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PNC BASED DISTRIBUTED MAC PROTOCOL IN WIRELESS NETWORKS

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Abstract - *Physical-layer network coding (PNC) allows nodes to transmit simultaneously. In this paper, PNC based distributed MAC protocol in multi-hop wireless networks has been implemented. This MAC protocol is based on the carrier sense multiple access (CSMA) strategy. In this protocol, each node collects information about the queue status of its neighbouring nodes. When a node finds that there is an opportunity for some of its neighbours to perform PNC, it notifies its corresponding neighbouring nodes and initiates the process of packet exchange using PNC, with the node itself as a relay. During the packet exchange process, the relay also works as a coordinator. The PNC based distributed MAC protocol also supports the conventional network coding and conventional relaying schemes when there are no possibilities of simultaneous transmissions. PNC usually makes use of the natural phenomenon of electromagnetic waves- they add together when they share the same physical space. The mixing of electromagnetic waves is a form network coding, performed by the nature.*

Keywords: Carrier Sense Multiple Access (CSMA), 802.11 MAC, Conventional Network Coding (CNC), Physical Layer Network Coding (PNC).

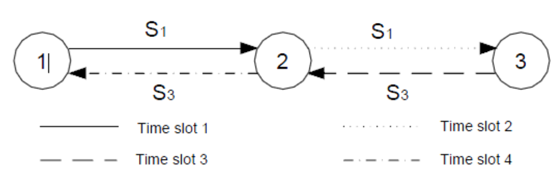
1. INTRODUCTION

Wireless networks [7] are being increasingly used for the advantages it is providing for personal communication such as mobility to the users. In these networks increasing bandwidth efficiency and minimizing interference are the two important criteria. This is because available bandwidth in wireless communication is limited when compared to wired networks and interference is also more due to the random nature of the channel. Bandwidth efficiency can be achieved with MAC protocols by coordinating the channel access between the multiple nodes. Several multiplexing schemes have been designed and being used to reduce interference. Also instead of treating interference as hindrance to be avoided, it is exploited to systems advantage for improving the throughput performance. One such scheme is physical layer network coding, which is dealt in this paper.

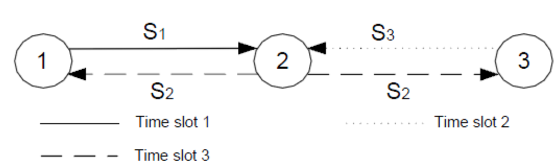
2. RELAYING SCHEMES

Physical layer network coding [2] is subfield of network coding. In network coding relay encodes the packets after receiving them in separate communication phases. The encoding function is used in network coding is logical XOR operation. Compared with conventional relaying/routing schemes, the network throughput, end-to-end delay and network reliability can be improved with network coding.

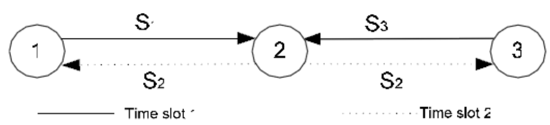
Physical layer network coding is comparing with the conventional network coding [2] and conventional relaying schemes in Fig.1 In conventional relaying method it needs 4 time slots to exchange the packets $x_a$and x_b between A and B through relay node R as shown in the Fig.1. In conventional network coding it needs 3 time slots and takes ¾ of the time compared with the conventional relaying schemes. In physical layer network coding it needs two times slots and half the time compared to the conventional relaying schemes. The physical layer network coding can achieve throughput gain of 2 over conventional relaying and 1.5 over conventional network coding.



(a)



(b)



(c)

Fig-1. Three relaying schemes:

(a) Conventional relaying, (b) CNC, (c) PNC.

3. PACKET EXCHANGE USING PNC

PNC based distributed MAC protocol modifies the request-to-send/clear-to-send (RTS/CTS) based IEEE 802.11 MAC protocol, to support PNC. In PNC based distributed MAC protocol, each node shares its queue status information with its neighbouring nodes by adding a few bytes of control information to the data and acknowledgement (ACK) frames. Using queue status and routing information relay node sense that there is an opportunity for two of its neighbouring nodes i,e. node A and node B to exchange packets through PNC, with *R* as the relay node, node *R* performs channel access with the CSMA strategy and coordinates the nodes *A* and *B* to send packets. CSMA is the probabilistic medium access control protocol, in which every node sense the medium before transmitting whether the medium is idle or busy, if the medium is busy, node defers its transmission. If idle, node transmits immediately.

When node *R* senses that there is opportunity to perform PNC, it sends an RTS-PNC frame, to its neighbouring nodes which are involving in PNC i,e. A and B. RTS-PNC contains the addresses of the two source/destination nodes *A* and *B* and the address of node *R*. The node that has a shorter packet to send (which can be known from the queue status stored at *R*) is set as node *A*, After receiving the RTS-PNC frame, the nodes *A* and *B* separately respond to *R* with CTS frames.

