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Hybrid Protocol for Molecular Communication in Three States Markov Model

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Abstract. Three states Markov model is considered for hybrid protocol of Packet Combining (PC) and Aggressive Packet Combining scheme (APC) to diffusion based Molecular Communication (MC). Different schemes of Stop and Wait ARQ have discussed for MC system but it needed attention on full of retransmission. Retransmission of duplicate copies may consume extra communication energy, time, and cost and hence resulting in low throughput. In order to reduce retransmission of duplicate copies, we have investigated this protocol for improving the performance of MC. In MC, like in wireless network, using feedback channel of Acknowledgement (ACK) or negative ACK (NACK), the transmitter may know that the packet is successfully received or not. In this study, our design of proposed protocol is compared with existing protocols using Mat lab. The proposed protocol is contributed for reducing mean energy consumption and also provided higher throughput than conventional APC and PC techniques.

Keywords: Molecular Communication, PC, APC, ARQ, MP, Throughput.

1 Introduction

The communication takes place between nanomachines inside the body's tissue using molecules as a carrier is called Molecular Communication (MC). MC is the most promising approach for the communication in nanonetwork. Different schemes of Stop and Wait ARQ [1] have discussed for MC system but it requires full of retransmission. [2] discussed about architecture, potential applications of MC and also defined key challenges between current research and application. T. Nakano et. al [3] found a novel approach for optimization of throughput and efficiency by controlling transmission rate between nanosender and receiver. In [4] network architecture, channel models, media access control, transceiver architecture and routing protocols are important key contributors for MC and Information and Communication Technology (ICT). Luis et. al [5] mentioned that Bacteria-Based Nanonetwork (BN), where bacteria are used as carrier for DNA molecules as data packet will be transferred between nanosender to receiver.

In order to increase the performance of stop and wait ARQ in MC, we have focused on PC [8], APC [9]. In MC, sender and receiver bio-nanomachines transferring the molecular packets through intermediate bio nanomachines. A sender forms a molecular packet (MP) and transfers the MP into the aqueous medium. An intermediate node (Bio-nano machines) detects MP and forwards it to the nearest nodes or to the destination. A destination bio-nanomachine,

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upon reception of a MP, produces an ACK MP and transmits back to the sender bio-nanomachine. Further, a sender bio-nanomachine retransmits a Molecular duplicate copy if NACK is returned or ACK MP is not returned within a time-out period. Thus, retransmission of MP repeatedly may consume extra communication energy. In order to reduce retransmission, it is required to combine with primitives protocols of wireless network. Thus, this protocol is investigated to achieve better performance. Table 1 shows the different parameters of conventional telecommunication and MC.

Table 1: Telecommunication and Molecular Communication [4], [6], [7]

Communication	Telecommunication	Molecular Communication
Devices	Electronic devices	Bio-nanomachines
Signal types	Optical/Electrical	Chemicals
Propagation range	m-km	nm-µn
Propagation speed	Speed of light	Extremely slow
Media	Air/cables	Aqueous
Energy consumption	Very high	low

In this work, the medium between sender and receiver is assumed as diffusing channel [1] where the Molecules will have capture probability (P(r0,t)), given by equation (1). As in figure.1, abstraction of MC system is given as; the encoded bio-molecules or Molecule1 is transmitted from transmitter nanomachine (Tx) and propagate to receiver nanomachine (Rx). Like in traditional communication, upon reception of Molecule1, Rx stimulates to release another Molecule 2, known as ACK packet. Once ACK packet is received by Tx then it will stop releasing of Molecule1 and start for Molecule 3.

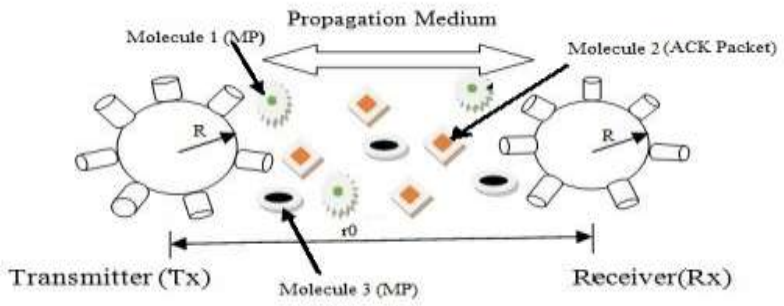

Figure. 1. Molecular Communication System

$$P(r0,t)=\frac{R}{r0}erfc\{\frac{r0-R}{2\sqrt{(Dt)}}\} \qquad (1)$$

Referring from figure 1, capture probability of molecule is given by equation 1, where R is the radius of transmitter (effective capture in µm), r0 is the distance between the

