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New Investigations of Aggressive Packet Combining Scheme to Reduce Transmission Delay and Three States Markov Model Using Multiple Routes to Increase Throughput

Sanjit Ningthoujam[1], Swarnendu K. Chakraborty[2] and Chandan T. Bhunia[3]

[1,2,3]Department of Computer Science & Engineering National Institute of Technology, Yupia, Arunachal Prdesh

[1]Sanjit.ningthoujam@gmail.com, [2]swarnendu.chakraborty@gmail.com, [3]ctbhunia@vsnl.com

Abstract

Aggressive packet combining (APC) was introduced to correct error with low latency in wireless network. Wireless Network is high error prone (Bit error rate varies from 10^{-2} to 10^{-4}). Several modified APC have been studied elsewhere for improving throughput and error correction. In this paper we propose new investigations of different basic protocols of APC to reduce transmission delay by checking Hamming Distance. Three state Markov model using multiple routes is studied to achieve high throughput.

Keywords: *Bit exchange, Bit error rate, Conventional Aggressive Packet Combining Scheme (CAPC), Majority Logic, Throughput, Hamming Distance, XOR*

1. Introduction

Aggressive Packet Combining scheme was introduced by Leung [1] for error control in wireless data communication. APC aimed to achieve error correction with low latency. Wireless link is high error prone. This makes devising of appropriate strategy for error correction with higher throughput, lower latency and higher error correction capability a legitimate research challenge. Many studies [2-12] conclusively established that Backward Error Correction (BEC) is more appropriate for wired transport whereas Forward Error Correction (FEC) is suited for wireless protocol. Wireless data communication is more challenging because of high error rate as compared to wired data transfer. In order to reduce transmission delay and to achieve higher error correction capability multiple/backup routes APC scheme with Hamming Distance and three states Markov Model are studied and analyzed in this paper.

2. Review of Conventional Aggressive Packet Combining Scheme (APC)

Aggressive Packet Combining Scheme (APC) is a modified technique of Majority Packet Combining. In order to illustrate APC assume that an original packet 10101010 be transmitted from source to destination. In the technique three copies of packet are sent from sender to receiver .The receiver does bit by bit majority logic of the three received copies. In table: (1) we have shown different possibilities of APC. In Case (1) there is no error received. In case (2) receiver received one erroneous copy and remaining two copies are not, so the correction is possible by majority logic. In Case (3) and Case (4) errors are found in two or more copies (at same bit location) in cases of which correction by majority logic is untenable. Several modifications of Aggressive Packet Combining Scheme have been studied elsewhere [13-16].

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Table 1. Different Cases of Aggressive Packet Combining Scheme

Case 1	Case 2	Case 3	Case 4
Copy-1= 10101010 Copy-2=10101010 Copy-3= 10101010	Copy-1= 00101010 Copy - 2=10101010 Copy-3= 10101010	Copy-1= 00101010 Copy - 2=00101010 Copy-3= 10101010	Copy-1= 00101010 Copy-2= 00101010 Copy-3= 00101010
Correction Probability is $(1-P^3)$	Correction Probability is $(1-P^2)$ P	Correction Probability is (1-P) P^2	Correction Probability is (P^3)
Correction not required.	Correction possible	Correction not possible	Correction not possible

3. Review of Multiple Routes Selection

Bhunia [3] suggested that use of multiple routes simultaneously; instead of a single route for transmitting three copies may improve the performance of APC. Use of multiple routes reduces the dependency on a single route, which results in more stable communication. This is because, if a single route fails, we need to again initiate the Route Discovery process. However, if multiple routes are used, when one route fails, another route can be used. Only when all the routes fail, the Route Discovery is to be done to search a new route. In general, for 'k' such parallel routes we would have, the probability of breakage as $P_k = (P1)^k$ where P1 is probability of breakage of single route. So, the probability of communication of breakage between Source and Destination reduces exponentially if parallel routes are used. Parallel routes should not have any common intermediate nodes. The technique may reduce latency.

4. Two Protocols in the Paper

4.1. Protocol-1

The proposed protocol-1 is illustrated as below:

1. Sender sends say eight bits data. Assume that the data is received erroneously at the receiver say error occurs at second bit position from MSB.
2. Receiver receives the same data with error say at fifth position from MSB after retransmission. These two erroneous packets are stored at Receiver's buffer.
3. By checking Hamming distance between two erroneous data that:

i) If Hamming Distance(H.D)<=2 then sender used to send only the erroneous bit positions by repeating each bit three times instead of retransmitting the whole packet. Let say the third received packets are again detected as erroneous but the receiver by taking majority logic to three successive bits may get the original bits. Therefore, erroneous locations are corrected by comparing the bits obtained after majority logic with the erroneous bit locations in the first two received packets.

ii) If H.D>2, then directly use three routes to reduce transmission delay from sender to receiver. This idea is illustrated with following examples.

