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Network Coded Cooperative Communication in Multihop Wireless Networks

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Abstract

In this poster, we present the network coded cooperative communication for the multihop wireless networks. This presentation has two main parts. The part one is network coded MAC protocol necoMAC which incorporates CSMA/CA, 2PSP, network coding aware CSMA (NCA-CSMA) and network coded 2PSP (NC-2PSP) protocols proposed for the MAC layer in multihop wireless networks. The second part describes network coded cooperative data exchange for ad hoc networks. We studied throughput, energy consumption, number of transmissions and fairness of the proposed systems.

Network Coded MAC Protocol (necoMAC)

In this section, we present a network coding-aware MAC scheme which consists of four different MAC protocols. The necoMAC is a scheme which selects the most beneficial MAC protocol among NCA-2PSP, 2PSP, NCA-CSMA and CSMA/CA protocols. Figure 1 depicts how this scheme works by a simple flow diagram.

Firstly, it investigates whether two opposite flows pass through a certain node on a golden chain or not. If the node detects that two data flows are incoming it from opposite directions, it tries to decide the source nodes are within the transmission range of each other. If they can reach each other with one-hop transmission, the NCA-2PSP protocol tries to find a helper relay node and transmission will be performed with NCA-2PSP protocol. The transmission in NCA-CSMA will be selected when the source nodes are outside the transmission range of each other and they are located on a golden chain. If only one incoming data flow exists at a node, the scheme checks if a golden triangle can be created or not. If the golden triangle can be created with the help of a relay, data transmission in 2PSP is chosen. It will access the medium and send the data with the normal CSMA/CA protocol if both golden triangle and chain do not exist.

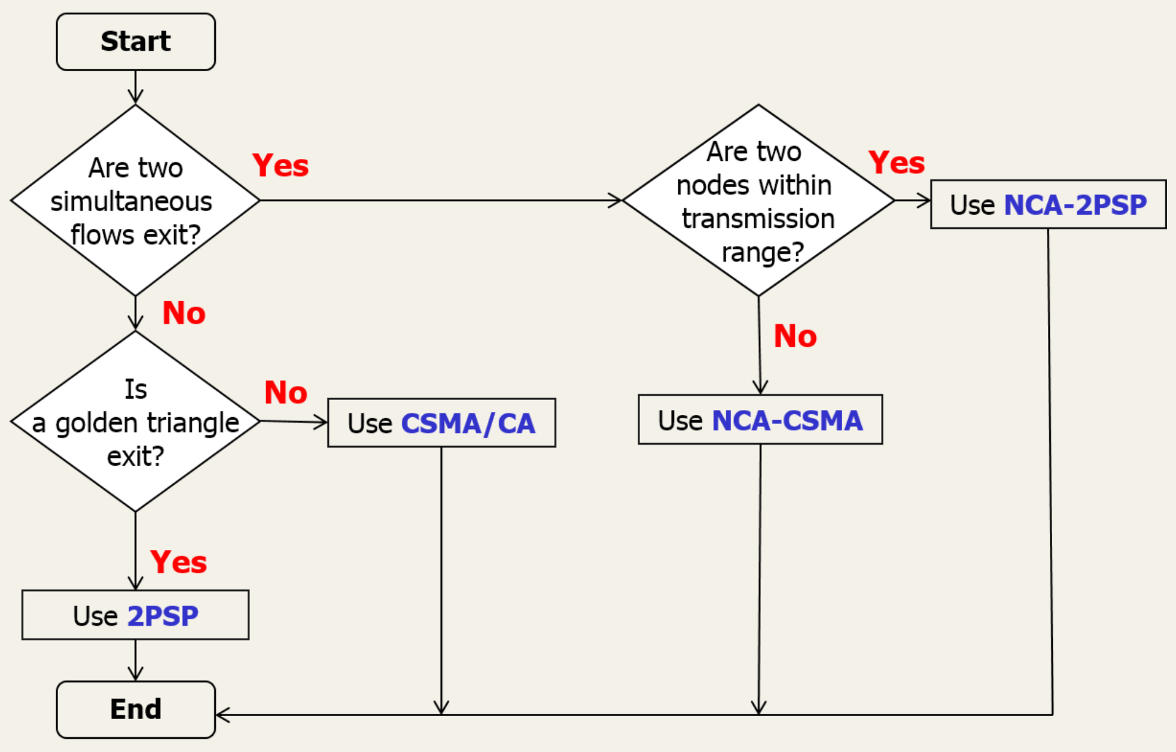
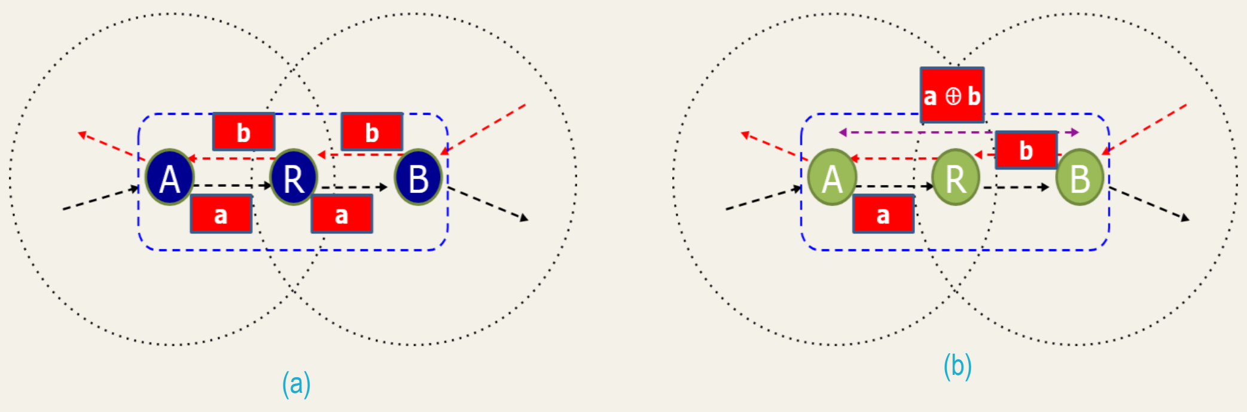


