Energy Efficient Transmission in Random Clustered Wireless Sensor Networks Using Cooperative MISO

Abhaya D S, Remya Annie Eapen

Abstract*— *Wireless sensor networks are composed of many wireless sensing devices called sensor nodes. These nodes are small in size, limited in resources and randomly deployed in harsh environment. The replacement or recharging of battery is difficult; therefore energy consumption is necessary for WSN. Employing Multi Input Single Output (MISO) links can improve energy efficiency in Wireless Sensor Networks (WSN). Although a sensor node is likely to be equipped with only one antenna, it is possible to group several sensors to form a virtual MISO link. Such grouping can be formed by means of clustering. Cooperative MISO is considered here which aims at reducing energy consumption in multi hop WSNs. In order to improve the energy efficiency a sleep technique is also considered

Index Terms*— *Random wireless sensor networks, cooperative multi-input-single-output, multi input single output

I. Introduction

Wireless Sensor Networks have nodes that are typically powered by batteries, for which replacement or recharging is very difficult [1]. Thus in many scenarios, the wireless nodes must operate without battery replacement for many years. Consequently, minimizing the energy consumption is a very important design consideration and energy- efficient transmission scheme must be used for the data transfer in sensor networks. Multi-Input-Multi-Output (MIMO) systems can support higher data rates under the same transmit power budget [2]. Also MIMO systems require less transmission than Single- Input- Single- Output (SISO) systems. However, direct application of multi antenna techniques to sensor networks is impractical due to limited physical size of a sensor node which typically can support only a single antenna. Consequently, if we allow individual single antenna nodes to cooperate on information transmission and/ or reception, a cooperate Multi-input- single- output (cooperative MISO) system can be constructed [3] [4] [5].

A cooperative scheme for a clustered WSN is considered in [6] to obtain the optimal solution of the tradeoff between the outage performance and the network lifetime. Also he considers the sub problem, the long haul transmit power per sensor node. For the clustered WSN the hop distance and the number of cooperating nodes on the energy consumption of multi-hop cooperative MISO transmission is analyzed in [7].

Some existing work says about the energy-efficient transmission in CMIMO systems. The energy consumption can be reduced by joining information transmission and reception in the CMIMO systems compared with non-cooperative systems [8]. The overall energy consumption is reduced by jointly adopting CMIMO and data-aggregation techniques. It is done by reducing the amount of data for transmission and better using network resources through cooperative communication. Here, the optimal cluster size that minimizes the average energy consumption per node is also obtained based on the energy model [9].

The performance of a cooperative communication scheme in a clustered wireless sensor network is analyzed with some practical assumptions such as error detection is done at the packet level also only nodes that correctly decode received packets can cooperate, leading to a random number of cooperates per packet transmission. The total energy consumption can be minimized by optimally adjusting the transmit energy levels for the intra cluster and inter cluster transmissions. Energy savings relative to direct transmissions can be achieved, even with strict requirements on throughput and delay [10].

In this paper, a cluster based cooperative communication is considered in which geographically dispersed nodes exchange information among themselves and thereby construct a MISO structure. First, we consider a random distribution of sensor nodes and divide the sensor nodes into clusters. The LEACH protocol is used for clustering. Here, we compare the energy consumption with inter cluster and intra cluster and also energy consumption with node density. Also a sleep strategy is incorporated to further reduce the energy consumption.

The remainder of the paper is organized as follows. Section II describes the system model. Section III provides the details about cooperative MISO. Section IV provides data transmission phase. The energy consumption minimization is explained in section V. The experimental results are discussed in Section VI and conclusions are presented in Section VII.

II. System Model

We consider a random clustered WSN, where hundreds or thousands of sensor nodes are equipped with single antenna. The clustering of sensor nodes is done by using LEACH protocol. If the cluster has data to send the cluster head will broadcast the data to other cluster members within cluster, then the cluster head and the cluster members within the cluster will send the data to the cluster head of the next cluster or destination together in a cooperative way. The cooperative transmission includes both intra cluster transmission and inter cluster transmission. In the intra cluster broadcasting the cluster head will broadcast the data to other sensor nodes within the cluster to enable cooperative transmission. In the inter cluster transmission the cluster head and the nodes within the cluster cooperatively form a virtual antenna array and transmit the data to the cluster head of another cluster.

