinedtoget original copy. The technique is done by PC and APC but they have low performance. Therefore,new proposed techniques are introduced to increase the performance of the conventional PC and APC. In the results, figure 1 and figure 2 clearly showed that comparison of proposed techniques of APC and PC in term of probability of receiving at least one correct packet at the receiver. In figures 3-6, it is also clearly evident that proposed PC and APC techniques using multipath provide higher throughput in bit error rate varies 10^{-4} to 10^{-2} and packet size from 512 to 1024 bits. Thus, multipath PC-APC is outperformed in terms of throughput and probability of receiving atleast one correct copy.

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