Figure 1 necoMAC scheme

Network Coding-aware CSMA (NCA-CSMA)

Figure 2 shows the data transfer in a golden chain. As nodes A and B are within the transmission range of relay node R, A and B cannot transmit their packets to R in the same time slot to avoid the collision. By the conventional CSMA/CA protocol, total number of 4 transmissions are needed to complete a successful data exchange between A and B via the relay R. Exclusive OR (XOR) network coding can be applied at the relay node R to reduce one transmission. With XOR network coding, node R broadcasts the network coded packet a ⊕ b upon receiving the packets a and b from node A and B in previous time slots respectively. Both A and B can receive the XOR-coded packet in one time slot and can recover the packets b and a by performing the XOR operation of their own packet with the receiving coded packet again. Therefore, data exchange between A and B is completed within 3 transmissions and energy for one transmission can be saved.



(a)

(b)

Figure 2 Data exchange in a golden chain (a) CSMA/CA (b) NCA-CSMA

Network Coding-aware 2PSP Protocol (NCA-2PSP)

NCA-2PSP protocol works when two nodes on a golden chain possess a helper relay between them and both of them have some data packets to be exchanged. We define three new control messages called relay RTS (RRTS), relay CTS (RCTS) and Ready to Relay (RTR) in our work.

When a sender wants to send a data packet, it first waits for the DIFS + CW time period before it can transmit the data. After the sender can access the idle channel, it transmits a RRTS message. If the receiver receives the RRTS message correctly, it replies a RCTS message to the sender. A relay node that hears these control messages waits for a random short backoff internal (SBI) period. Within this period, the relay node decides whether to help the sender or not by estimating the energy consumption of direct transmission and the transmission with the help of relay. Firstly, the relay node determines a suitable pair of higher data rates based on the signal strength of the receiving RRTS and RCTS messages. Then it calculates the energy consumption with one-hop transmission and that with two-hop transmission. If two-hop transmission saves more energy, the relay broadcasts a Ready to Relay (RTR) message. This message contains the information about the selected rates that the sender and receiver should use when they send their data packets. If the sender cannot hear any response after SBI interval times out, the sender will transmit the data packet according to the standard DCF procedure.

