Implementation and throughput analysis of aggressive packet combining scheme in Rayleigh fading channel

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Abstract—Aggressive packet combining (APC) is one of the reliable schemes in wireless communication and it is well established in literature. To combat fading processes in wireless communication, antenna diversity is widely used, but aggressive packet combining scheme with receiver diversity has not been discussed so far. In this article various protocol of aggressive packet combining schemes are studied and compared with different established protocol of channel diversity. The simulation result shows that the proposed protocol is superior in terms of selective repeat (SR) with selection diversity.

Keywords - aggressive packet combining; automatic repeat request; signal to noise ratio; throughput

I. INTRODUCTION

A wireless channel poses some issues for reliable communication due to extreme noisy and non-stationary nature. To overcome the problems of interference, delay, fading and other noise processes; space diversity reception technique is widely and efficiently exercised [1]. In addition with space diversity reception, Automatic Repeat Request (ARQ) has been investigated to achieve reliable communication over fading channels [2]. In this paper, packet combining scheme has been considered and it is merged with the existing space diversity reception. The corresponding change in throughput is reviewed. Cyclic redundancy check (CRC) is equipped with the basic form of ARQ blocks. But in case of packet combining scheme, probabilities of error correction are considered in three consecutive steps and in this proposed scheme these are equiprobable. Hence, the average number of packet required for successful transmission of a packet is (1+2+2) /3 = 1.666 [3]. And acquired block after diversity reception and the decision process is considered to be either correct or erroneous. According to that, another couple of packets are sent to the receiver. In this context, two important space diversity techniques namely, non switch diversity (NSD) and Switched antenna diversity (SAD) [4] are to be taken into account. In NSD, all branches are observed for correct reception of a transmitted block. SAD is a pre-reception technique. When instantaneous envelope of received signal falls below a predetermined threshold, blocks are switched from one branch to another branch. Classical selection diversity (CSD) [1, 5] comprises some differences from NSD, as in CSD post reception technique is used to select the diversity branch. After continuous monitoring of the diversity branches, the branch having desirable signal to noise ratio (SNR) is taken to output. A correctly received block is chosen at the output after block-by block transmission, based on the criteria NSD have been chosen. NSD with block-by block operation brings selection diversity closer to the SAD scheme conceptually. There will be certainly some loss of performance, if SAD scheme is applied to minimize the complexity of channel sensing requirements of selection diversity [4].

In NSD, the outputs of the other antennas are neglected when the present antenna has incorrect reception. The crucial aspect of NSD is that even if all the blocks received by the diversity branches are erroneous, they can be combined with an aim to retrieve the original packet.

Two packet combining strategies [6] are described in the light of code and diversity combining schemes, when it is possible to receive multiple copies of a packet. In time diversity system, code combing methods are applied. Though here all transmissions are not same and incremental redundancy may be achieved from retransmission in according to correct a corruptly received packet. At a code word level, packet combining is done. In case of diversity combining, copies of the same packet are combined to create a single code word. Code combining can be applied considering both soft and hard decision.

Extended ARQ (EARQ) is an ARQ technique with packet combining is proposed in [7]. In this particular technique erroneous copies of packet are XORed to locate the error in the received copy. A brute force method (replacing with 0 or 1 vice versa) is applied to recover the correct copy. EARQ is a potentially good approach to use in diversity combining [2]. In this work, the modification of existing diversity combining scheme is investigated by proposing a variation of aggressive packet combining (APC) to achieve considerably better throughput.

II. ARQ IN CHANNEL DIVERSITY SCHEME

A. Basic ARQ scheme)

SR-ARQ scheme consists of a transmitter- receiver pair which is shown in Figure 1. If erroneous packet is received, it is discarded and another copy is retransmitted by the transmitter.