Example of step1-3 i)

#1 Original packet- 11100110

First transmission erroneous at second position from MSB-1**0**100110

Second transmission erroneous at fifth position from MSB-1110**1**110

…………………………….

H.D 01001000

Now Hamming Distance (H.D) =2

According to step3 i): the third packet will be sent as 111 000 and again if it is received erroneously as 011 010 then by taking majority logic of three successive bits at receiver side may get as 011=1(2nd), 010=0(5th). Now comparing the third packet with the first erroneous packet, the second bit location in the first erroneous packet is corrected to 1 instead of 0. Similarly, comparing third packet and second erroneous packet, the fifth erroneous position is corrected to 0 instead of 1 from MSB; therefore, receiver gets the original packet as 11100110.

Explanation and Examples of step3 ii) is illustrated here.

When H.D>2, use multiple routes selection to reduce transmission delay. If we use bit repetition technique when H.D>2 then size of the transmission packet will be greater than say eight bits packet. Let say H.D is 3, 4, 5... Then repeated bits will be 3*3=9bits, 3*4=12bits, 3*5=15bits….

As in case of multiple routes, eight bits of packet size will be sent from sender to receiver using three routes simultaneously. At the receiver side taking majority logic and may get original packet.

Example:

Let say an original packet as 10011111. The first copy of original packet is sent to Route1 (R1). It is assumed that erroneous found at 2nd and 3rd bits positions consecutively as 11111111 from MSB. The erroneous packet stores at receiver's buffer for performing majority logic.

Again, second copy of first packet is sent to Route2 (R2) after two bits exchange from MSB. The received packet is found say erroneous at 2nd and 3rd bits position as 00011110.The erroneous packet is stored at receiver's buffer after two bits exchange from LSB as 10000111.

Since, we use three routes, so third copy of same packet is sent to Route3 (R3) after five bits exchange from MSB. It is assumed that erroneous detects at same bits position. The erroneous packet is stored at the receiver's buffer for performing majority logic after five bits exchange from LSB as 10011100

At Receiver side, taking majority logic may get original packet (underlined bits are taken as error) i.e.

11111111
10000111
10011100
……………
10011111 which is original packet

#2. Original packet as 11110000 (erroneous at 6th and 7th bit position)

First erroneous copy at receiver- 11110110
Second erroneous copy at receiver-01110001
Third erroneous copy at receiver- 11000000
……….. ………………..
11110000 which is original packet

#3. Original packet as 10011110 (erroneous at 1st and 3rd bit position)
First erroneous copy at receiver- 10011110
Second erroneous copy at receiver-10110110
Third erroneous copy at receiver- 10011011
……………………………………..
10111110 which is original packet

#4. Original packet as 00001111 (erroneous at 7th and 8th position)
First erroneous copy at receiver- 00001100
Second erroneous copy at receiver-11001111

Third erroneous copy at receiver- 00010111

……………………………………..

00001111 which is original packet

4.2. Analysis And Result of Protocol-1

Transmission delay (T.D) =message size/ bit transmitted rate in bit per second [17]. Comparison of T.D in case of repeated erroneous bit location technique by using Hamming Distance and multiple routes selection scheme of APC are shown in Table 2 and Table 3, and result is also portrayed in Figure 1.

Table 2. Bandwidth (50mbps)

Hamming Distance	Packet size in bits	Transmission Delay(µsecond)
1	3	0.08
2	6	0.12
3	9	0.18
4	12	0.24
5	15	0.30
6	18	0.36
7	21	0.42

Table 3. When Three Routes of APC (MRAPC) Are Taken Then

Packet size in bits	Transmission Delay(µsecond)
8	0.16

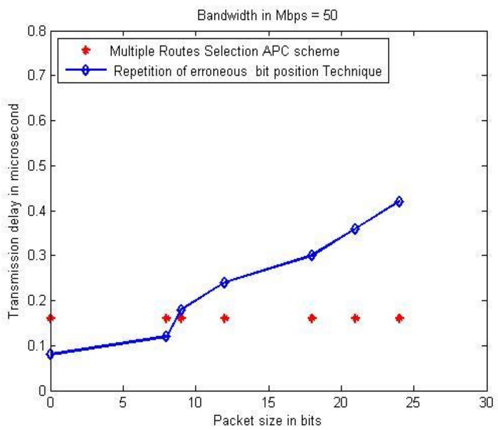

Figure 1. Comparision of T.D in Microsecond

Let us 'n' is the packet size and alpha (α) is the BER (Bit Error rate). Therefore, error correction that can be done for single bit is (1-α). Let say eight bits data packet and its error correction for each single bit as

1	**1**	**1**	**1**	**0**	**0**	**0**	**0**
1- α	**1- α**	**1- α**	**1- α**	**1- α**	**1- α**	**1- α**	**1- α**

Therefore, for n packet size, we get the error correction capability is $(1-\alpha)^n$. Hence, the probability of error for 'n' packet size is $[1-(1-\alpha)^n]$. Comparing of three techniques and investigate the Probability of error is shown in the Figure 2 with bit error rate (α) as .005, as bit error rate in wireless data network is 10^{-4} to 10^{-2}.