When node *R* successfully receives both CTS frames, it sends a coordination (CO-PNC) frame, to coordinate packet transmissions of the nodes *A* and *B*. After receiving CO-PNC, node *A* starts data transmission after time *T*SIFS, node *B* starts data transmission after time 2*T*SIFS + *T*PHY-Hd + *T*MAC-Hd. This process requires that nodes A and B are synchronized. The data frame of node B is bit reversed order i,e. tail of the data frame is in the beginning and header is at end. This is done to make sure that node R can successfully decode the headers of both data frames.

After the relay *R* receives the simultaneously transmitted and partly superimposed signal, it performs the coding operation *C*PNC(·) to the superimposed part of the signal. The encoding function *C*PNC(·) can be either amplify and forward or two phase DF schemes. The resulting coded packet is forwarded to the nodes *A* and *B*. When node *A* or *B* receives the coded packet, it attempts to extract the packet, which it intends to receive, from the coded packet with the help of its own which was sent to other node.

If successful, an ACK frame is transmitted to the relay node R. After the relay *R* receives the ACK frames from destination nodes A and B, an ACK-PNC frame are generated which contains the address(es) of the source node(s) to be acknowledged. After receiving ACK-PNC, each acknowledged source node flushes the packet, which it has just sent, from the queue.

4. MANAGING QUEUE

In PNC based distributed MAC protocol, each node manages two sender queues, which are *actual queue* and *virtual queue*[1].

4.1. Actual queue

The actual queue stores the actual data packets that remain to be sent by the node, as in traditional communication networks.

4.2. Virtual queue:

The virtual queue does not store actual data packets. It stores virtual data packets which contain some essential information of the packets in the actual queue of the node's neighbors. Virtual packets are denoted by *pv* and reverse virtual packet is denoted by *pv'*.

5. PNC MAC ALGORITHM

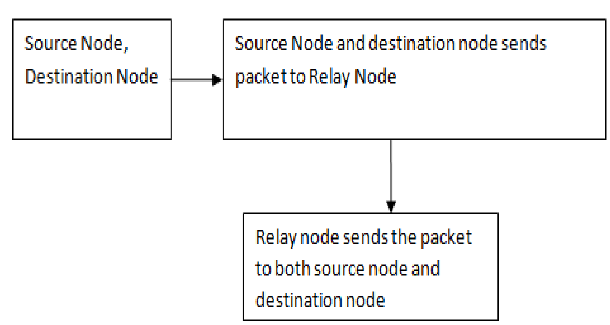


Fig- 2 PNC MAC algorithm

1. Source Node first sends the RTS control Packet to the Relay Node
2. The Relay node will send CTS control packet to the initiator.
3. The Source Node and Destination Node sends the actual Data Packet to the Relay Node
4. The Relay Node stores the packet in its Queue
5. The relay node performs encoding operation such as amplify and forward method or decode and forward method.
6. The Relay Node will send the data packet to both source node and destination node.

6. Data flow diagram

Data flow diagram (DFD) explains how information is processed by system in terms inputs and outputs. DFD focus on the flow of data, where data comes from, where it will go, and where it will store in the system. It does not show information about the timing of process, about whether processes will operate in series or in parallel. As shown in fig-2 source and destination nodes first sends the RTS control Packet to the relay node. The Relay node will send CTS control packet to the source and destination nodes. The source and destination nodes send the actual data packet to the relay node simultaneously. The relay node stores the packet in its queue and coded into a single packet. The relay node will send the data packet to the destination node as well as the source node. The destination will extract the data packet which intends to receive from source node.

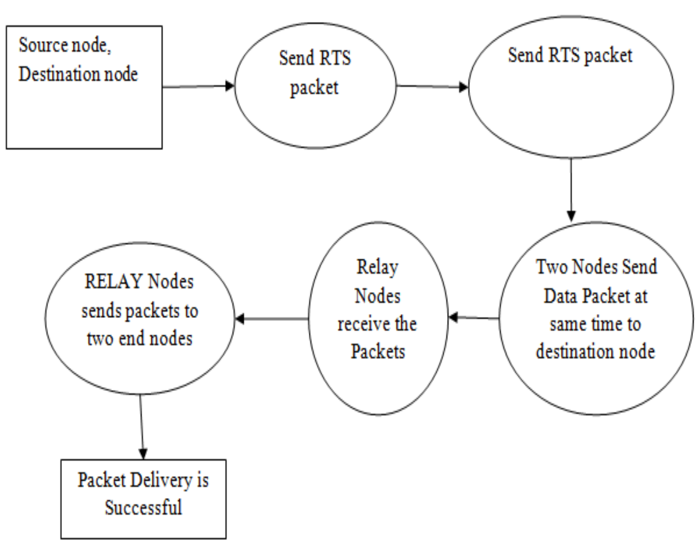


Fig-3. Data flow diagram of the PNC based distributed MAC protocol

7. RESULTS AND DISCUSSIONS

Results for PNC based distributed MAC protocol is obtained by simulation using the MATLAB tool. Linear topology has been deployed with one source node, one relay node, and one destination node respectively as shown in figure 3.