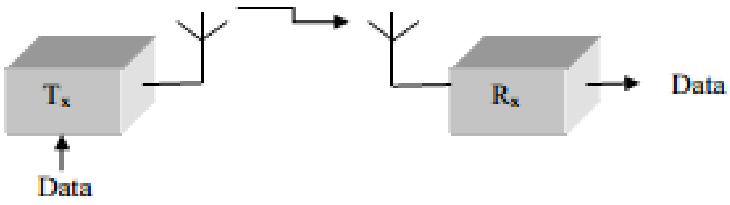

Figure 1: Schematic representation of SR-ARQ scheme

B. SR-ARQ with SAD

In this particular enhancement of SR-ARQ (basic ARQ) is implemented with M number of antennas leaving a constraint of only one will work at a time. In this example (as shown in Figure 2), M = 2 is considered for all the space diversity reception system. Same as in [8], if the receiver receives erroneous packet, receiver starts using another path (or antenna) with a decision that there is a deep fade in the current transmission path. This scheme is equivalent to have M different transmitters. But the difference is that transmitter gathers some information in accordance with the transmission channel and accordingly changes the antenna. In both the cases, SR-ARQ and SR-SAD have almost equal throughput.

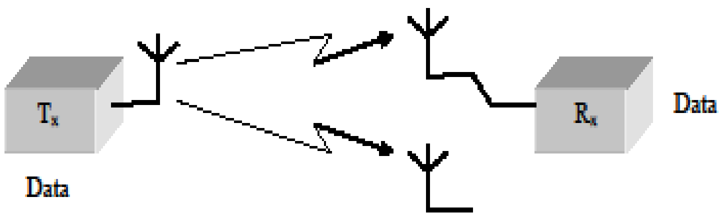

Figure 2: Schematic representation of SR-SAD scheme

C. SR-ARQ with SAD

In this particular technique, individual receiver has its dedicated antenna as shown in Figure 3. If the reception is correct by any of the diversity branches, decision is processed accordingly. Throughput of the scheme is reported to be higher than SR-SAD scheme [2].

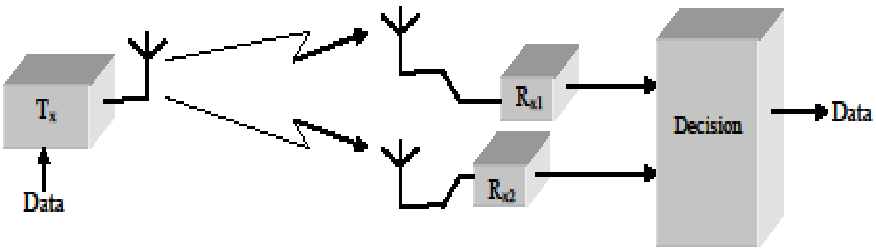

Figure 3: Schematic representation of SR-NSD scheme

D. EARQ with receiver diversity

In time diversity system, the EARQ scheme [7] is proposed as a simple enhancement to the basic SR scheme. In earlier studies [2], it is observed that this EARQ scheme is combined with SR-NSD technique. The scheme operates as follows in the Figure 4.The scheme worked same as SR-NSD, but in decision making process if both the copies are erroneous the XOR-ed operation is done to locate the bit errors. Receiver failed to retrieve correct packets if there is at least one bit position where both copies are erroneous or the number of errors in the combined copy exceeds a predefined value N_{max}. If the packet combing process for a pair of erroneous copies fails then they are dropped and retransmission of packet is asked by the decision process.