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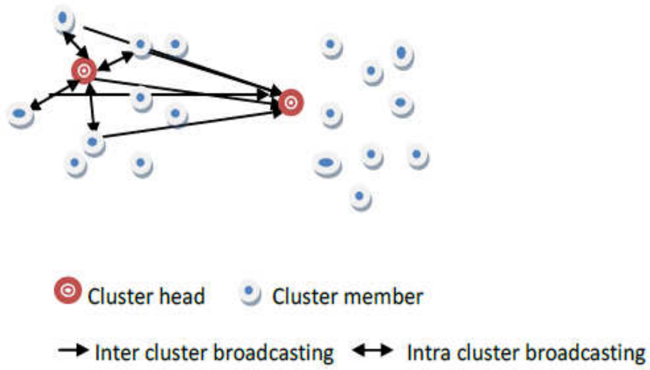

Fig 1: System model

III. COOPERATIVE MISO

The clusters are organized and cooperative MISO nodes are selected according to the steps described below:

A. Cluster Head Advertisement

Initially, when clusters are being created, each node decides whether or not to become a cluster head for each round as specified by the original LEACH protocol. Each self-selected cluster head, broadcasts an advertisement (ADV) message using non-persistent carrier sense multiple access (CSMA) protocol. The message contains the header identifier (ID).

B. Cluster Setup

Each non-cluster head node chooses one of the strongest Received signal strength (RSS) of the advertisement as its cluster head, and transmits a join-request (Join-REQ) message back to the chosen cluster head. The information about the node's capability of being a cooperative node, that is, its current energy status is added into the message. If a cluster head receives an advertisement message from another cluster head say y, and if the received RSS exceeds a threshold, it will mark cluster head y as the neighboring cluster head and it record the ID. If the sink receives the advertisement message, it will find the cluster head with the maximum RSS, and sends the sink-position message to that cluster head marking it as the target cluster head (TCH).

C. Schedule Creation

After all the cluster heads has received the join-REQ message, each cluster head creates a time division multiple access (TDMA) schedule and broadcasts the schedule to its cluster members based on the LEACH protocol. This prevents collision among data messages.

D. Cooperative Node Selection

After the cluster formation, each cluster head will select N cooperative sending nodes for cooperative MISO communication. Nodes with higher energy close to the cluster head will be elected as sending cooperative nodes for the cluster. At the end of the phase, the cluster head will broadcast a cooperative request (COOPERATE-REQ) message, which contains the ID of the cluster itself, the ID of the neighboring cluster head y, the ID of the transmitting cooperative nodes and the index of cooperative nodes in the cooperative node set. The cooperative node on receiving the COOPERATE-REQ message, stores the cluster head ID and sends back a cooperate-acknowledgement (ACK) message to the cluster head.

IV. DATA TRANSMISSION PHASE

During this phase, the data sensed by sensor nodes are transmitted to the cluster head and forwarded to the sink using multi-hop MISO scheme.

A. Intra Cluster Transmission

In this phase, the non-cluster head nodes send their data frames to the cluster head as in LEACH protocol during their allocated time slot. The duration and the number of frames are same for all clusters and depend on the number of non-cluster head nodes in the cluster.

After a cluster head receives data frames from its cluster members, it performs data aggregation and broadcasts the data to cooperative MISO sending nodes. When each cooperative sending node receives the data packet, they encode the data using space time block code (STBC) and transmit the data cooperatively.

B. Inter Cluster Communication

In the inter cluster transmission the cluster head and the collaborating nodes transmits the data to another cluster head cooperatively by forming a virtual antenna array.

V. ENERGY CONSUMPTION MINIMIZATION

The overall energy consumption is the combination of intra cluster energy consumption and inter cluster energy consumption. When there is large number of data packet to be transmitted to longer distances energy minimization can be done by participating large number of nodes cooperatively for the data transmission. Only small number of cooperative nodes is needed to send the data packets within smaller distances. The energy consumption can be further minimized by using sleep approach. Sleep approach, aims to increase the WSN lifetime by using reducing the energy consumption as well as increasing the Packet Delivery Ratio (PDR). The C-H is selected based on energy efficiency and subsequently the data packet transmission will takes place. First the C-H creates a path to Base-station. Then the Base station can send the WORK REQUEST message to C-H. The cluster head will send a work message to the sensor node and then the transmission takes place. Here the nodes are selected based on the residual energy. The sensor node with more residual energy take part in the transmission. Nodes with less residual energy will go to sleep. After that the data packet transmission will taken place to base station. Subsequently, the sleep node does not send the data packet to base station. The initial energy of the nodes is given as 1000J. The energy consumed is calculated from the trace file.