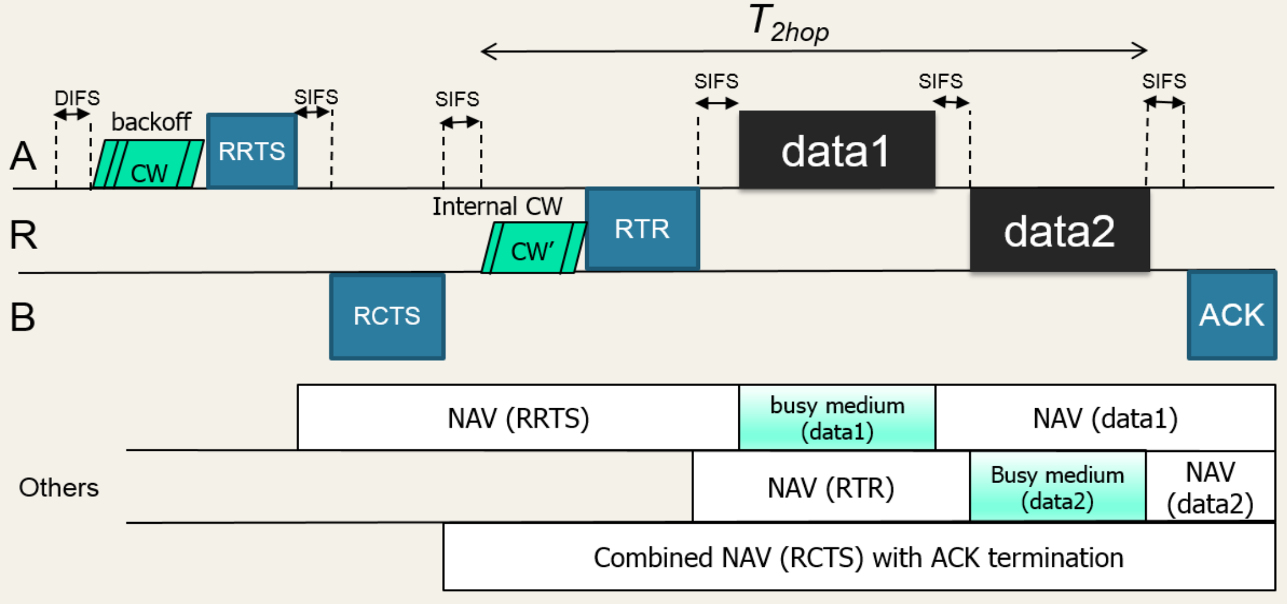


Figure 3 2PSPmessage handshaking

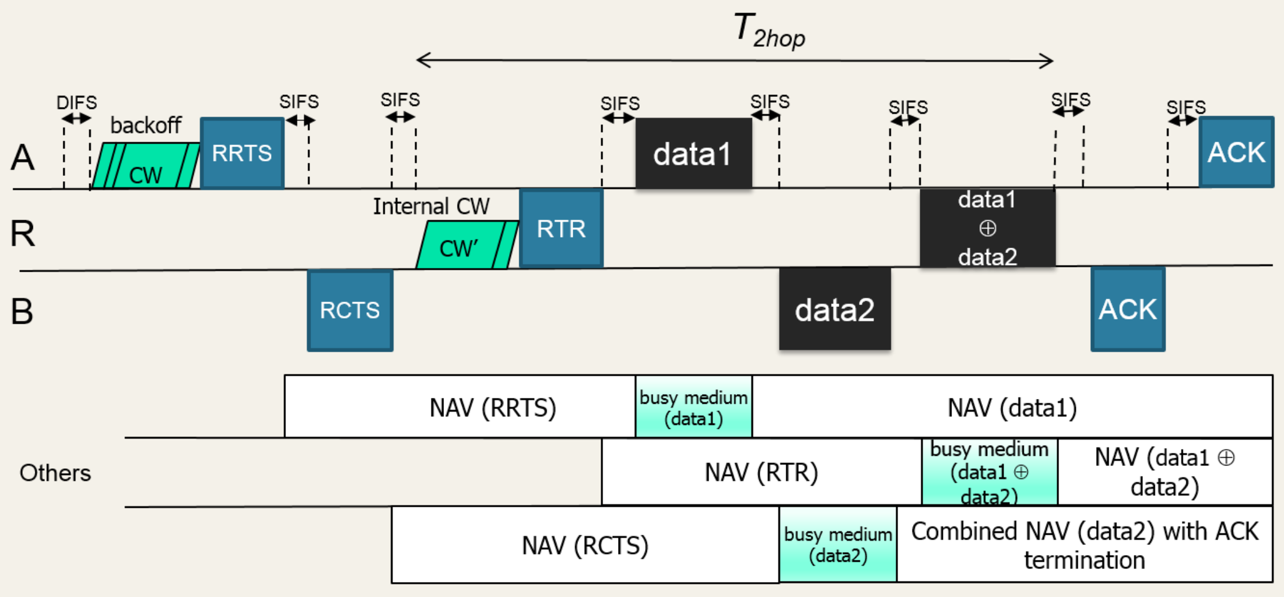


Figure 4 NCA-2PSP message handshaking

Results (Throughput, Energy Consumption, Fairness)

