Mathematical Comparison of throughput Analysis of ARQ Mechanism

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***Abstract*—Aggressive Packet Combining (APC) scheme is the well-established protocol in case of reliable data transport in wireless network. APC has different type of limitations which includes low throughput. Several modifications are made in earlier researches to achieve higher throughput. In this particular we are establishing the existing work numerically. Throughput efficiency of the proposed method is higher than conventional ARQ technique.**

***Index Terms*— Packet combining scheme Throughput, Aggressive Packet Combining (APC), Automatic Repeat Query (ARQ)**

I. INTRODUCTION

There are basic two techniques by which accuracy of data communication is maintained, FEC (Forward error Correction) and BEC (Backward error Correction) [1-9] Packet combining scheme plays very important role in BEC and FEC. [10-15] And throughput is one of the major issues for transferring packet. Successful transmission of a packet implies achieving higher throughput. Several researches have done to achieve higher throughput by modifying the existing packet combining scheme [16]. Probability of successful transmission of packet for each scheme are also varied thus the corresponding throughput. In this paper the previous work is numerically analysed and compared with the other schemes.

II. BASIC BEC TECHNIQUES

Basic BEC techniques: Three basic techniques, these are there in BEC: 1) Stop-and-wait Automatic Repeat Request (S/W), 2) Go-Back-N automatic Repeat Request (GBN) and 3) Selective Repeat Request (SRQ) [3-10].

In case of S/W ARQ technique [4] an ACK (acknowledgement) message is send to the sender after successful reception of packet. After receiving the packet sender sends the next packet. On receiving a packet at receiver side, receiver checks whether the packet is correct or not. It uses error detection method. According to that, the receiver sends a positive acknowledgement (ACK) or a negative acknowledgement (NACK) to the transmitter by using the feedback path. After receiving ACK sender sends next packet but on receiving NACK sender retransmits the previous packet and it repeats the process until a packet delivered correctly.

The performance of this technique is measured by a parameter known as throughput efficiency (ν). It can be defined as ratio of the number of the information bits correctly transmitted to the total number of bits transmitted for the purpose. If we assume (i) m, n code are used for this protocol (ii) processing time at the transmitter and receiver for ACK or NACK is negligible (iii)transmission time for ACK or NACK is negligible and (iv) feedback path is error free;

$$\nu(s/w) = \frac{n}{(m+RT)E} \quad (1)$$

Where E = expected number of transmission for successful delivery of a packet,

R = Rate of transmission,

T = Total round trip delay

When each packet has similar probability that it is received with error E becomes,

$$E = 1/\beta \quad (2)$$

β is the probability that for a given packet this is last transmission.\

$$\beta = 1 - P_e - P_{ue}$$
$$= 1 - P_e \text{ where, } P_{ue} << P_e$$

If t_{pt} is the propagation time and t_{tt} is the transmission time of a packet, we have $T = 2t_{pt}$, $R = \frac{m}{t_{tt}}$ and $a = \frac{t_{pt}}{t_{tt}}$.
Using these values the following equation can be formed,

$$\nu(s/w) = \frac{n(1-P)}{m(1+2a)} \quad (3)$$

Throughput efficiency is also calculated from the following equation [15]

$$\eta_{basic} = \frac{n(1-P)}{(m+RT)} \quad (4)$$

Where, n = 960,
m = 980
R = 2400 bits per second

T = 600 msec
P = 0.5
Throughput obtained is 19.83%.

III. SASTRY`S MODIFICATION

Sastry [8] has suggested to increase the throughput efficiency of S/W ARQ by stating that instead of retransmitting one packet, i copies of one packet must be sent after receiving NAK for the transmitted packet. In this process the propagation delay distributed over i copies of packets. Whereas, a single copy of packet is in basic S/W ARQ technique. Also, the probability of getting correct copy of a packet by the receiver increases by the power of i. It is due to the retransmission of i copies of packet in error. Throughput of Sastry's scheme is reported as:

$$v(Sastry's S/W) = [n/\{(m+RT)+(im+RT)P(1-P^i)\}] \quad (5)$$

Sastry has shown that increased throughput is improved only when

$$i < [\{1+P(RT/m)\}/(1-P)] \quad (6)$$

And also reported that maximum improvement is achieved when

$$m = -(\log P)(im+RT)\{P^i/(1-P^i)\} \quad (7)$$

But the throughput improvement is conditional in case of Sastry's technique, it is achieved only when RT >> m.

