An Enhanced Scheme for Using Error Correction Codes in ARQ Protocol

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Abstract. In previous work, MPC(Modified Packet Combining) and PRPC(Packet Reverse Packet Combining) schemes are understood to offer higher throughput and better error correction capability at high bit error rate (BER) and large packet size only. An analysis was performed to corroborate this claim of higher throughput and better error correction capability in high as well as in low bit error rate (BER) for large and medium packet size. To pacification high bit error rate some researchers proposed to use Error Correction Code (ECC) in place of Error Detection Code (EDC) in ARQ scheme. But no incontrovertible result is found to justify the idea in terms of throughput. The recent investigation is an attempt to analyze the throughput. In this paper, we investigate the analysis of both PRPC and MPC in a Modified way over Conventional PRPC, and report the findings available. We propose a combined protocol of Modified PRPC and MPC, and find that it will offer higher throughput and better error correction capability at high and low BER with medium and large packet size as we have used MPC (Modified Packet Combining) scheme with PRPC (Packet Reverse Packet Combining) scheme in a Modified way by combining BEC (Backward Error Correction) with FEC (Forward Error Correction) Codes especially Space-Time Ring-Trellis Coded Modulation (ST-RTCM) code for Communication and Networks by using MATLAB ™ software.

Keywords: MPC, Modified-MPC+PRPC, Space-Time Ring-Trellis Coded Modulation (ST-RTCM) code.

1 Introduction

To insure the reliable delivery of packets in the error-prone wireless channel, automatic repeat request (ARQ) protocols are employed to acknowledge correct packet reception [1]. The principle behind the proposed protocols is intuitive, allowing multiple outstanding packets to be sent without acknowledgment by the base station and then have the mobile node acknowledge a group of packets with just a single acknowledgment. Through simulation we evaluate the throughput of different packets using Space-Time Ring-Trellis Coded Modulation (ST-RTCM) code. To

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resist errors, ARQ and FEC have been widely adopted - ARQ combats channel errors through retransmission and FEC through redundancy [2].

1.1 Related Work

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 double bit error or higher in the packet is insignificant compared to that of single bit error. In the MPC technique, on getting a retransmission call from the receiver the transmitter sends i (i>1) copies of the requested packet. Receiver on getting i copies make a pair-wise XOR ed to locate error positions [3]. FEC is one of the best methods when the communication is simplex or broadcasted to many users [4]. Binary Space-Time Coded Modulation (STCM) uses phase shift keying (PSK) modulation, especially QPSK and 8-PSK.

2 Throughput Analysis

2.1 Previous Case

Throughput of all ARQ techniques depend on the average number (n) of times a packet needs transmission (including retransmission) for successful reception by the receiver.

In normal stop and wait ARQ:

$$n_{sw} = 1 / (1-P), \quad (1)$$

Where, P=Packet error probability $= 1-(1-\alpha)^{k}$,
Where, α = bit error rate, k= packet size.
In PRPC, all single bit errors will be corrected. The probability that a packet is with single bit error is:

$$P1= {}^{k}C_{1}\, \alpha\, (1-\alpha)^{k-1} \quad (2)$$

Thus the probability of packet in error except singlebit error is:

$$P-P1 \quad (3)$$

In previous scheme, when a negative acknowledgement is received, transmitter will transmit two copies one in PRPC mode and another copy in original form of the original packet. Then in MPC with PRPC, up to double bit errors will be corrected at receiver. The probability of packet in error except with single bit error and double bit error is:

$$P'' = P - P1 - P2 \quad (4)$$

P2 is the probability of packet with double bit error and

$$P2 = {}^{k}C_{2}\, \alpha^{2}\, (1-\alpha)^{k-2} \quad (5)$$

2.2 Proposed Case

To dispute high bit error rate with Error Detection Code (EDC) in Conventional PRPC scheme, in place of Error Correction Codes (ECC). But no convincing result is found to justify the idea in terms of throughput. The inquiry is an attempt to explore the basic fissure.