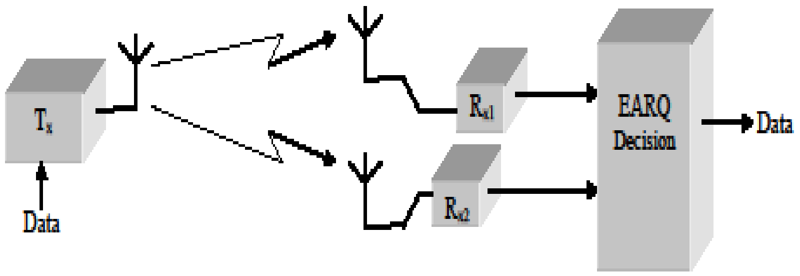

Figure 4: Schematic representation of EARQ scheme with receiver diversity

E. Protocol- I (Packet Combing) with Receiver Diversity

In time diversity system, the Protocol-1 scheme [3] as an enhancement to the packet combining scheme is investigated. Here, the protocol-1 is combined with NSD system which is shown in Figure 5. In this particular scheme, one copy of packet is sent through the channel 1. If it is received successfully, sender sends second packet. If the first received copy is erroneous, then receiver requests transmitter to transmit the copy of the packet. Here, unlike EARQ, transmitter sends two copies of the packet. If application of majority logic fails to retrieve the original copy, transmitter repeats the process. Finally, three copies of packet will be received by the receiver.

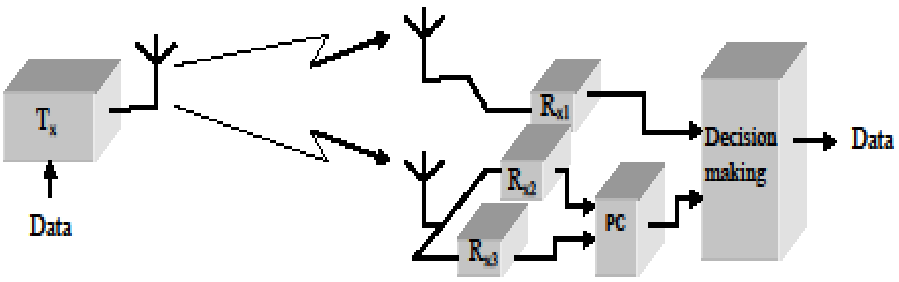

Figure 5: Schematic representation of APC (protocol-I)-scheme

F. Protocol- II with Channel Diversity

Chakraborty *et al*. [3] carried out Protocol-II which deals with the state of the channel. Channel may be in H-state (High error state) or L-state (low error state). When the channel is in L-state, transmitter will send only one copy of packet but if it is in H-state, transmitter will send three copies of the packet at a time. State of the channel will be measured with respect to number of acknowledgements (ACKs) and negative acknowledgements (NACKs). Figure 6 describes the proposed scheme [3].

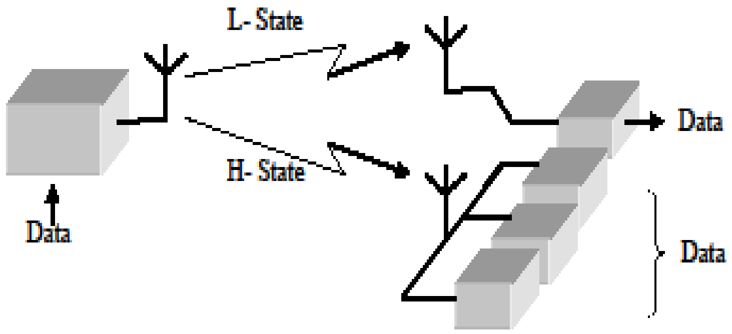

Figure 6: Schematic representation of APC (protocol-II)-scheme

III. PERFORMANCE ANALYSIS OF PROPOSED SCHEME IN AWGN CHANNEL

Mathematical analysis is examined to know the performance of different schemes in additive white Gaussian noise (AWGN) channel. Considering the Binary Phase-shift keying (BPSK) modulation technique, code rate of the channel is assumed to be R_c with signal to noise ratio (SNR) is E_b / N_o then the bit error probability in an AWGN channel becomes [8].

$$p = \frac{1}{2} erfc(\sqrt{\frac{E_b R_c}{N_o}}) \tag{1}$$

where p is bit error probability, R_c denotes code rate channel, E_b is the energy per bit and N_0 is the noise power spectral density.