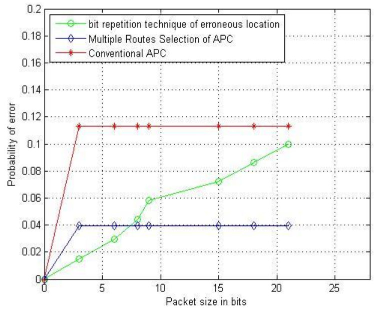

Figure 2. A=0.005

4.3. Protocol-2

The proposed protocol-2 is studied based on three states Markov Model [18]. Assume that the three states are namely as Best, Average, and Worst. In best state only single route is used as on demand. In average state 'n' packet size of double route protocol and in worst state n/2 packet size of three routes will be applied.

Assume that initially the channel is in best state. The sender sends 'n' packet (P_1) size to receiver. Receiver checks the received packet and sends +ACK if no error is found otherwise receiver stores the erroneous packet and send -ACK to sender. If +ACK is received then sender assumes that the channel is in best state. Sender sends next packet P_2 and receiver detects erroneous at the receiver. Sender discovers that available channel is not in best state if it is received -ACK from receiver. Sender investigates that the channel is switched to Average State as it receives +ACK followed by -ACK. Sender uses double routes to send the copies of packet P_2. At the receiver side performing majority logic of three erroneous packets may get original packet. Sender if received +ACK sends third packet P_3 and assume that it is found erroneous at receiver side. The channel is still not in best state. Therefore, sender uses double routes to send P_3 packet to the receiver and performed majority logic at the receiver. It is assumed that receiver again detects erroneous packet. The channel is switched to worst state as sender receives continuous -ACK. It uses three routes and sends truncated 'n/2' size of third packet to each route. Assume that the packet is investigated no erroneous after performing majority logic at the receiver. Hence sender will keep on sending the next packet using above techniques.

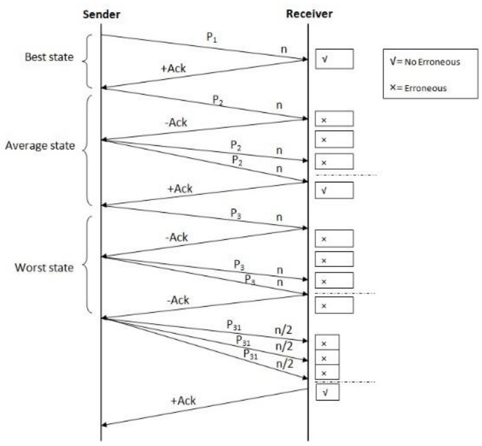

Figure 3. Pictorial Representation of Propose Technique

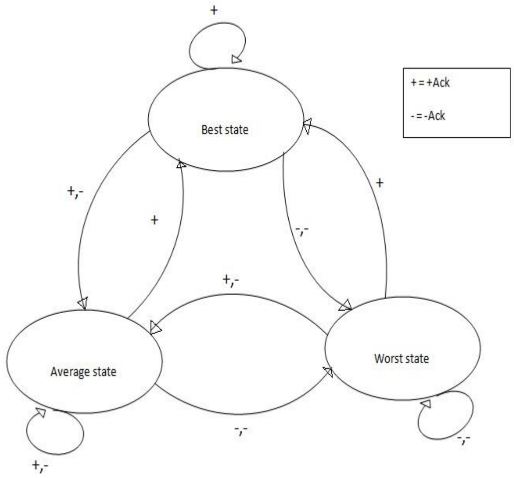

Figure 4. Transition Diagram of Three States Markov Model

4.4. Analysis and Result of Protocol-2

The probability of error for Aggressive packet combining (APC) as PEapc [17] = $[1-(1-\alpha)^n]^i$….(1), Here, α = bit error rate, n = packet size in bits and i=number of retransmitted packet in single route .The probability of error for 'n' packet size sending independently in double routes as M1RPEapc = $[1-(1-\alpha)^n]$…..(2).

Similarly, The probability of error for 'n/2' packet size sending independently in three routes as M2RPEapc= $[1-(1-\alpha)^{n/2}]$……(3)

From Equations (1), (2) and (3), we have

Throughput of APC as = [(1-PEapc) / (i+PEapc)]…….. (4)

Throughput of 'n' packet size sending independently in double routes as M1Rapc= [(1-M1RPEapc)/ (i+M1RPEapc)]….. (5)

Throughput of 'n/2' packet size sending independently in three routes as M2Rapc= [(1-M2RPEapc)/ (i+M2RPEapc)]……. (6)

Here, the result of protocol-2 is made and studied using Mat Lab for different packet sizes.