VI. EXPERIMENTAL RESULTS

The simulation results for the proposed scheme are presented in this section. The simulation platform used is NS2. The system parameter considered here is the energy consumption. We consider a simulation setup which consists of a network of 40 nodes which are placed in the flat grid and it is shown in figure 2.

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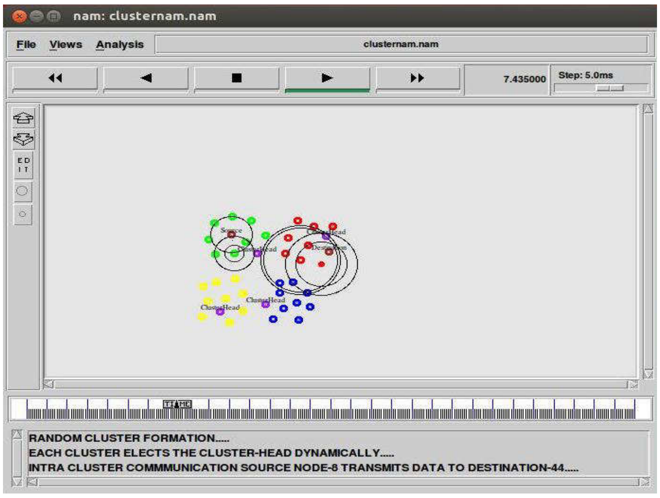

Fig 2 : Nam window showing node placement

Fig.3 compares the distance and the energy consumption. It shows that for the smaller distance, that is, the data transfer between the nodes within the cluster consumes less energy and for larger distances it consumes more energy.

Fig.4 shows the comparison between the energy consumption and the number of nodes. From the graph it is clear that, if more number of nodes participate in the cooperate transmission the energy consumption decreases.

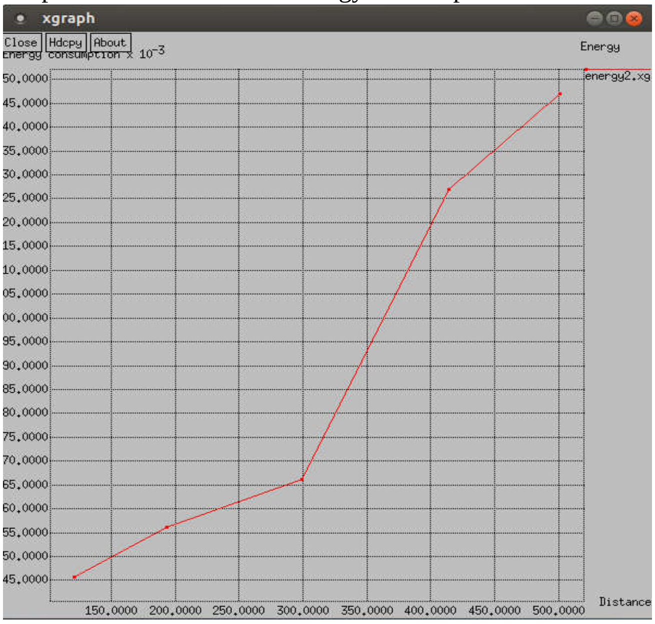

Fig.3. Energy consumption vs distance

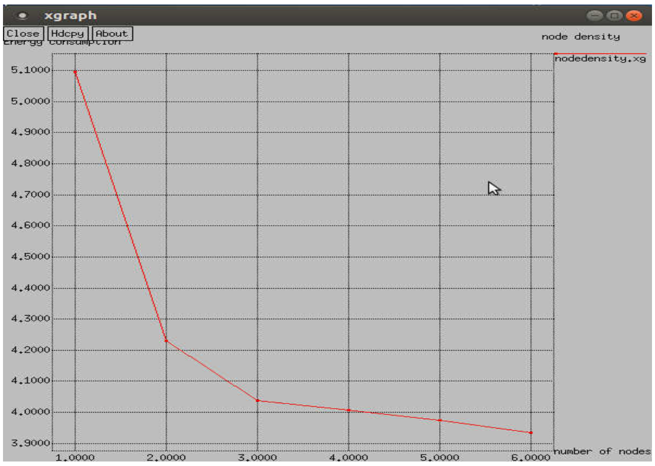

Fig.4. Energy consumption vs number of nodes

Fig.5 illustrates the comparison between the energy consumption and the node density. The optimal number of nodes to transmit data to a cluster head at a distance of 100m is one. The figure shows that, as the number of cooperative nodes increases the energy consumption also increases for shorter distances.