When packet with n bits are used which consist of k bits information and $n-k$ CRC bits, then $R_c = k/n$ and the throughput of basic SR scheme is given by [9],

$$\eta_{SR} = R_c (1-p)^n = \frac{k}{n}(1-p)^n \tag{2}$$

where η_{SR} defines throughput of basic SR scheme, k is information bits and n is the packet size.

In AWGN channel, packet errors seem to be random as bit errors are random. So, the SAD scheme does not provide any benefit over basic SR scheme in AWGN channel. In NSD scheme, the probability of successful reception of a packet is given by,

$$P_1 = 1-(1-(1-p)^n)^2 \tag{3}$$

where P_1 is the probability of receiving a packet successfully in SR-NSD scheme.

And throughput is

$$\eta_{NSD} = \frac{k}{n} P_1 \tag{4}$$

where η_{NSD} is the throughput of SR-NSD scheme.

In SR-NSD-EARQ scheme, if received copies are erroneous in nature, then a packet can be correctly retrieved by combining them (assuming there is no double error). Therefore, the probability calculated by taking the total number of errors in combined copy is at most $N_{\max}$ [2].

$$P_2 = \sum_{k_1=1}^{N_{\max}-1} \sum_{k_2=1}^{N_{\max}-k_1} [\binom{n}{k_1}\binom{n-k_1}{k_2} p^{k_1+k_2} (1-p)^{2n-k_1-k_2}] \tag{5}$$

where P_2 is the probability of receiving a packet successfully in SR-NSD-EARQ scheme, N_{max} is the total number of bit errors in combined copy, k_1 and k_2 denotes information bits in first and second packet respectively.

In this paper, protocol-I is proposed to merge with the receiver diversity scheme, here, transmitter transmits the packet, if the packet is not received correctly then transmitter transmits two more copies of the same packet using the other channel. In protocol-II, first the channel is sensed for the H-state or L-state. According to the state of the channel, transmitter transmits a total of three packets (as stated in Protocol-I). In this proposed scheme, both protocol-I and protocol-II are combined together and represented with the combination of channel diversity.

After implementing protocol-I [3] with receiver diversity scheme, the probability is obtained as

$$P_{C1} = 1-(1-(1-p)^n)^2 \quad (6)$$

where P_{C1} is the probability of receiving a packet in Protocol-I scheme.

And throughput is also calculated.

$$\eta_{protocolI} = \frac{k}{n} P_{C1} \quad (7)$$

where $\eta_{protocolI}$ denotes the throughput of the protocol-I scheme.

Similarly, for the protocol-II ,

$$P_{C2} = \sum_{k_1=1}^{N_{\max}-1} [\binom{n}{k_1} p^{k_1} (1-p)^{n-k_1} \times$$
$$(1-p)^{k_1} \{ \sum_{k_2=1}^{N_{\max}-1} \binom{n-k_1}{k_1} p^{k_2} (1-p)^{2n-k_1-k_2}$$
$$\times (1-(1-p))^{k_2} (\sum_{k_3=1}^{N_{\max}} \binom{n-k_2}{k_2} p^{k_3} (1-p)^{3n-k_1-k_2-k_3})\}] \quad (8)$$

P_{C2} is the probability of receiving a packet successfully in protocol-II scheme, k_1,k_2 and k_3 are the number of information bits in consecutive first three packets respectively received by the receiver.

TABLE I.SIMULATED VALUES OF THROUGHPUT OF PROPOSED SCHEME.

p	P_{C1}	P_{C2}	η OUR SCHEME
0.0001	0.9999009843395	.008109482891	0.846728792
0.0026	0.9474630335059	0.008548568296804	0.803049745
0.0051	0.8397699013019	0.037469148905081	0.736880802
0.0075	0.720194152926	0.074341074294486	0.66740959
0.0100	0.5980850076885	0.107917621946102	0.593042208

Combining both the protocol-I and protocol-II, throughput is also calculated from the given equations,

$$\eta_{(protocol-I+protocol-II)} = \frac{k}{n}(P_{C1} + P_{C2}) \quad (9)$$

where $\eta_{(protocol-I+protocol-II)}$ denotes the throughput obtained from mixture of protocol-I and protocol-II scheme**.**

IV. RESULT AND ANALYSIS

Throughput is the basic measure of performance used in this study. The throughput of the different ARQ schemes along with the proposed scheme (shown in Table 1) with respect to the average SNR are plotted considering $n = 100$ bits and the parameter $N_{\max}$ equals to 10. Figure 7 represents that the SAD scheme is superior to the basic SR scheme for the wide range of SNR.