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nanomachines, µm and D is the diffusion coefficient, in $\mu m^2 s^{-1}$, and t is time in second. The capture probability or receiving of MP will be reduced when distance between the transmitter and receiver increases. The result is shown in figure 11. Again, if the MP is received then error detection and correction schemes will be implemented. However, in conventional Stop and Wait ARQ, erroneous copies are discarded and requested for duplicate copies. To overcome the drawbacks of Stop and Wait ARQ, this protocol is studied and combined with conventional PC and APC techniques in three states Markov model. Many researchers [10-17] have also investigated different protocols for enhancing the performance of PC and APC in wireless network. In PC, the first erroneous copy is stored and XORed with second erroneous copy. By using this technique, the erroneous bit positions will be identified only if erroneous bits will be in different positions. Once, the bit error position is identified then bit by bit inversion process will be performed by using brute force method. However, this technique may be applicable only when bit error rate is low. In APC, triplicate copies are required. The brief example of conventional APC technique is given here:

- "11111" is taken as original packet from sender. It is assumed that three copies are received as C-1 11011, C-2 11110 and C-3 11011
- After performing majority logic bit by bit on three erroneous copies, 11011 is generated at the receiver side. Thus, error detection technique is applied to check the generated copy is original or not.
- If it is not original packet, then find the least reliable bits from majority logic. Therefore, in this example the 3rd and 5th bit from the MSB is chosen.
- Brute force correction technique is applied to 3rd and 5th bit position as done by PC. This process may lead to get original packet. If original packet is not generated in the above process then it will discard all erroneous copies and requests for duplicate copies again. The block diagram is shown in figure 2.

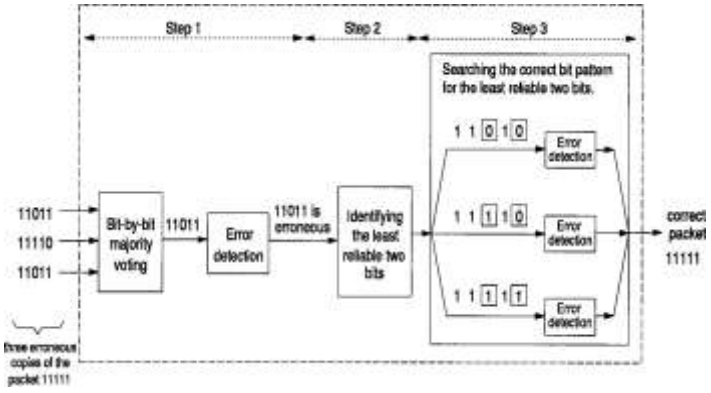

Figure. 2. Block diagram of APC [9]

The manuscript is categorized by three parts and organized as follows. We have established a proposed protocol which is mentioned in section 2 as under the heading of proposed protocol. The remaining of this paper is organized as follows. Simulation results in terms of

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throughput, probability of packet error and energy consumption are shown in section 3. Lastly, conclusion is discussed in section 4.

2 Proposed protocol

We consider three states Markov model for defining the channel (aqueous Medium) using feedback channel (either ACK/NACK). In conventional ARQ, either ACK or NACK are sent from receiver by using feedback channel. Depending on either ACK or NACK received by sender, it will send either next packet or duplicate copy. But, sending duplicate copy repeatedly without knowing the channel state may consume huge amount of time and cost in MC. Thus, the sender is required to define with three states channel by counting number of ACK(s) or NACK(s). The three states are "BEST (B), AVERAGE (A) and WORST (W)". The transition diagram of three states Markov model is portrayed in Figure 3.

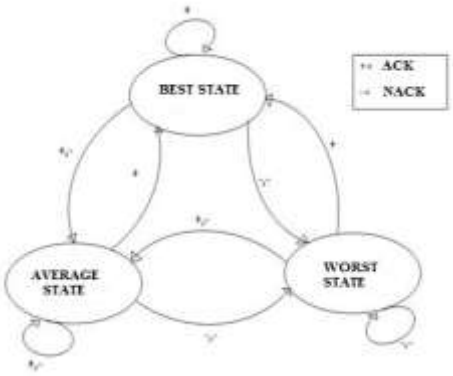

Figure. 3. Three states Markov Model

Depending upon the number of contiguous ACKs or NACKs received by the transmitter, status of the channel will be decided either B, A or W states. But, in conventional PC and APC or (ARQ techniques), it neither considers channel states nor different protocols. In order to get higher throughput and less energy consumption, the protocol is proposed here. Referring to figure 3, status of channel will be either 'B', 'A' or 'W' states. The channel is in 'B' state only if contiguous ACKs are received from nanoreceiver. Again, the channel is in 'A' state if sender receives ACK followed by NACK and switch to 'W' state if it receives contiguous NACKs.