The energy consumption is plotted against node density for a distance of 500m is shown in figure.6. Here, the optimal number of cooperative nodes for transmission is 2.The energy consumption is 1.3J.

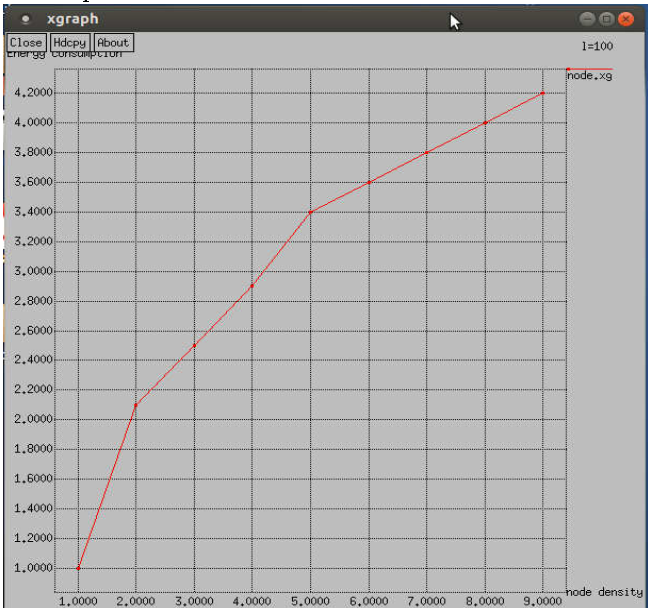

Fig.5. Energy consumption vs node density for distance = 100m

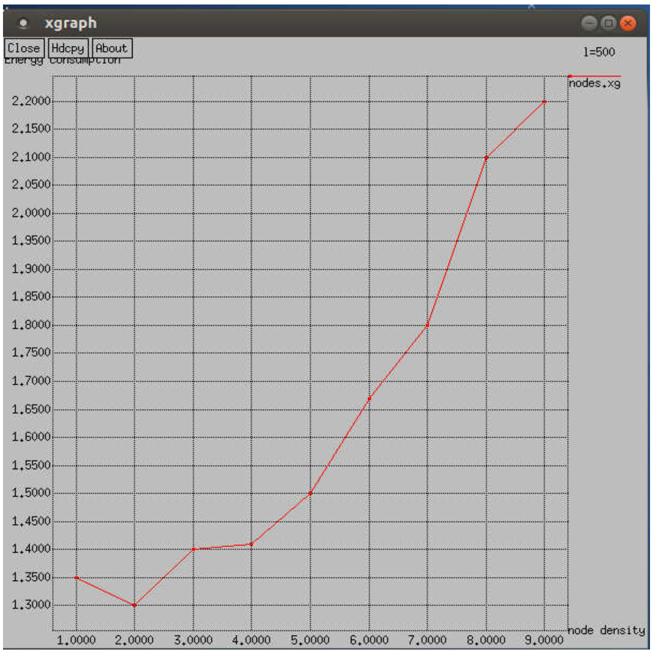

Fig.6. Energy consumption vs node density for distance = 500m

Fig.7 shows the comparison between the energy consumption and the node density for a distance of 1000m. Here, the optimal number of nodes for transmission is 4, because the energy consumption is very low for cooperative transmission of four nodes at a distance of 1000m. The energy consumption is about 1.2 J.

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Sleep schedule will further decreases the energy consumption of nodes than cooperative MISO. In this sleep strategy the node which is very nearer to the CH and also nodes with higher residual energy is employed for transmission and others are forced to sleep for a period of time.

In figure 8,for distance of 100 m between the clusters, the energy consumption decreases when more number of nodes is allowed to sleep. This is because, when the node is kept sleep the idle energy consumed for the nodes can be avoided and more energy can be saved.