By modified Sastry`s technique throughput is calculated for each and every case [8].

$$\eta_{Sastry} = n / (m+ RT) + (i m + RT) P / (1- P^4) \quad (8)$$

Where, n = 960,

m = 980

R = 2400 bits per second

T = 600 msec

And the throughput is found $\eta_{Sastry} = 28.95\%$ where n = 0.5 and i = 3.

IV. REVIEW PACKET COMBINING SCHEME

Computer Packet combining scheme, a very simple and elegant method is suggested by the Towsley [17] and Chakraborty [18-19]. Under this particular technique limited error can be corrected, like one or two bit error of erroneous copies. The proposal can be explained by using an example:
It is assumed that '11110000' is the original packet which has to be transmitted between a transmitter and a receiver. The packet is received as '11110010' erroneously by the receiver. The receiver requests for another copy and keeps the erroneous copy. The transmitter retransmits the packet, but again the received copy is erroneous one, as 11110001. Hence the author suggested by using these two erroneous copies receiver can recover the original copy. By using bit wise XOR operation between erroneous copies, receiver can identify the error position. The operation can be followed like this:

1st erroneous copy: 11110010
2nd erroneous copy: 11110001

After using bit wise
XOR operation: 00000011

The error location can be identified as last two bits. Author suggested that the receiver can apply the brute force method for correcting the error by changing received '1'to '0'or vice versa for the received copies. In the example, the average number of brute force application will be ½ and in general if n bits found error it will be 2^n-1. Various modifications of PC have been studied in [17-20].

V. REVIEW : CONVENTIONAL PACKET COMBINING SCHEME

Majority packet combining (MjPC) [21] scheme modified into aggressive packet combining (APC). To illustrate following scheme, it is assumed that an original packet '11110000' is transmitted between transmitter and receiver. In APC scheme, three copies of a packet are transmitted between transmitter and receiver. Bit by bit majority logic is applied on three copies of packet.

TABLE I. CORRECTION PROBABILITY AT DIFFERENT STEP

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x	Case1	Case2	Case3	Case4	Case5	Case6
1	(1-P)	P				
2	$(1-P^3)$	$(1-P^2)P$	$(1-P)P^2$	P^3		
3	$(1-P^5)$	$(1-P^4)P$	$(1-P^3)P^2$	$(1-P^2)P^3$	$(1-P)P^4$	P^5

VI. MATHEMATICAL REPRESENTATION OF CHAKRABORTY`S TECHNIQUE

Chakraborty [22] has proposed two new protocols to improve the throughput of the channel. In this work, both the protocols are mathematically analysed showing the improvement with respect to the basic ARQ protocol.

Protocol 1: In this particular protocol author has improved the basic ARQ technique. In the APC technique the minimum average number of times a packet needs to be transferred for successful delivery of a packet is 3. Here author has suggested if corrected copy of packet is not recovered after transmission of 3 copies of packets, then two more copies are sent. And repeat the process until original copy is retrieved (for worst case situation).

Under the proposed scheme, these are the following situations:

Number of times NAK received for A particular packet	1 2 3 4 5…………… j
Number of copies to be transmitted under protocol -I follows APC	1 2 2 ………2 up to j times
Number of copies of a packet received at each instant	i 2i 2i ……………..(2j-1)

The proposed technique having three steps is the best case scenario and it is equi-probable. For successful retransmission of a packet, average number of copies are (1+2+2) /3 = 1.666.