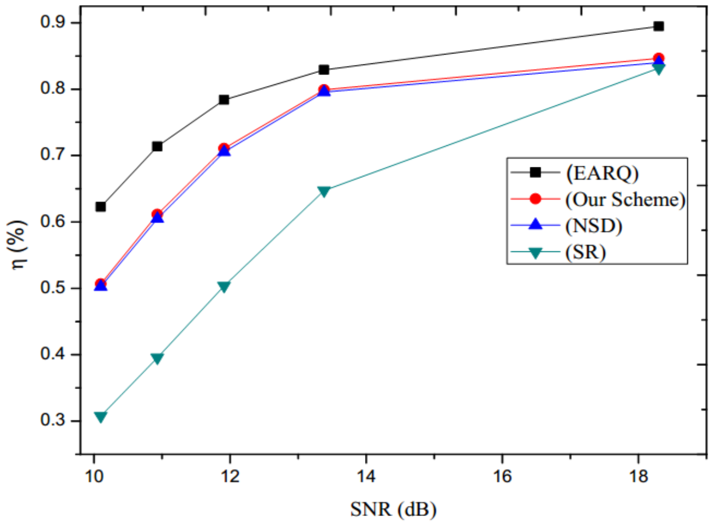

Figure 7: Comparison of throughputs between existing and proposed scheme

The switched antenna diversity improves the performance significantly when the average duration of fades is fairly long. Figure 7 also shows that the performance can be improved in case of proposed scheme and EARQ scheme. Hence, combination of proposed scheme along with EARQ can be introduced to the system to achieve better throughput. Simulated throughputs of the four schemes vary with respect to the probability of bit error rate which is illustrated in Figure.8.

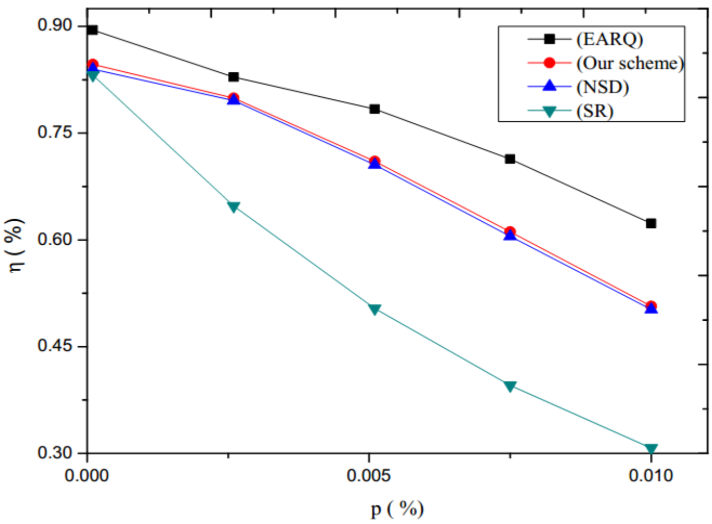

Figure 8: Comparison of throughputs with respect to p (Probability of bit error rate)

From Figure 9, it is observed that a major change in throughput occurs for different values of p whereas it is almost same irrespective of the values of N_{max}. In Rayleigh fading channel throughput is mainly related with packet size. In our experimental studies, throughput of the scheme for packet sizes 100,200 and 400 bits are simulated. In Figure10 it is observed that packet size affects the performance. For low SNR values, packet size of 200 bit seems to be reasonably good choice but at high SNR values the bigger packet size proves to be a better option.