2.2.1 Modified MPC with PRPC over Conventional PRPC with ECC

We propose MPC operation, which is a combined scheme of MPC and PRPC, called MPC with PRPC in a *Modified* way correct both single bit error (with PRPC) and double bit error with (MPC) at receiver by erroneous copies. In proposed scheme, when a negative acknowledgement is received, transmitter will transmit two copies one in PRPC mode and another copy in original form of the original packet. Then in *Modified* MPC with PRPC, the probability of single bit aswell as double bit errors will be corrected at receiver is as follows: If P1 and P2 are the single bit error and double bit error, then the receiver will acknowledge without single bit and double bit error is:

$$P1*P1 + P1*(1-P1) + P2*(1-P1) + P2*P1 + P2*P2 + P2*(1-P2) = P1 + 2*P2 \quad (6)$$

Thus in *Modified* MPC with PRPC when implemented in stop and wait protocol, the average number of times, n_{mmpc} a packet needs transmission (including retransmission) for successful delivery is:

$$n_{(MMPC+PRPC)} = [(P1 + 2.P2) + (P''/(1-P''))] \quad (7)$$

First part of right hand side of eq: 7 is for *Modified* MPC with PRPC correcting up to double bit error and second part is for correcting in Normal Stop and Wait ARQ with bit errors other than single bit and double bit error. PRPC corrects all single bit error in packet. *Modified* MPC with PRPC corrects up to double bit error as well as with single bit error.

Then the probability gain in correcting packet by*Modified* MPC with PRPC over conventional PRPC is:

$$Gain_{mpcprpc}\ \% = (P1 + 2*P2) / P1 *100 \quad (8)$$

The Throughput of PRPC in Normal S/W ARQ with single bit error is:

$$(2.P1 + (P'/ (1-P'))) \quad (9)$$

Where, P'=P-P1

The first part is for PRPC in correcting single bit error; second part is for Normal S/W ARQ other than single bit error.

Now Coding Efficiencyis: k (Packet Size in Bits) / (k+c)); where, c is the Check Bits

Here we are using CRC-16 as an Error Detection Code (EDC).

So the Throughput efficiency will be: (Throughput) * (Coding Efficiency)

$$\text{i.e: } Throughputeff_{S/W} = (2.P1+ (P'/ (1-P')))*(k / (k+16)) \quad (10)$$

So, for this scheme in S/W ARQ system, the throughput'llbe, from eq: (7)

$$n_{(MMPC+PRPC)} = [(P1 + 2.P2) + (P''/(1-P''))] \quad (11)$$

Now Coding efficiency = k / (k + c), where, c is the check-bits. In eq (10), we have used CRC-16.

Using ST-RTCM (213 132/3) Code [5] in eq: 11 we are getting the Coding efficiency = k / (k / 132* (213-132) +k+1) = (132*k / (213*k +132))

So the Throughput efficiency of Modified MPC+ PRPC scheme will be:

$$Throughputeff_{(MMPC+PRPC)} = [(P1 + 2.P2) + (P''/(1-P''))] * (132*k / (213*k +132)) \quad (12)$$

Using ST-RTCM (25 12/47) Code [6] in eq: 11 we are getting the

Coding efficiency = k / (k / 12* (25-12) +k+1) = (12*k / (25*k +12))

So the Throughput efficiency of Modified MPC+ PRPC scheme will be:

$$Throughputeff_{(MMPC+PRPC)} = [(P1 + 2.P2) + (P''/ (1-P''))] * (12*k / (25*k +12)) \quad (13)$$

3 Discrete Event Simulations

Simulation Parameters

Simulation Parameters	Values
Simulation time	10 s
Uplink frame	0.5 ms
Downlink frame	0.5 ms
Duplex mode	TDD
Application profile	CBR (100 bytes, 0.2 ms)
Agent profile	UDP
ARQ _ WINDOW_ SIZE	500
PHY rate	1 Mbps

4 Simulated Results and Justification

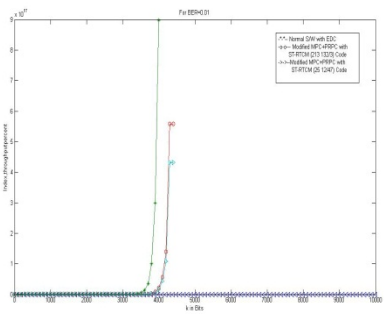

Fig. 1. Throughput percent with respect to packet size k= 10000 Bits by using ST-RTCM (213 132/3), ST-RTCM (25 12/47) codes for BER=0.01