we investigate the performance of the proposed necoMAC scheme over the conventional CSMA/CA scheme and 2PSP protocol. Nodes are randomly generated in a 160 x 160 m^2 coverage area. Source and destination pairs are randomly selected and data flows are created along the paths produced by the AODV routing protocol. We generate all the nodes and flows, and run the simulation in the MATLAB environment. Then the proposed protocol tries to find the three-node golden chains and golden triangles along the paths to the destination. In each run of simulation, all the nodes, source-destination pairs and corresponding data flows are newly generated. We run the simulation 100 times and simulation results are averaged of 100 times.

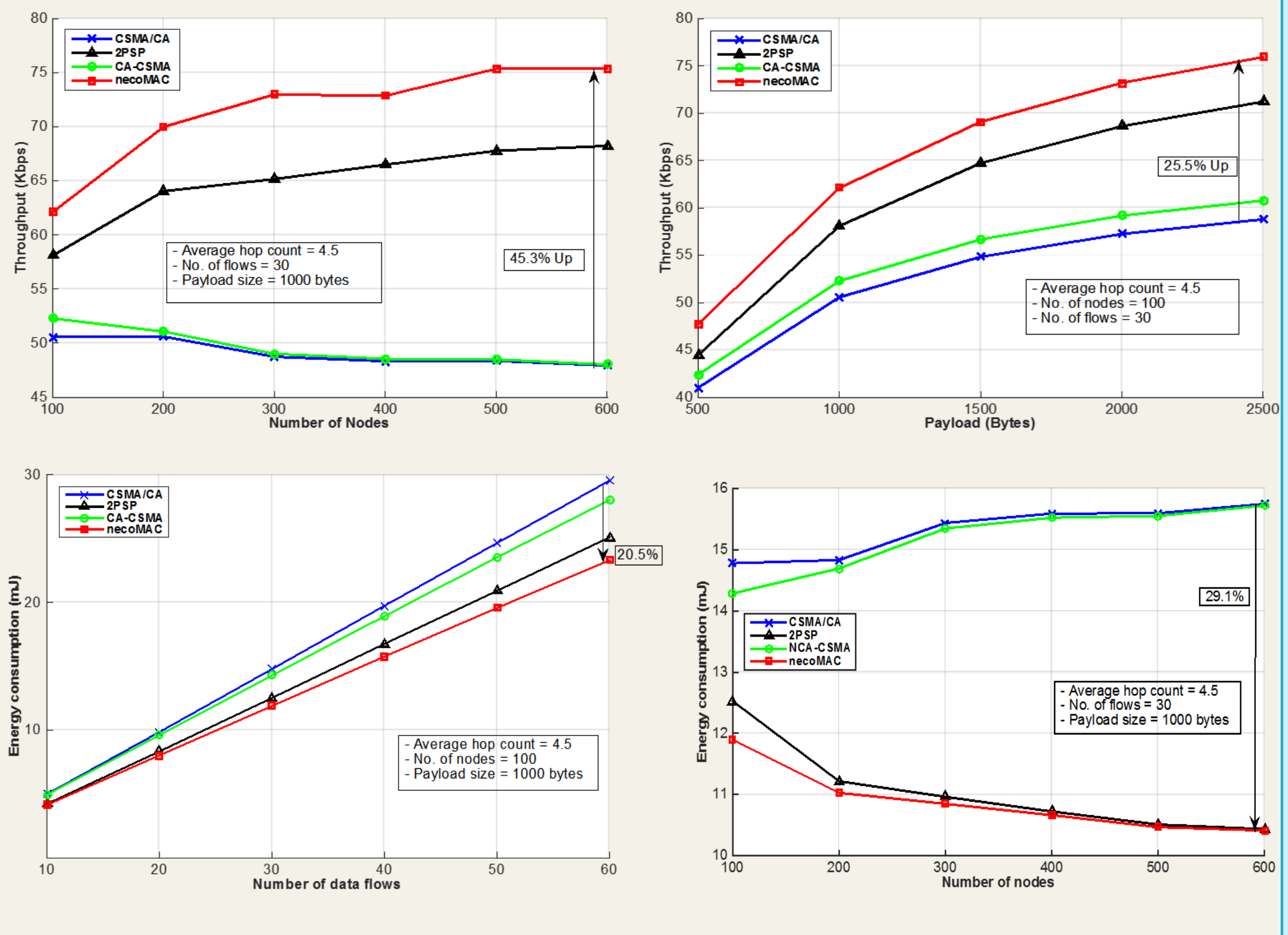


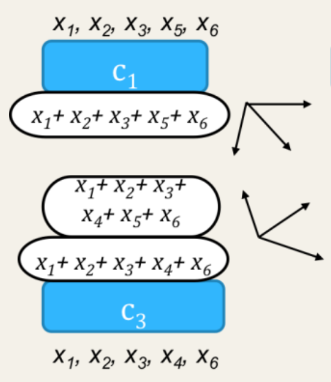
Figure 5 Throughput, Energy consumption

Network Coded Cooperative Data Exchange

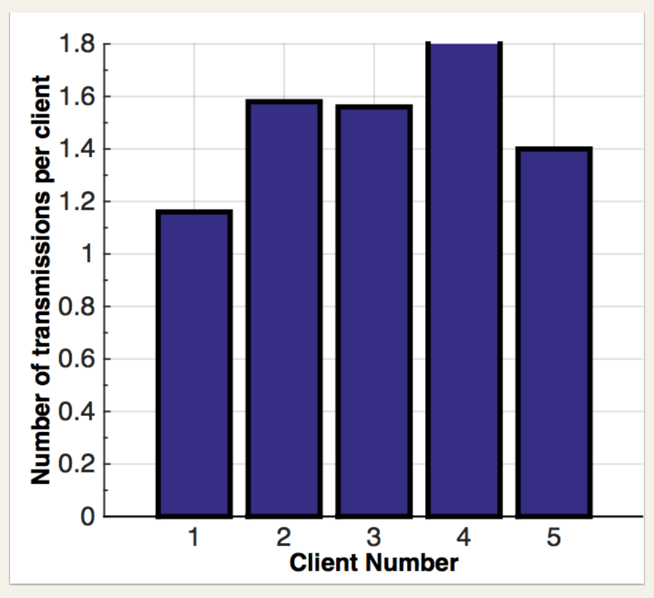
In this part, we consider a group of nearby wireless end devices such as mobile phones cooperating to exchange their received packets from a common base station in order to fulfill the lost packets in other members. This problem can be solved by the linear coding in which each client transmits linear combinations of the received. As the end devices have the limited energy resources, fairness should be a desirable property for each of them to support each other until all members in the group satisfy their