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Performance Analysis of Distributed Mac Protocol with Physical Layer Network Coding Scheme

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Abstract: Mobile ad hoc network consists of mobile nodes and all the mobile nodes arrange in a distributed architecture. This network is an infrastructure less network connected by mobile devices. Each node in the mobile ad hoc network can move free from one place to another place. From cooperative communication can increase the throughput and reduce the cost of the network. Conventional network coding (CNC) and physical layer network coding (PNC) are the existing techniques for the wireless network to share the medium simultaneously to avoid the collision. But these existing techniques cannot apply in the multi hop network. To overcome these issues proposed a new technique called physical layer network coding in distributed medium access control protocol (PNC-DMAC). This technique is applicable for simultaneously transmit the data from source to destination without collision in multi hop wireless network. This proposed protocol is used to increase the throughput, packet delivery ratio and network lifetime. Using the relay nodes can perform the transmission with CSMA (Carrier Sense Multiple Access) strategy and used the extension of IEEE 802.11 medium access control protocol. Simulation results analyze the performance of the proposed protocol using quality of service parameters.

Key words: PNC · CNC · Multihop networks · MAC Protocol · QoS Parameters and distributed network

INTRODUCTION

Mobile ad hoc network consists of distributed architecture and contains number of mobile nodes can linked by multi hop wireless links. All the nodes in the mobile ad hoc network will act as intermediate nodes to forward the packets from source to destination. To transmit the packet, it requires the wireless medium. For that wireless medium, developed the medium access control protocol. It is used to develop the channel for access the medium. Time division multiplexing and frequency division multiplexing are not suitable for distributed wireless network, because it requires central scheduling to transmit the data. For multi hop wireless network, it requires random access mechanism like carrier sense multiple access (CSMA). This mechanism is used to sense the carrier when multiple users access the channel at a same time. It has two parts one is CSMA/CD and CSMA/CA. CSMA/CD is used to detect the collision alone but CSMA/CA scheme will detect and avoid the collision completely in wireless ad hoc network.

The major issue in the physical layer network coding PNC is not suitable for multi hop networks. This was designed based on the physical layer. Generally physical layer is used for the transmission medium between the two nodes. That medium required the medium access control protocol to share the wireless medium for all the mobile nodes. In physical layer network coding, packets are transmitting the packets in an encoded format and that will be decoded in the receiver side. Mostly this physical layer coding protocol used for small topologies. In this tail and header contains the same information that will be added to the data packet. Based on the header and tail information only, receiver side can decode the respective packets. This protocol can transmit the data packet simultaneously to the destination. All the data packets in PNC protocol should be encoded before transmit to the destination. It can transmit the data using single hop network. This PNC protocol used the SIC (self-interference cancellation); it will cancel the interference among the nodes in the wireless ad hoc network. Mostly distributed network requires cooperative communication

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for the successful transmission. Using the SIC scheme can access the simultaneous transmission for ad hoc networks.

Related Work: Muir *et al.* [1] explains about the group allocation multiple accesses with packet sensing. This technique will be suitable for the contention based and contention free methods. It is used to reduce the collision by packet sensing method. Transmission will start based on the medium is idle or busy state. Singh *et al.* [2] suggests the power aware protocol. This protocol is used in a medium access control scheme for multipath channels. This scheme will initiate in receiver side. That protocol is power aware medium access control with signaling [PAMAS]. Here control signals are exchanged using the signaling channel and the data signals are exchanged using data channel. Shan *et al.* [3] proposed the cooperative triple busy tone multiple accesses. It is used to reduce the hidden terminal problem. It uses the transmitter busy tone and receiver busy tone to protect the control and data frames. To reduce the joint optimization problem relay assignment has considered. Song *et al.* [4] have developed a distributed MAC algorithm, named Collision Aware DCF (CAD), in which each node reserves only the smallest possible area which is enough to protect it and the ongoing communications and thus helps increase the spatial reuse. Zhai *et al.* [5] discusses the network coding technique. It is used to improve the throughput performance and motivate the neighbor node to cooperate. Zhou *et al.* [6] suggests the new scheme to separate the channel by data and control signal. Zhu *et al.* [7] discusses the problem caused by low quality link and faster two hop link in multi hop network. Zhang *et al.* [8] explains the medium access control in distributed network. This will reduce the transmission rate and transmission reliability.