So, here 1.666 copies of packet are considered for successful transmission. In Sastry`s technique and conventional APC 3 copies of packet are transmitted. So it could be a advantage to obtain better throughput.

If x is considered as different steps in the scheme, the number of case for each step will be $2x$ which is shown in the table1 with correction probability.

Considering the packet correction probability for protocol I up to step 2 and step 3, throughput are also calculated.

Step 2:
$$\eta_{proposed} = \frac{n}{(n+m)} \times [1-(1-(1-P)) \times (1-P(1-P^2))] \quad (9)$$

Step 3:
$$\eta_{proposed} = \frac{n}{(n+m)} \times [1-(1-(1-P)) \times (1-P^2(1-P^3)) \times (1-P(1-P^2))] \quad (10)$$

The throughputs obtained for the scheme are 34.02% and 37.40% which are considerably higher than conventional technique. Fig. 1 shows the comparative analysis of throughput of the scheme with basic and Sastry`s technique.

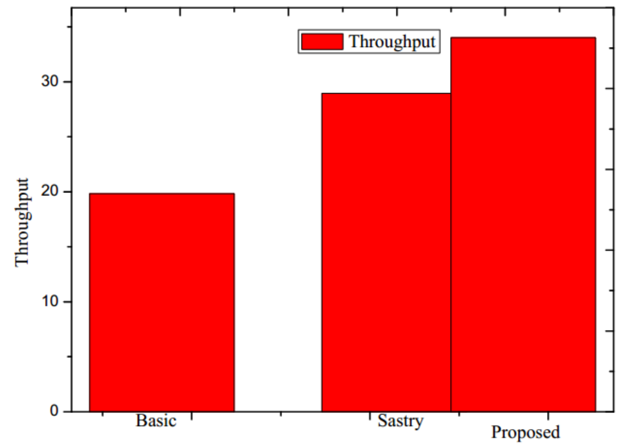

Figure 1. Comparison of throughput with respect to the techniques

Protocol 2: In protocol 2 Chakraborty [22] has proposed a channel known as Gilbert channel [23-24]. The Gilbert channel has two states, good state and bad state. It is not necessary to send all the three copies of packet. In that case sender will send a single copy of packet. On other hand, when the channel is in bad state, three copies of packets will be sent. Positive and negative acknowledgement from receiver decides whether the channel is good or bad. Chakraborty proposed an equation to calculate average number of packet transmission

$$X = (P_0 \times 3 + P_1 \times 1) \quad (11)$$

Where, P_0 is the probability of channel being good.

P_1 is the probability of channel being bad.

Numerically "X" has different value with respect to different values at P_0 (in terms of P_1) Based on average values of packet throughputs are also calculated and plotted in the Fig. 2.

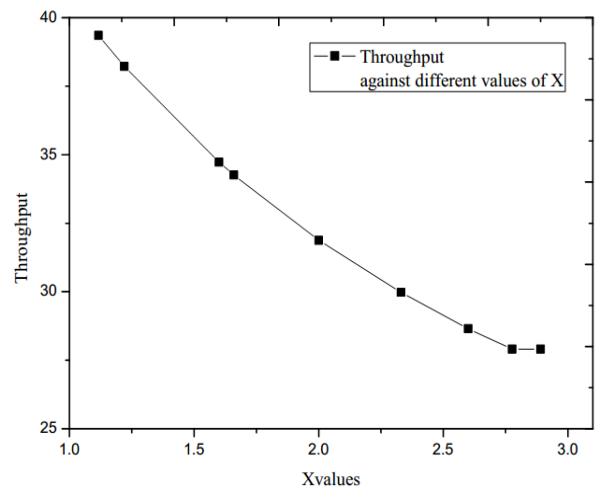

Figure 2. Comparison of throughput with respect to the Different values of X in Gilbert Channel

VII. CONCLUSIONS

Several important schemes are studied and throughputs are calculated. Mathematical analysis for the estimation of throughput efficiency is done. The numerical analysis shows Chakraborty`s proposed scheme provides considerably better throughput over the conventional schemes.

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