needs. We introduce a cooperative algorithm that will maintain the fairness among nodes by distributing the number of transmissions they make. Moreover, we also incorporate physical layer network coding into this problem domain in order to further reduce the required transmission time slots and accomplish the data exchange process as quickly as possible.

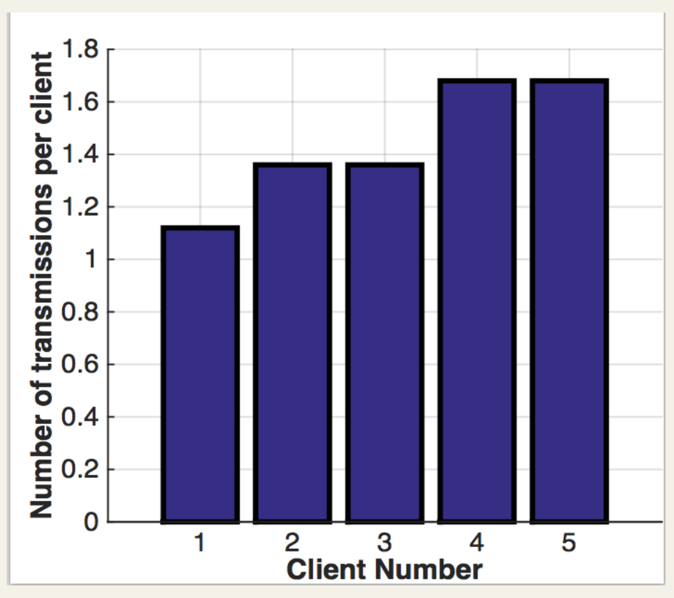
Balanced Cooperation for Data Exchange

In this algorithm, each client changes the role of transmitter and receiver based on the information they keep in each round of data transmission. Moreover, each node should also take into account the number of transmissions it made so far in order to maintain the fairness among the nodes. Our approach is to keep an information table like Table in every client. At the start of data exchange, all clients should broadcast the index information of their packet receiving status. Then the client with the maximum number of packets calculates the linear combination of its received packets and starts to transmit a combination. Deciding on a best combination is described in next section. After each round of linear coded packet transmission, every node updates its information table and can easily decide who should take turn for transmission in next round based on this information. This is possible because all nodes are within the transmission range and every node can hear the transmission from each other.