CNC Mac Protocol: Conventional network coding medium access control protocol is used to transmit the encoded packets in separation phases. It cannot transmit the data simultaneously. This is the major difference between the physical layer network coding MAC and conventional network coding MAC. Both of the protocols are used to transmit the data in an encoded format. These protocols are not suitable for the multi hop wireless network. Here used the IEEE 802.11 wireless LAN protocol for the medium sharing technique. SIC scheme is used in the receiver side to decode the data packet. It will be decoded the data using the neighbor node's knowledge. To overcome the issue proposed a new medium access control with the help of physical layer coding protocol. That new technique is PNC-DMAC which is suitable for the multi hop wireless network. Here going to design a physical layer for multi hop network and medium access control protocol for distributed network. This technique reduces the collision and increase the throughput and network performance [9].

Proposed PNC DMAC Protocol: The proposed protocol physical layer network coding distributed medium access control modify the control messages to perform the multi hop operation in distributed networks using physical layer network coding. In PNC-DMAC protocol, all the nodes notify the queue status of the neighbor node. It will add more bytes to the control information to know the queue status of the neighbor nodes. Based on the queuing status it will transmit the data. This proposed protocol uses proactive routing protocol and it will create the routing table using the control messages such as RTS (Request to send) and CTS (Clear to send). This protocol is used to maintain the topology and know about the topology within the two to three hop counts. Here using relay node denoted as R, which is used to update the routing information and stored the queue status of the neighboring nodes. Consider relay node R has two neighbor nodes such as A and B. this relay node R store the queue information of the neighbor nodes of A and B. The transmission between the R and neighbor nodes of A and B is shown in Figure 1 [10].

This packet exchange is initiated by using relay node. This relay node sometimes will act as coordinator node for packet transmission. Relay node R is used to perform the PNC, first it sends RTS-PNC frame to the neighbor nodes. It contains the source address of R node and destination address of A node and B node. Queue status of node A and node B to be stored in the CTS frame node A and node B. After receiving the CTS frame, R node sends coordination PNC frame to node A and node B. A node receives the CO-PNC frame after that time TIFS, it starts to send the data. Likewise B node receives the Co-PNC frame after the time of 2TIFS+Tphy-Hd+Tmac-Hd., it will start to send the data. Tphy is the time taken for the process in the physical layer and Tmac is the time taken for the process in the mac layer. In this propose protocol, neighbor nodes of A and B should not be synchronizing each other. During the transmission of data, A and B should not be collide each other and to avoid the collision using relay node. Using the CO-PNC frame relay node maintain the synchronization between the neighbor nodes of A and B. To maintain the synchronization, it needs to perform the physical layer network coding method [11].

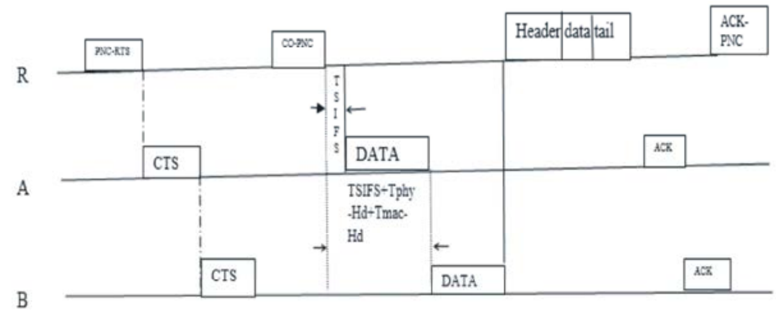

Fig. 1: Packet exchanges in DMAC

Data from the node B contains the bit reversed order; it will send the tail of the data at first and header of the data at last. Compared to the node a, node B has longer packet. During the time period of TSIFS and TSIFS+Tphy-Hd+Tmac-Hd, node B will not be interfered with node A. Relay node R can successfully decode the data by using the time difference between the two different frames. When the relay R node decode the header data frames, from that it will update the queuing status of the node A and node B will be updated in the relay node R. Relay node R will code the data signal that is received from the node A and B. after that relay node R send the coded packets to the neighbor nodes of A and B. if successfully data packets received from the relay nod R, node A and node B sends the ACK acknowledgment frame to the relay node R. after that R relay node sends the ACK-PNC frame to the node A and B, that contains the source node address and destination node address. After that ACK-PNC frame, the entire source node in the network clears the cache [12].

NAV Setting: Network allocation vector NAV setting is most important during the packet exchange process. This NAV setting is mainly purpose of avoiding collision between the node A and B which will transmit the data to relay node R. Network allocation vector is a virtual carrier sensing scheme. It will avoid the collision from the hidden terminal problems. Here in proposed protocol NAV setting occurs in two stages. The length of NAV will depend on the duration of the frame. Each frames carry different NAV length.