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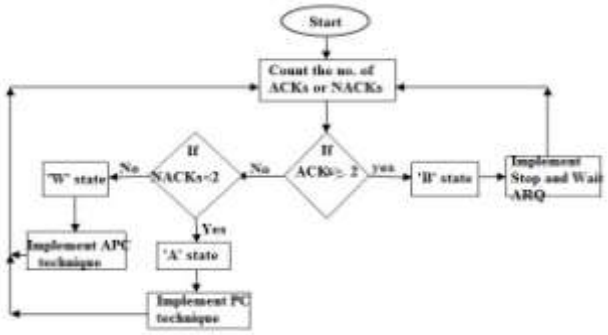

Figure. 4. Flow chart of proposed protocol

It assumed that 'μ' is the probability of bit error in Molecular Nano Network of packet having 'n' bits size. Let a single bit '1' is sent from sender and receiver received erroneously as '0'. Then, probability of bit error correction for single bit will be given by equation (2).

$$Perr\_cor=1-\mu \qquad (2)$$

For 'n' packet size, the probability of bit error correction for MC will be given by equation (3)

$$Perr\_cor=(1-\mu)^{n} \qquad (3)$$

Therefore, the probability of error for whole packet of n bit packet size is given by equation (4)

$$PE=[1-(1-\mu)^{n}] \qquad (4)$$

Let one unit of energy (E) is consumed for one time transmission of packet size 'n' from source to destination. Since, the energy consumption of packet transfer will be maximum only when retransmission will occur. Therefore, the required energy (E) consumption for proposed protocol in MC when the technique is successful to get original copy will be given by equation (5).

$$E=\frac{1}{[(1-\mu)^{n\times i}]} \qquad (5)$$

Where i is the number of duplicate copies required for error correction technique.

According to the three states Markov model, we have 'B', 'A', and 'W' states, the probability of packet error for B, A, W states will be given by equation (6), (7) and (8)

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$$PE_B=[1-(1-\mu)^n] \quad (6)$$

$$PE_A=[1-(1-\mu)^n]^2 \quad (7)$$

$$PE_W=[1-(1-\mu)^n]^3 \quad (8)$$

Therefore, the probability of these states, $PE_B+ PE_A+ PE_W=1$, the probability of packet error for the proposed protocol will be given by equation (9)

$$PE_{Pro}= PE_B\times PE_A\times PE_W \quad (9)$$

Throughput (TH_{pro}) of the proposed protocol will be given by equation (10)

$$TH_{pro}= TH_B\times T0+ TH_A \times T1+ TH_W \times T2 \quad (10)$$

Where $TH_B = (1- PE_B)/(i+ PE_B)$, $TH_A=(1- PE_A)/(i+ PE_A)$, $TH_W=(1- PE_W)/(i+ PE_W)$, where i=1, 2, 3 for B, A, W states and T0, T1 and T2 are equally likely occurrence of Markov three states for B, A, W. Therefore, T0=T1=T2=1/3.

3 Simulation results and discussions

In MC, the bit error rate will be very low as compared to wireless network which has been assumed by few researchers but not proved with specific value. In order to correlate with the wireless network, the bit error rate of 10^{-4} to 10^{-3} (bit error rate of wireless network) with packet size of 2048 bits has been taken. However, three states are defined equally likely as T0, T1 and T3 of 0.33 and unequally as T0=0.25, T1=0.25, T2=0.5 in simulation sections 3.1 and 3.2.

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3.1 Comparisons of proposed protocol with Stop and Wait ARQ , PC, APC in terms of throughput, probability of packet error, energy consumption at T0=T1=T2=0.33

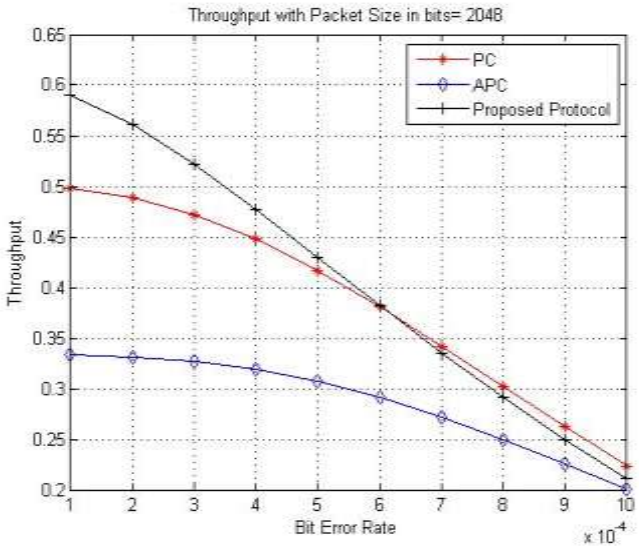

Figure. 5. Throughput efficiency is higher compared to PC and APC with 2048 bits packet size