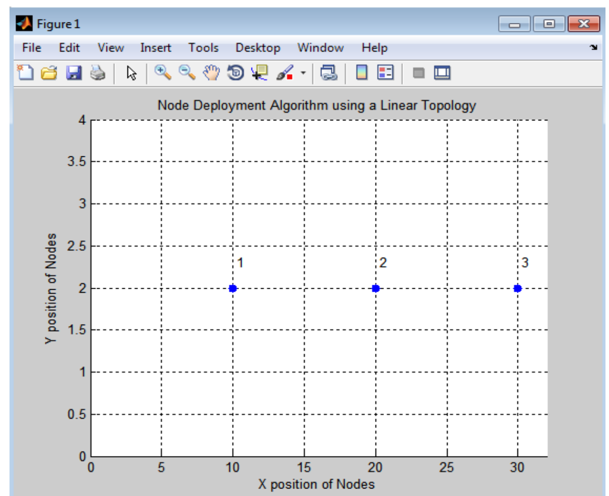


Fig-4. Linear topology node deployment

Now we will compare the performance parameters - throughput, time taken to complete packet exchange, and energy consumption by PNC based distributed MAC protocol with 802.11 MAC protocol and CNC-MAC protocols.

7.1 THROUGHPUT

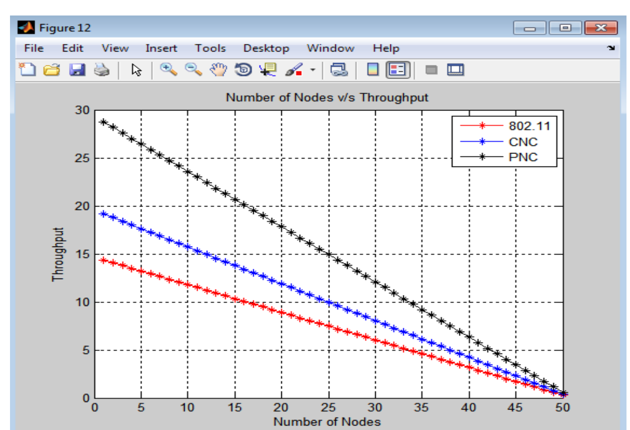


Fig-5. Throughput comparison plot

We can observe from the figure 4 throughput of the PNC based distributed MAC protocol is more than other two protocols. As the no of nodes in the network increases collisions also increases, so throughput also decreases for all three protocols. Throughput can be defined as the ratio of the number of packets transmitted to the number of packets delivered at the destination.

7.2 ENERGY CONSUMED

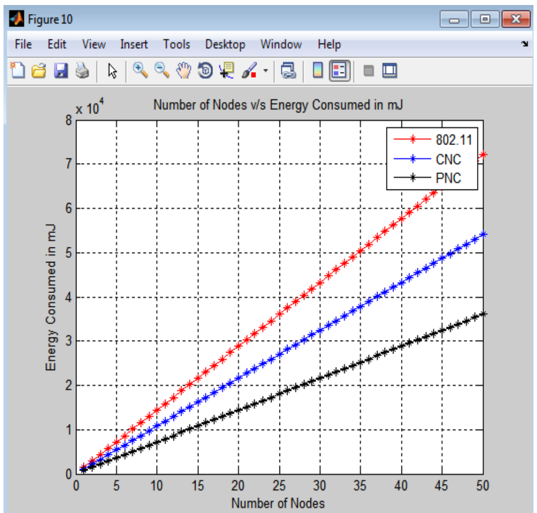


Fig-6: Energy consumption plot

Energy consumption of PNC based distributed MAC protocol is less when compared to CNC-MAC and 802.11 MAC protocols. This is because when the number of nodes increases collision will occur due to hidden node problem. To avoid this hidden node problem PNC based distributed MAC protocol uses the virtual carrier sensing mechanism with help of network allocation vector.

7.3 END TO END DELAY

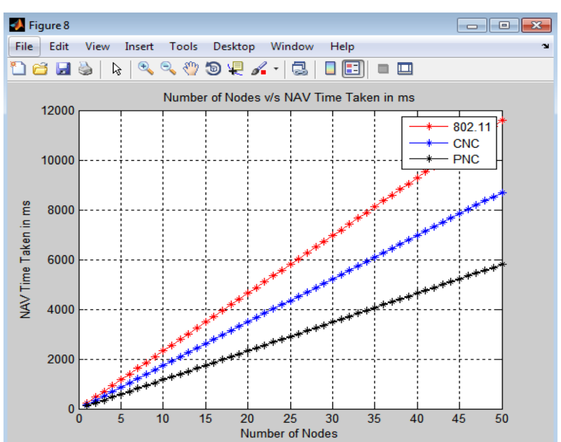


Fig-7: End to End delay plot

The end-to-end delay of PNC based distributed MAC protocol in the linear topology is the lowest compared with the other two protocols, the reason is that when using PNC, the data packets do not enter the queue of the relay. Instead, they are forwarded to the destinations immediately after they have been received by the relay.

8. CONCLUSION

The simulation results show that the proposed PNC based distributed MAC protocol brings throughput, energy consumption, and end to end delay improvement in various scenarios compared with the protocols that do not support PNC, while maintaining a similar delay as CNC-MAC. It follows that PNC-MAC is beneficial for throughput-sensitive applications of wireless networks.

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BIOGRAPHIES

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