NAV length from the relay node R sends RTS-PNC to the neighbor nodes of A and B is shown in equation 1. NAV length from the node A sends CTS to the R relay node is represented in equation 2. This length is used to cover the transmission time. Likewise node B send CTS to the relay node that NAV length is shown in equation 3.

$$Lnav(R, RTS\text{-}PNC) = 3Tsifs + 2Tcts + Tco\text{-}pnc \rightarrow \quad (1)$$

$$Lnav(A,CTS) = 4Tsifs + Tcts + Tco\text{-}pnc + Tdata(A) + Tack \rightarrow \quad (2)$$

$$Lnav(B,CTS) = 4Tsifs + Tco\text{-}pnc + Tphy\text{-}Hd + Tmac\text{-}Hd + Tdata(B) + Tack \rightarrow \quad (3)$$

After receive the CTS from node A and B, relay node R will send the CO-PNC frame to the neighbor nodes of A and B. This frame field is used to get the queuing information from the neighbor node of A and B. The NAV setting is shown in below equation.

$$Lnav(R,CO\text{-}PNC\ A) = Lnav(A,CTS) - 2Tsifs - Tcts - Tco\text{-}pnc \rightarrow \quad (4)$$

$$Lnav(R, CO\text{-}PNC\ B) = Lnav(B,CTS) - Tsifs - Tco\text{-}pnc \rightarrow \quad (5)$$

If one node either A or B transmit the data frame, NAV will not be updated. That NAV value still is to be zero. After received the both the data, R node generates the headers and tail information for the data that contain the source and destination address. After that only it can coded the header frames then get the queuing status of the neighbor nodes of A and B. the length of the NAV for transmit the data from node A to R relay node is shown in equation 6. The length of the NAV for transmit the data from node B to relay node is shown in equation 7.

$$Lnav(A,DATA) = Lnav(R, CO\text{-}PNC\ A) - Tsifs - Tphy\text{-}Hd - Tmac\text{-}Hd \rightarrow \quad (6)$$

$$Lnav(B,DATA) = Lnav(R,CO\text{-}PNC\ B) - 2Tsifs - TphyHd - Tmac\text{-}Hd - Tdata \rightarrow \quad (7)$$

The data frames from node B using queuing condition is first in first out (FIFO) technique. It will collect the data from the tail side as first and then it will move to the header side. It is also called as bit reverse order. This FIFO queuing technique follows the first come first serve process. The data packets arrive earlier in the queue will be taken as earlier. The proposed protocol PNC-DMAC uses the same FIFO technique to serve the queue in multi hop transmission. So the initial transmission will generated by the relay node and not the source node. In this proposed protocol PNC-DMAC, all the nodes should maintain two types of queues they are actual queue and virtual queue.

Actual and Virtual queue: Actual queue is used to store the actual data packets from the node. The actual contains the data packet, neighbor node address, hop count and the time taken to transmit the packets in the queuing field that is denoted by Taq. These information is collected from the routing table after the control message transmission. Virtual queue will not store the actual data and it contains the information of the neighbor node. Virtual queue contains virtual data packet. Virtual data packet has the following information.

- Previous hop [node that contains the virtual data corresponding to its actual queue].
- Next hop [second hop of the actual packet.
- Length of the actual data packet.
- Time taken to transmit the packets in the virtual queue is denoted by Tvq.

This queuing information occupies more memory and also actual queue contains lesser information compared to the virtual queue. It has some rules to reduce the unnecessary memory space in the queuing fields. These rules are used to satisfy the connection of the virtual queue node R and actual queue of the neighbor's node A or B.

- Virtual packets contain in the relay node R and it contains the virtual queue and the actual packets in the actual queue contain the neighbor's node of A. In the routing table, which node has the next hop of R relay node that node information will be stored in the virtual queue of R.?
- In virtual queue of node R stores the virtual packet with previous hop and next hop of node A and B respectively.
- In this first packet will be stored in the actual queue of node A and then follows the next hop R and second hop B.
- If adding the actual queuing time (Taw) and actual previous hop time (Taq-prev) is equal to the virtual queuing time (Tvq), it will initiate the physical layer network coding PNC process.
- The virtual queue satisfies the above condition, it will achieve the fairness of the nodes in the distributed network.