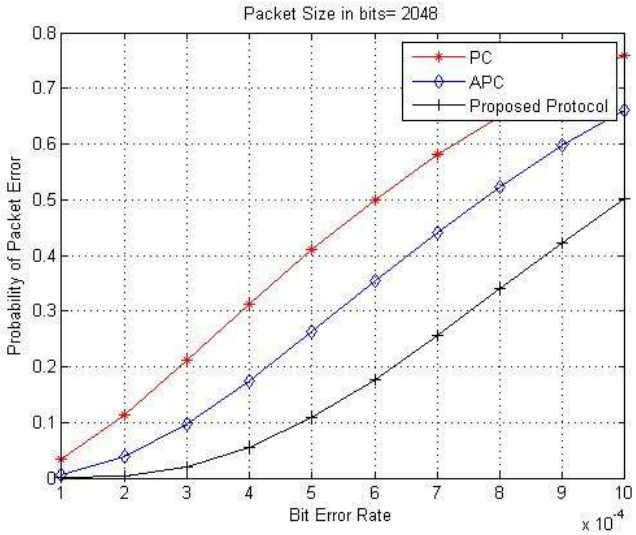

Figure. 6. Probability of packet error is lower in proposed model compare to PC and APC with 2048 bits packet size

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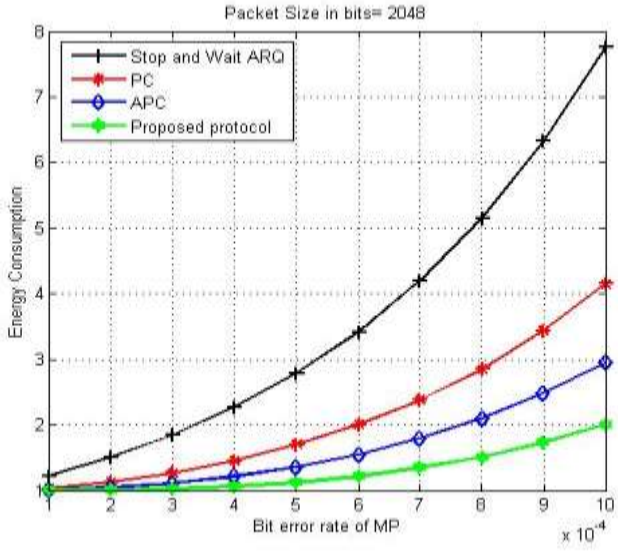

Figure. 7. Energy consumption of proposed protocol is lower compared to PC and APC techniques with 2048 bits packet size and bit error rate of 10^{-4} to 10^{-3}

3.2 Comparisons of proposed protocol with PC, APC in terms of throughput, probability of packet error, energy consumption at T0=0.25, T1=0.25=T2=0.5

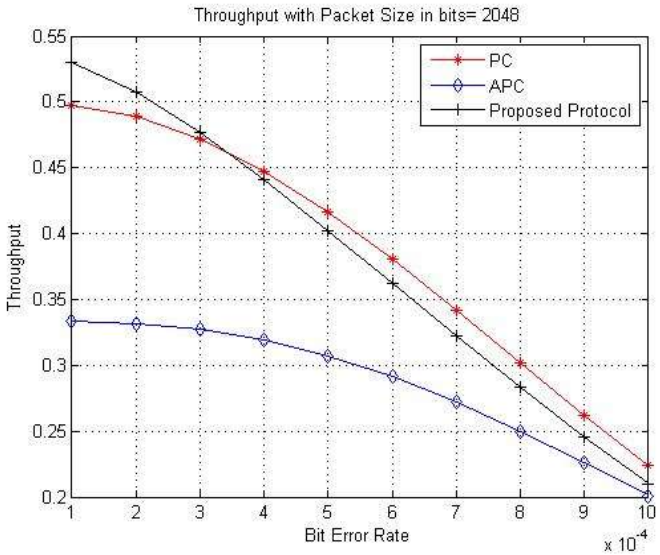

Figure. 8. Throughput efficiency is higher in proposed protocol compared to PC and APC with 2048 bits packet size