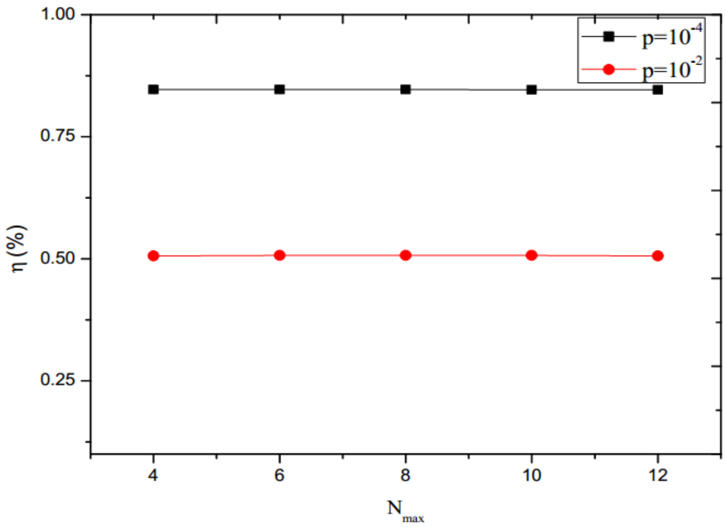

Figure 9: Simulated throughput of the proposed scheme for different values of N_{max} , when $p=10^{-4}$ and $p=10^{-2}$

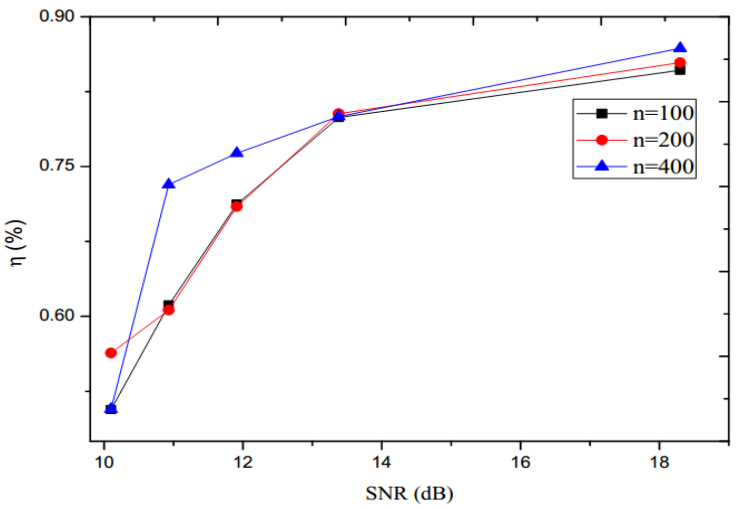

Figure10: Simulated throughput of proposed scheme for three different packet size when $N_{max}=10$

V. CONCLUSION

In this paper the performance of four different SR-ARQ based error control system with the proposed scheme are investigated. Of these, basic SR scheme (SR-SAD) is used in switched antenna diversity. SR-NSD is another scheme which employs selection diversity. SR-NSD-EARQ and the proposed scheme use receiver diversity along with packet combining. In fading channel environment the SR-SAD scheme provides better performance than basic SR scheme. When the average duration of fade is sufficiently long the performance gain becomes significantly high. Use of selection diversity in SR-NSD scheme becomes more advantageous when user velocity is high. But at poor SNR condition, it's throughput falls down. EARQ maintains high throughput efficiency even in such conditions.

Here, a new scheme is proposed which also provides significantly better throughput. Hence, an adaptive channel can be designed which can select between EARQ or proposed scheme depending upon the requirements of the channel. This hybrid system may provide better values of throughput. Even if in poor SNR conditions both the schemes provide higher throughput efficiency compared to other schemes. With the perceptive choice of packet size and other parameters like N_{max} ,the proposed technique can be a good choice to use in diversity combining scheme.

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