Actual queue of the node is transmitted to the neighbor's node of data and ack frame, from this information neighbor node will update the virtual queue. Each data frame contains the next hop address and information of the next packet. In virtual queue, contains the same information which contains the actual queue. The virtual queue has additional control information that will be contained in the data frame. If does not have the second hop, next packets are not valid in the information of the data frame. The actual queue contains the remaining time of the queue of its previous hop. So data frame contains the same information that belongs to the actual queue. After transmitted the data frame to the neighbor node, it will get the Ack frame from the relay node. The ACK frame contains the actual queue of the next neighbor node. The next neighbor node indicates that the next hop and second hop of the relay node. These information will be updated by the receiver in the virtual queue. After that it will initiate the PNC transmission for single transmission. The proposed algorithm is used for the data packets to transmit and relaying scheme for that particular data packet. The steps of the proposed algorithm is given below.

Step-1: in actual queue it will find the first data packet.
Step-2: it will check the status of the medium, is it in wait state.
Step-3: if it is not waiting for PNC, it will move to the virtual queue. If rule 4 satisfied, it generates the PNC scheduling.
Step-4: if it gets the PNC scheduling, packet will be sent.

Algorithm-PNC-DMAC:

- Let PNC in OFF
- Assign P=1st packet (actual queue)
- If (P == PNC)
- Pend=2nd packet (actual queue)
- Assign Py= 1st packet (virtual queue)
- While (Taq+Taq-prev = Tvq)
- Pyend=2nd packet (virtual queue)
- If PNC=ON
- Encode P
- Schedule to send P
- Endif
- Repeat steps 1 to 6.

Algorithm 1 explains that the physical layer network coding PNC will initiate at first. The medium will wait for the PNC scheduling. This will update the actual queue or virtual queue. Initially P assign as data packet that will be stored in the actual queue. Next it gets the PNC scheduling it will continue to store next data packet in the actual queue. Then rule 4 of virtual queue is satrifistied first packet will be stored in virtual queue. After that it will check for the PNC scheduling. If it satisfies the PNC scheduling, it will start to store next data packets in the virtual queue. After that it will encode the data packet and it will get the queuing status of the neighbor node. If the medium is idle, it will start to transmit the data. The node is in the queuing status, it shows that the busy state. After the queuing packets completed, the medium moves to the idle state. After the every successful transmission, automatically actual and virtual queue will be updated. If one source node transmit the packet, it will select the relay node. If two source nodes transmit the packet, it will select at least one node as relay node. If it gets the unsuccessful transmission, it will move to the queuing packets. After that, it will try to resend the data to make the successful transmission. It will make the retransmission for the particular threshold time, if it reaches over the node will clear all the packets from the queue. Likewise virtual packets are also cleared from the virtual queue after the particular threshold time. After clearing the packets from the actual queue and virtual queue, the medium will moves to idle state. This scheme is used to apply in the multi hop network and also it supports the PNC scheme. So the proposed protocol PNC-DMAC is suitable for the multi hop communication in distributed networks.

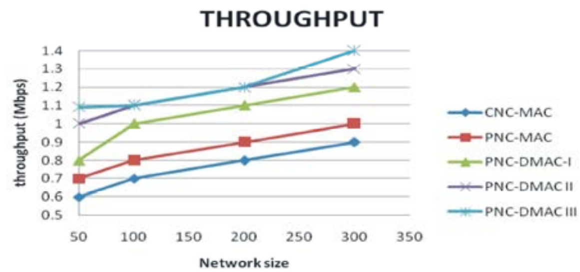

Fig. 2: Throughput Analysis

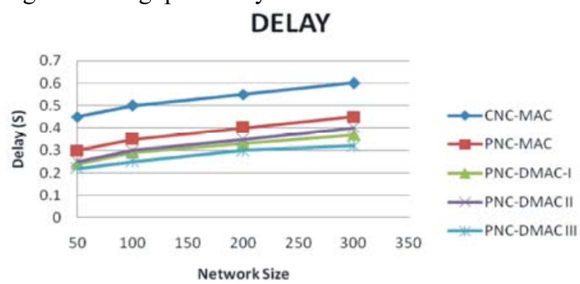

Fig. 3: Delay Analysis

Fig. 4: Delivery Rate Analysis

RESULTS AND DISCUSSION

The performance of the proposed PNC-DMAC protocol is analyzed using network simulator NS-2. The number of nodes vary from 50 to 300 nodes. The topology size is 1000x1000. The physical layer data rate used here is 1Mbps. The transmission power is 3db. The transmission range is 250m. The packet size used for the transmission is 1000 bytes. The actual queue size is 50 packets, it will vary from 50 packets to 150 packets. The virtual queue size is vary from 50 packets to 150 packets.

