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An analytical approach to compare various MIMO techniques in wireless communications

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ABSTRACT

Today the world largely depends on the wireless network than the wired network, since the features like adaptability and extensibility has made the extensive use of the wireless network possible. In recent years the improvement in efficient use of energy of wireless sensor network is important so that the nodes should be working for a large time and the lifetime of the wireless network should be enhanced. In this paper we would be comparing various MIMO techniques.

Keywords - WSN, MIMO.

1. INTRODUCTION

WSN is a collection of nodes or sensors which monitors the physical or environmental conditions like temperature sound etc, it send sends the collected information to the main system through the gateway sensor node. The main characteristic of WSN include that it has the ability to cope with the node failure, here the mobility of node is possible while the nodes type could be heterogeneous and is easy to use. But here the power consumption is larger the constraints can be put on the nodes but it is not enough therefore we would be using MIMO technique to ensure efficient energy management.

MIMO (Multiple-Input Multiple-Output) is a technique in which the use multiple antennas concept or exploitation of spatial diversity techniques come into picture. It was proposed to fulfill the demand for providing high speed wireless communication links in harsh environments but subsequently it spread amongst the WAN, base stations etc. While in the WSN we have to deal with the energy constraints as WSN depends on the energy of the node.

Since the new WSN design does not require the high transmission rates but the battery is still a problem so to tackle that a cooperative MIMO [1] comes into picture. In the traditional MIMO we have to attach multiple antennas to a single node and then the transmission takes place, but this method is extremely costly and can drain the energy faster than the normal routine therefore the cooperative MIMO was used, here rather than giving multiple antennas to the single node multiple nodes are combined to send the data.

The concept of the cooperative MIMO was introduced in sensor networks by utilizing the collaborative nature of the nodes that is they can they can be clustered and make one, with this property the broadcast wireless medium is used to provide reliable communication links in order to reduce the total energy used by the network as the energy consumption will ow be divided on multiple nodes. Here multiple sensor nodes are combined to receive or transmit the data, another advantage is that the communication within the group that if the nodes are communication within the cluster then the energy consumed is very low. In this paper we will be comparing three cooperative MIMO which are as follows:

2. LEACH MIMO

If in a wireless sensor network we have N sensors which are distributed over a square area of side M meters. Let us assume that all the sensors are stationary, heterogeneous and energy-constrained. Here all the nodes can communicate with all the other nodes and the base station. The base station is independent of the energy and has receiving antenna. The sensors are clustered and each cluster consist a cluster head and other nodes which sense the environment for the data. The cluster heads are changed time to time as in the LEACH protocol. The proposed cooperative MIMO transmission scheme is discussed below. Here we propose the multi hop cooperative MIMO LEACH, it is also called as C-LEACH. The transmission model is shown in Fig.1.

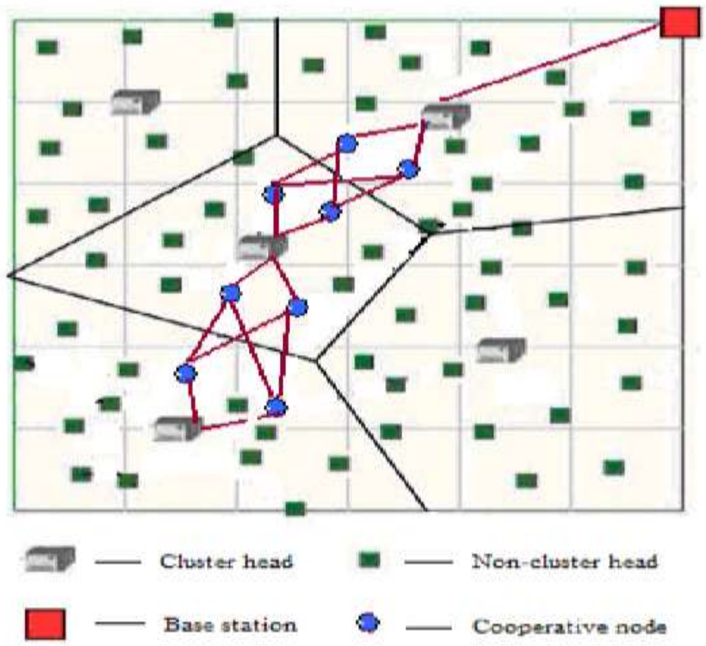

Fig.1. C-LEACH transmission model

The transmission procedure has multiple rounds and each rounds contain three phases which are as follows:

i. Cluster Formation phase

Here the clusters are organized and the MIMO nodes are selected from the following steps

a. Cluster Head Advertisement

Here when the clusters are made the LEACH protocol is applied and the cluster head is selected. Here the nodes can decide to become cluster heads or not. If the self-selected cluster head is made it broadcasts an advertisement (ADV) message using the non-persistent carrier sense multiple access (CSMA) protocol. The message contains the cluster head ID.