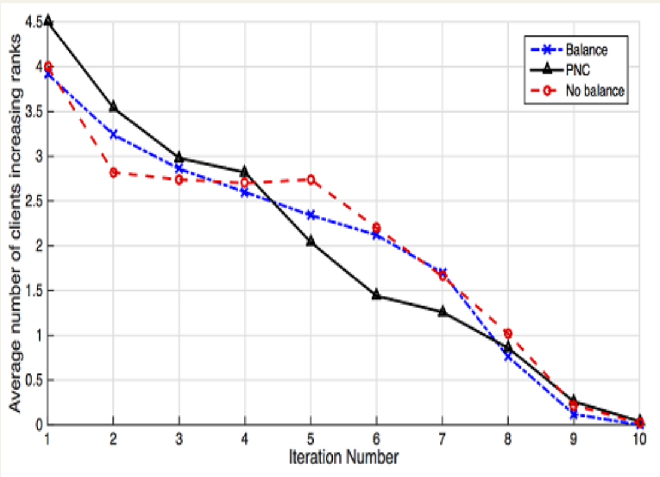
Clients	Packets	Transmissions
	$P_1P_2P_3P_4P_5P_6$	
C1	111011	1
C2	110001	0
C3	111101	2
C4	110101	0

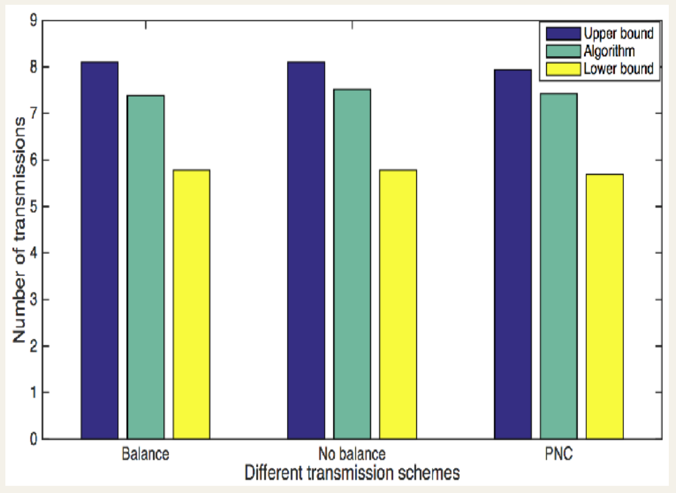




Physical Layer Network Coding for CDE

We apply the concept of PNC to data exchange algorithm. We consider transmitting the addition of two linear combinations from two clients. First, our algorithm chooses a linear combination from the client with maximum number of packets. Then it finds another linear combination from the second maximum-rank client. These two combinations are transmitted simultaneously and allowed to add in the air naturally when electromagnetic (EM) waves are superimposed on one another. We assume a relay node in a PNC system to deal with the mapping of the mixed signal to the desired network-coded signal $S_R = S_1 \oplus S_2$. Relay broadcasts S_R to the other clients in the second time slot. In the algorithm, we add two combinations first and then transmit the addition.





Conclusion

We have studied the network coding-aware CSMA which is applied at three-node golden chains and network coding-aware 2PSP that works for golden triangles with multirate transmission capability. We created a network coding aware medium access control scheme which incorporates NCA-CSMA, NCA-2PSP, 2PSP and CSMA/CA protocols. The simulation results reveal that more than 20% of energy is saved and 20--40% of throughput is improved by the proposed scheme.

We proposed a scheme for the balanced linear data exchange problem to maintain the fairness among the client devices to ensure that a certain client does not leave the group and lose the independent packets it stores. We used an information table that keeps the number of transmissions each client makes in each round of data exchange process to be taken into account in deciding the next transmitter client. By this approach, the total number of transmissions decreases while distributing the work load among the clients.

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