This protocol varies in three stages based on the actual queue size and virtual queue size. In the PNC-DMAC I will consider the actual and virtual queue size is 50 packets. PNC-DMAC II considers the actual and virtual queue size is 100 packets. In stage III, the actual and virtual queue size is increased by the 50 packets. So PNC-DMAC III has the actual and virtual queue size is 150 packets. This proposed protocol analyze the performance using quality of service parameters such as throughput, packet delivery ratio, end to end delay, routing overhead and control overhead. Throughput is defined as the number of packets delivered with respect to the time. Packet delivery ratio is defined as the ratio of number of packets delivered with respect to the number of packets sent. End to end delay is defined as the time taken to transmit the data packets from source to destination. Routing overhead is defined as the ratio of number of data packets delivered to the number of control messages delivered. Control overhead is defined as the ratio of number of control messages transmitted with respect to the time.

Figure 2 shows the throughput analysis. It compares the performance of the proposed protocol in three stages with the existing protocols of CNC and PNC. Compared to the existing CNC (coordination network coding), PNC (physical layer network coding) protocol, proposed PNC-DMAC achieves high throughput. Figure 3 shows that

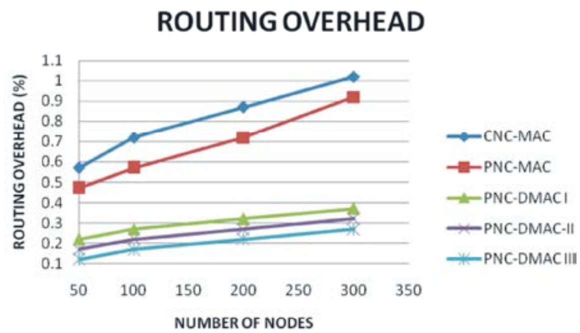

Fig. 5: Routing Overhead

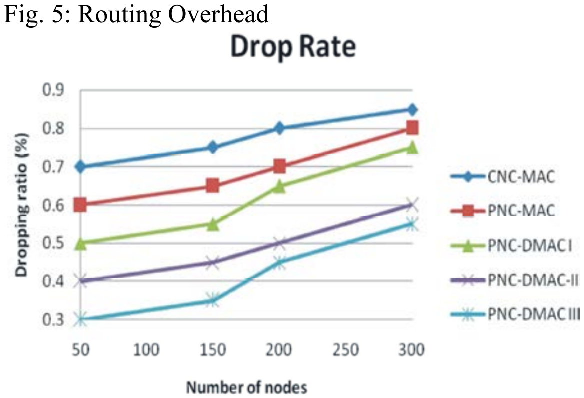

Fig. 6: Drop Rate

the delay analysis. Compared to the existing protocol, proposed protocol reduced the delay performance of the entire network. Figure 4 shows the delivery rate analysis. It analyzes the performance of the proposed protocol in three different stages by varying the queue packet size. Compared to the existing protocols, proposed achieves high delivery rate.

Figure 5 shows that the routing overhead. It has lesser overhead compared to the existing technique. Figure 6 shows that the drop rate analysis. From this graph, propose protocol achieves lesser drop in different condition compared to the existing protocol.

CONCLUSION

The proposed protocol PNC-DMAC, this extends from the IEEE 802.11 protocol and it will add the PNC protocol. This protocol is used to transmit the data simultaneously in multi hop network. The existing protocol CNC and PNC is used only for single hop network. To overcome this issue, move to the PNC-DMAC protocol. This PNC-DMAC protocol achieves the successful transmission using the actual and virtual queue. It used the relay node R to transmit the data from coordinator node to neighbor node. The simulation results show that the performance of the proposed protocol PNC-DMAC in three different stages by varying the actual and virtual queue size. This protocol increased the performance of the entire network and it will suitable for the multi hop communication. PNC protocol will only applicable for single hop communication, apply this PNC scheduling in distributed network and it will generate the multi hop transmission using relay node. This research work concentrates on the bidirectional flows in the distributed network. In future, unidirectional flow with the listening of medium using PNC scheduling will be developed with mobile scenario. It will support the opportunistic listening and it will estimate the future channel conditions. Because this will not be overlap the sources and destination nodes. This future work may help the MAC protocols to improve the entire performance of the distributed network even in unidirectional flow between the source and destination.

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