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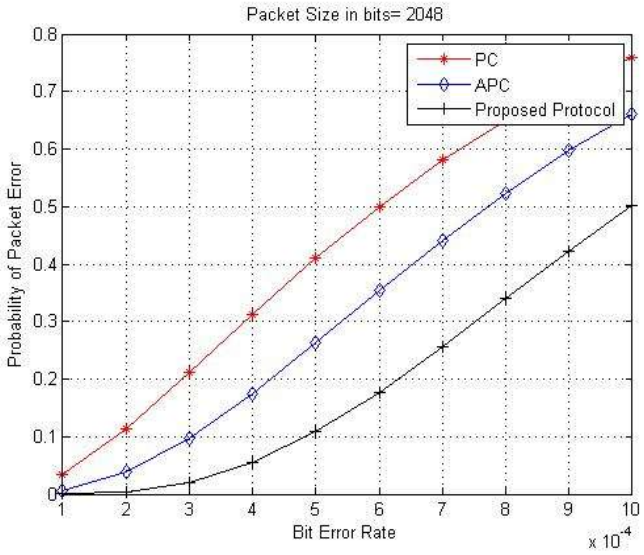

Figure. 9. Probability of packet error is lower in proposed protocol compared to PC and APC with packet size of 2048 bits

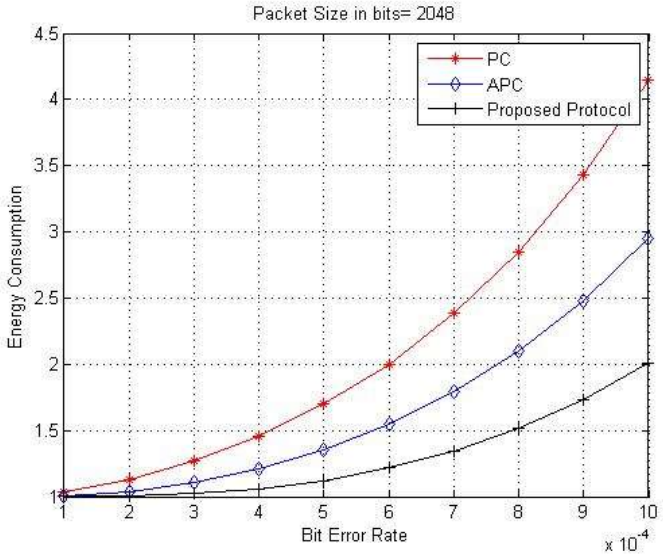

Figure. 10. Energy consumption is lower in proposed protocol compared to PC and APC with 2048 bits packet size

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3.3 Comparison of capture probability failure.

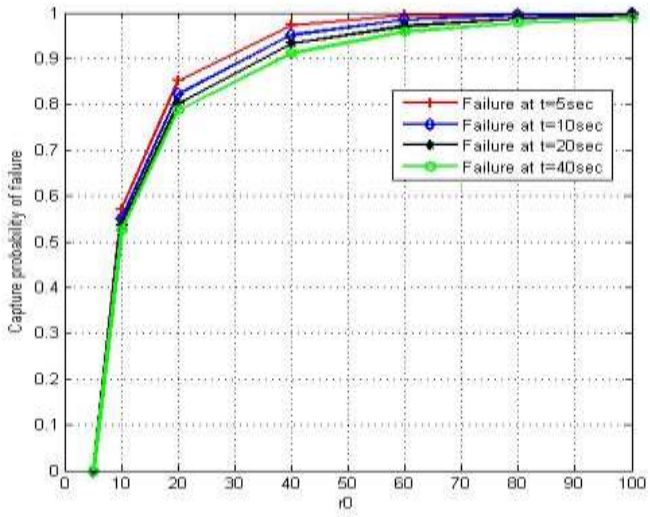

Figure. 11. Portrayed that capture probability of failure is increased when distance between the sender and receiver increases at different time (t) in second.

4 Conclusion

APC for ARQ protocol is a good concept in conventional wireless network for successful packet delivery. Thus, in order to make a complete framework for MC, this protocol is studied and simulated using Mat lab. However, we have already discussed about, how the proposed protocol outperformed using the Markov Model in figure 3 and 4 in simulation .The simulation results are shown that proposed protocol is ensuring higher throughput than conventional PC and APC in terms of parameters like throughput, probability of packet error and energy consumption. Meanwhile, it is also shown that new proposed protocol is consumed less energy compare to Stop and Wait ARQ when bit error rate varies from 10^{-3} to 10^{-4} and packet size of 2048 bits.

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