b. Cluster Setup

When a normal node or the non-cluster head receives the ADV it checks for the received signal strength imagine if two cluster heads are present say “X” and ”Y” and both sends the ADV to the other nodes and if the RSS of the Y is greater than the node will records it ID, same process is repeated with the Base station. Once the node accepts the ADV it sends the Joining request (Join-REQ) message back to the cluster head. The information about the node’s capability of being a cooperative node, i.e., its current energy status is added into the message.

c. Schedule Creation

Once all the nodes sends the Join-REQ to the head it creates a time division multiple access (TDMA) schedule and broadcast to all the cluster members so that they know their work and time as in the LEACH protocol.

d. Cooperative Node Selection

Once the cluster will form they will select the nodes which will transmit and receive the data respectively for the MIMO communication. The neighboring nodes with high energy will be elected as the sending and receiving cooperatives nodes for the cluster. At the end of the phase the cluster head will broadcast a COOPERATE-REQ message which contains the cluster heads, ID, the ID of the transmitting and receiving cooperative nodes and the index of cooperative nodes in the cooperative node set of each cluster head to each cooperative node. The cooperatives nodes stores the information and sends a COOPERATE-ACK message to the cluster head for the approval.

ii. Routing Table Construction

In this phase the cluster will maintain the routing table. The table will consist the destination cluster ID, next hop cluster ID, IDs of cooperative sending and receiving nodes. Every time the table is updated the ACK message is sent to the cooperative nodes by the cluster heads o update their routing table. The Cluster head also sends the information to the base station for the processing.

iii. Data transmission phase

This is the last phase here the data collected by the sensors will be sent to the base station with the help of multi hop MIMO scheme and the routing table created. The transmission held are as follows:

a. Intra Cluster Transmission

As we are using the LEACH protocol the cluster member were given time slots to collect the data and to transfer it to the cluster head. The duration and the number of the frames are same for all the cluster but the cluster member can vary so the output data.

b. Inter Cluster Transmission Broadcasting

Once the cluster head has received all the data from all the cluster members, it will perform the aggregation of the data. After that it will send a broadcast to the Cooperative Sender node. The broadcast will contain the data and the synchronization information. The number of cooperative nodes involved for MIMO transmission is based on space time block coding requirement. The advantage of using STBC technique is that they provide transmit and receive diversity gain in cooperative MIMO system. The diversity gain therefore provides reliable and energy efficient transmission.

3. VIRTUAL MIMO

Virtual MIMO system is developed where multiple single user antennas share their antennas to create virtual antenna arrays [3]. This cooperation is achieved using the help of Distributed Space Time Block Codes (DSTBCs). The system model of the Virtual MIMO is shown in the following figure.

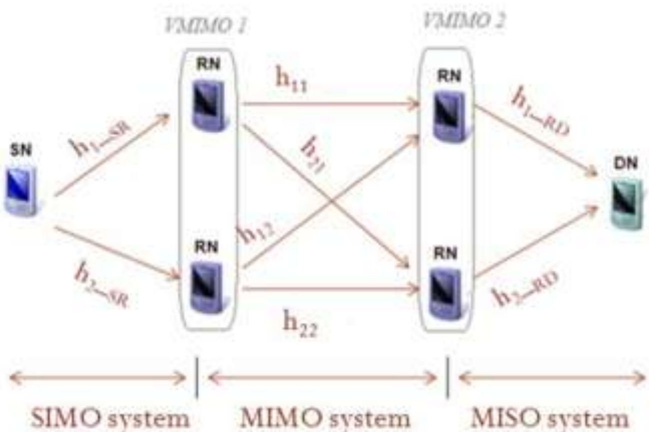

Fig. 2 Block diagram of 3-hop virtual MIMO System

Here as shown in the figure all the nodes that is the source, destination and intermediate nodes considered are single antenna nodes. In the figure shown we can see two VMIMO consisting of the two nodes the source transmits the data to first VMIMO and VMIMO process the data using DSTBC and sends the data to the second VMIMO, now again the processing is done and the data is transmitted to the destination.

i. Relay Selection

The relay plays an important role in the performance of the virtual MIMO system, because if the relay is equidistant from the source and the destination then we can get the best performance from the system. Based on all such concept relay selection algorithms are developed which are as follows:

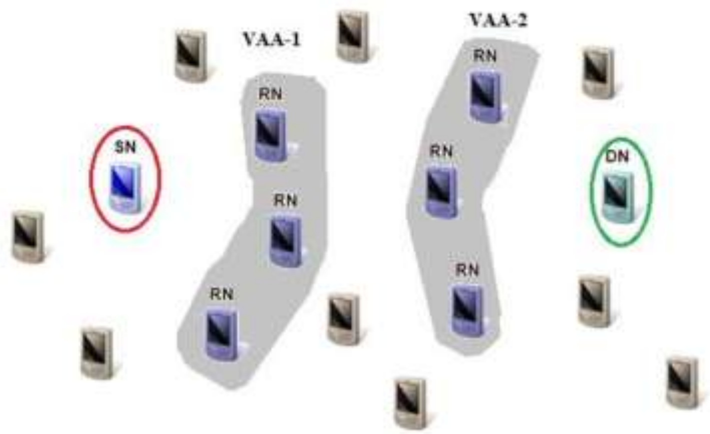

Fig. 3: Relay Selection

A. Simple Relay Selection Algorithm

In the simple relay algorithm the Euclidean distance between the nodes is calculated and the positions are assigned randomly to the set of nodes involved in the relay selection. Only the source and destination are fixed. The simple relay selection algorithm is as follows:

1. For each node N, calculate the distance DNS and DND where DNS is the distance between node N and source(S) and DND is the distance between node N and destination (D).
2. Sort the nodes in ascending order based on DNS and DND to form VAA-1 and VAA-2.
3. The first two nodes from VAA-1 and VAA-2 are chosen to form VMIMO-1 and VMIMO-2.

Major disadvantage of this algorithm is that if the distance is more than the performance of the system degrades.

B. Adaptive Relay Selection Algorithm

The Adaptive relay overcomes the problem of the Simple algorithm by introducing an intermediate VMIMO relay if the distance is more. Initially, as detailed in simple relay selection algorithm, nodes for VMIMO-1 and VMIMO-2 are selected. The adaptive algorithm is as follows:

1. Calculate the distance between the two VMIMO nodes.
2. If distance > threshold
3. » Intermediate virtual MIMO relay needs to be considered. The intermediate nodes are chosen based on distance to form the 4-hop system.
4. » Calculate the distance between the VMIMO nodes of 4-hop system.
5. » If the intermediate relay is too far, then that relay is avoided and 3-hop system is chosen.
6. Else » Continue with the 3-hop system.

4. GENETIC MIMO

In the genetic method the solutions to the optimization problem are encoded in set known as chromosomes. These chromosomes crossover, mutate, and evolve to get the optimal solution over multiple iterations. The chromosomes are termed fit if they can pass their solution as parameters to the next order. The genetic algorithm is defined briefly below.
The initialization stage: A set of “N” chromosomes is randomly set. Each chromosome has a vector “K” which indicates the schedule of the user. If K = 1 then the user is scheduled whereas if K=0 then user is not scheduled. The chromosomes are constrained to be between 1 and k_0, since if there are multiple k_0, Available then they all can be scheduled at same time. There is also a second part known as tail to the chromosome it indicates a user precoding order. But for the Block

Diagonalization we do not need the encoding order and hence it is left off. So here only the Genetic Algorithm is used to schedule users in the context of zero-forcing beamforming.

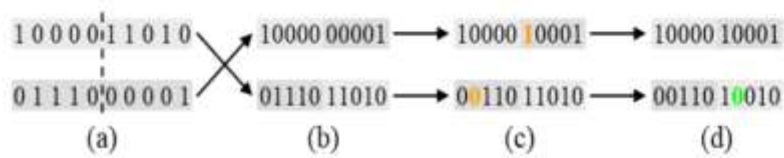

Fig. 4 Example of GA chromosomes for scheduling with $K_0 = 4$ and $K = 10$ in a BD system, and typical breeding process during one generation. (a) Two typical chromosomes, showing scheduling of users $\{1, 6, 7, 9\}$ and $\{2, 3, 4, 10\}$, respectively. Random crossover point also shown. (b) Crossover operation. (c) Mutation. (d) Repair of invalid chromosomes.

The Selection stage: The probability from which the parent two chromosomes is selected is as follows:

$$p_i = G_i / \sum_{\forall n} G_n,$$

Here G_i is the utility function values of the ith chromosome or we can say the FIT part. The Breeding Stage: Here a chromosome is given a random position, then the two parents will swap their data bits with the child data bits. This crossover operation occurs when there is probability p = 1. The next step is when the child undergo mutation operation where the child has the probability

$$p_m = 1/(\beta_1 + \beta_2 \sigma_G / \mu_G)$$

Here μ_G and σ_G are the mean and the standard deviation of the fitness of the current population chromosome before selection. If the is solution generated by the child which violates the constraints then that chromosome is altered to match the constraints. Here the 1 is toggled to k_0 and if 0 is found then it is toggled to 1.

The Iteration Stage: The selection and the breeding process is repeated until a new set of chromosomes is created, once these are created they will override the old set of the chromosomes. This process will repeat until the G generations. The Genetic algorithm here is so efficient that it keeps the best outputs of the past generations into the new one. During each iteration, the set of chromosomes are created the best ones from them are kept same and the others are swapped with the bests of the past generations the above figure shows the typical example of the chromosomes and the genetic algorithm.

CONCLUSION

All the three above mentioned cooperative MIMO techniques are reviewed and they have their own advantage and disadvantage. We will be creating all the three and will test for the best technique to implement the Cooperative MIMO in the WSN.

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