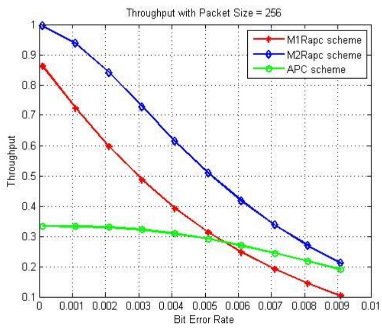

Figure 5. Throughput of Packet Size 256 Bits

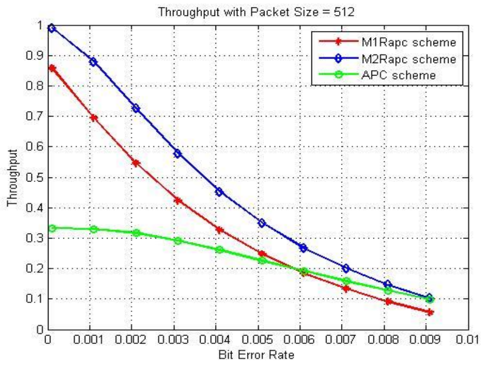

Figure 6. Throughput of Packet Size 512 Bits

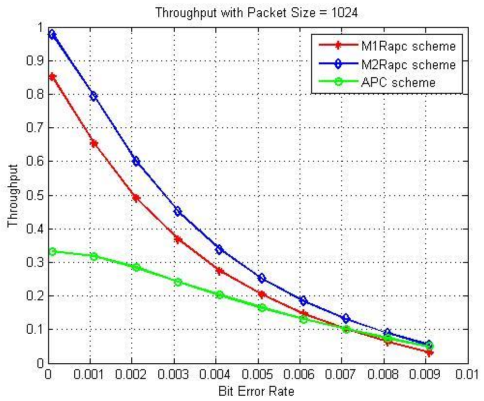

Figure 7. Throughput of Packet Size 1024 Bits

5. Conclusion

We can conclude from the above analysis that protocol-1 using Multiple Routes selection provides better performance when Hamming Distance>2, otherwise bit repetition technique of erroneous location will be better in terms of transmission delay and throughput. We have done simulation/numerical studies to analyze performance over APC of protocol-1. From protocol-2 it can be concluded that APC of 'n/2' and 'n' packet size in average and worst states using multiple routes give higher throughput than normal APC using single route. Proposed techniques require to be made with experimental study to arrive at some definite conclusions.

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Authors

Sanjit Ningthoujam received B.Tech in Computer Science and Engineering from NERIST (Deemed University, Arunachal Pradesh) and also completed M.Tech in Mobile Communication and Computing under CSE Dept. at NIT Arunachal Pradesh. He is currently pursuing Ph.D in Computer Science and Engg. at NIT Arunachal Pradesh under the guidance of Dr. Swarnendu K Chakraborty.

Swarnendu K Chakraborty is currently a HOD of CSE Dept. at NIT Arunachal Pradesh.

Research Interests: Networking, Network Security, Cryptography, and Area of Specialization: wireless Network.

Chandan T Bhunia earned his B.Tech in radio physics and electronics in 1983 from the Calcutta University, and then joined DVC of Govt. of India as telecommunication engineer. He got M.Tech in radio physics and electronics in 1985, and then joined North Bengal University as a lecturer of computer science & application in 1988, and became Assistant Professor of electronics & communication engineering at the North Eastern Regional Institute of Science & Technology (NERIST) of Govt of India in 1990. He got his PhD in computer science &engineering from the Jadavpur University. He became full Professor in 1997 at NERIST where he was HOD of ECE & CSE for about 6yrs and Dean (Academics/Post Graduate Studies) for about 1.5 years. He then switched to private engineering colleges from 1999 to 2003 as HOD, Deputy Director and Director. Lastly, he was a full Professor of computer science & engineering of the Indian School of Mines (Deemed University) of Govt of India. He was a senior Professor and Dy Director (Acad) of Haldia Institute of Technology. He has extensively visited foreign countries, namely China, Italy, Singapore, UK and Bangladesh on several assignments including BOYSCAST Fellowship and ICTP senior associate ship. He has published around 200 research papers and technical articles/reports in national/international journals/magazines/seminars. He is the author of the books a) "Introduction to Knowledge Management"published by Everest Publishing House, Pune in 2003 and b) "Information Technology, Network and Internet", published by the New Age International Publishers, New Delhi. He is Fellow of the IETE and the IE(I), and a senior member of the IEEE & CSI. He is currently as a director of NIT Arunachal Pradesh.