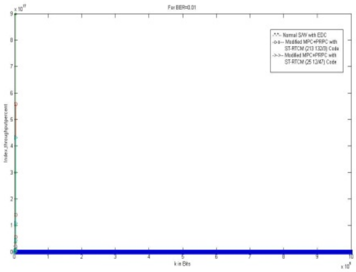

Fig. 2. Throughput percent with respect to packet size k= 1000000 Bits by using ST-RTCM (213 132/3), ST-RTCM (25 12/47) codes for BER=0.01

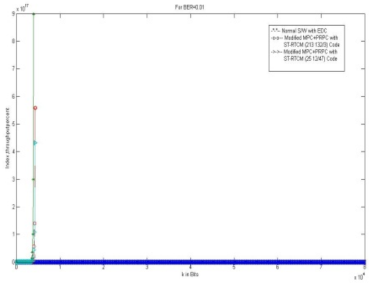

Fig. 3. Throughput percent with respect to packet size k= 80000 Bits by using ST-RTCM (213 132/3), ST-RTCM (25 12/47) codes for BER=0.01

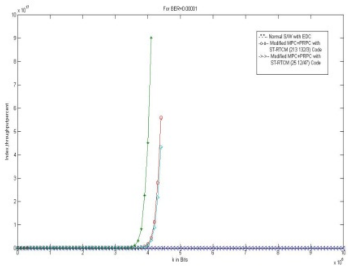

Fig. 4. Throughput percent with respect to packet size k= 10000000 Bits by using ST-RTCM (213 132/3), ST-RTCM (25 12/47) codes for BER=0.00001

5 Justification of the Simulated Graphs

In fig: 1, we see that the throughput percent is high with respect to medium packet size (k=10000 bits) for Normal S/W with CRC-16, than *Modified* MPC+PRPC Scheme with ST-RTCM (213 132/3), ST-RTCM (25 12/47) codes, though ST-RTCM (213 132/3) code has shown better performance than ST-RTCM (25 12/47) at

BER=0.01. In fig: 2, we see that the throughput of *Modified* MPC+PRPC Scheme with ST-RTCM (213 132/3) and ST-RTCM (25 12/47) shows very high result than the *Modified* MPC+PRPC Scheme without ECC and PRPC Scheme in Normal S/W with CRC-16 Code with respect to large packet size (k= 1000000Bits) for high BER (0.01). In fig: 3, we see that the throughput percent is high with respect to medium packet size (k=80000 bits) for Normal S/W with CRC-16, than *Modified* MPC+PRPC Scheme with ST-RTCM (213 132/3), ST-RTCM (25 12/47) codes, though ST-RTCM (213 132/3) code has shown better performance than ST-RTCM (25 12/47) at BER=0.01.In fig: 4, we see that the throughput percent is high with respect to large packet size (k=10000000 bits) for Normal S/W with CRC-16, than *Modified* MPC+PRPC Scheme with ST-RTCM (213 132/3), ST-RTCM (25 12/47) codes, though ST-RTCM (213 132/3) code has shown better performance than ST-RTCM (25 12/47) at BER=0.00001.

6 Conclusion and Future Work

Throughput comparison of *Modified* MPC+PRPC Scheme in Normal S/W with and without using Space-Time Ring-Trellis Coded Modulation ST-RTCM (213 132/3), ST-RTCM (25 12/47) codes and conventional PRPC scheme in Normal S/W with CRC-16, with respect to medium as well as large packet size for high and low BER (Bit Error Rate), in ARQ protocol for Communication and Networks have been investigated.*Modified* MPC+PRPC Scheme shows better result and the throughput also increases when we are using ST-RTCM (213 132/3), ST-RTCM (25 12/47) codes in our proposed scheme than without using ECC, though it provides better reliability than the previous schemes. Further, we can add some other feature such as the authenticity of the transmission in order to make the system more reliable and acceptable. Authenticity feature may be including with the help of tag formation based on RSA Algorithm with Data Encryption Standard (DES), which help to realize the hardware implementation of the whole system easily.Our initial theoretical work and practical implementation with one bit error correction code give encouraging results.

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