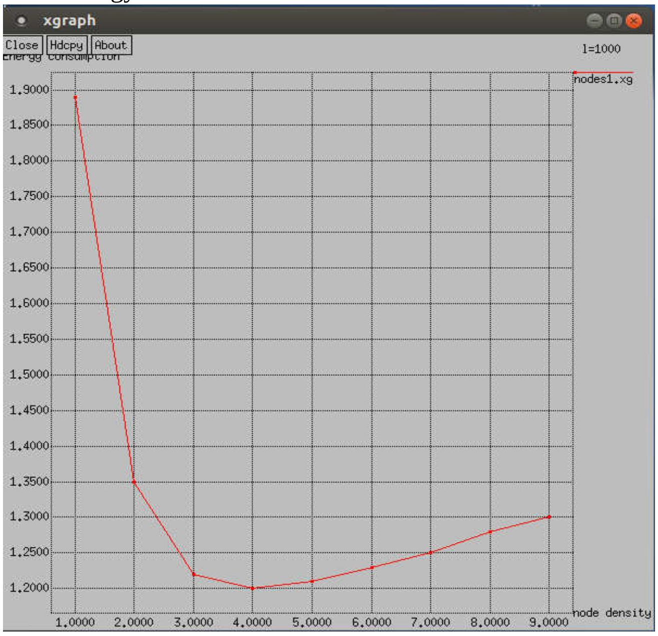

Fig.7. Energy consumption vs node density for distance = 1000m

In fig.9 the energy consumption is plotted against number of nodes allowed to sleep. It shows that when the inter cluster transmission takes place between two CHs which are placed 500 m apart, the optimal number of sleep nodes are 8.

From the fig.10 the optimal number of sleep nodes to transmit at a distance of 1000m is 6. The energy consumption at the sixth node is very low. Therefore the remaining energy of the nodes will be high. That is the network life time increases.

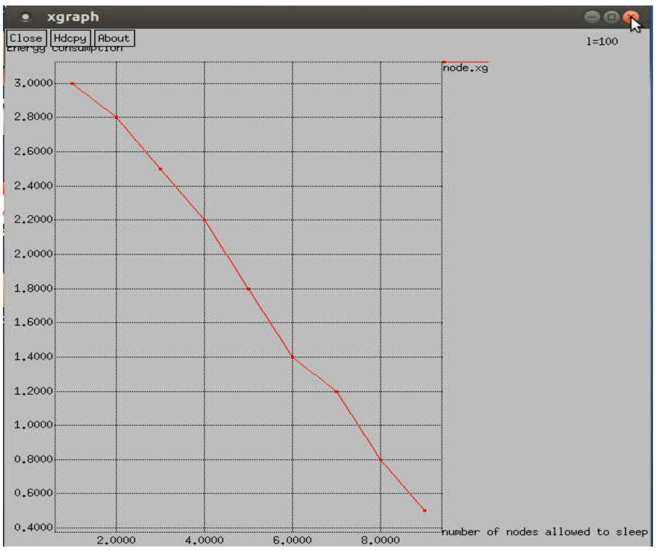

Fig.8. Energy consumption vs number of nodes allowed to sleep for distance =100m

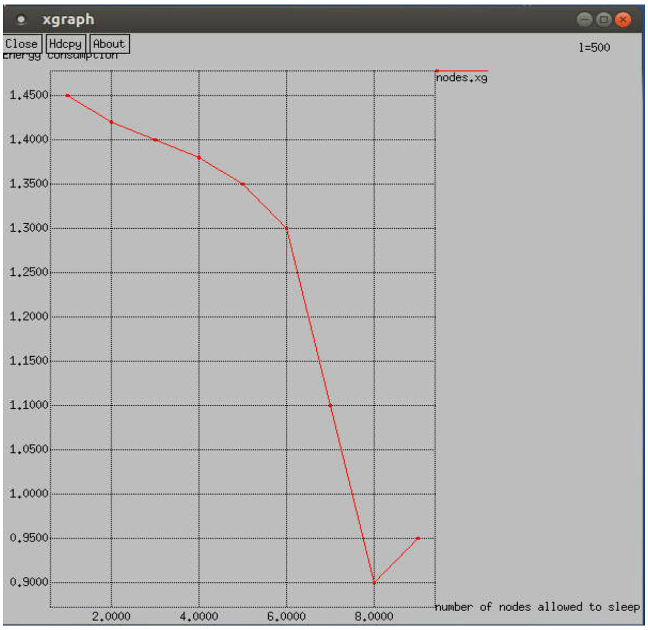

Fig.9. Energy consumption vs number of nodes allowed to sleep for distance =500m

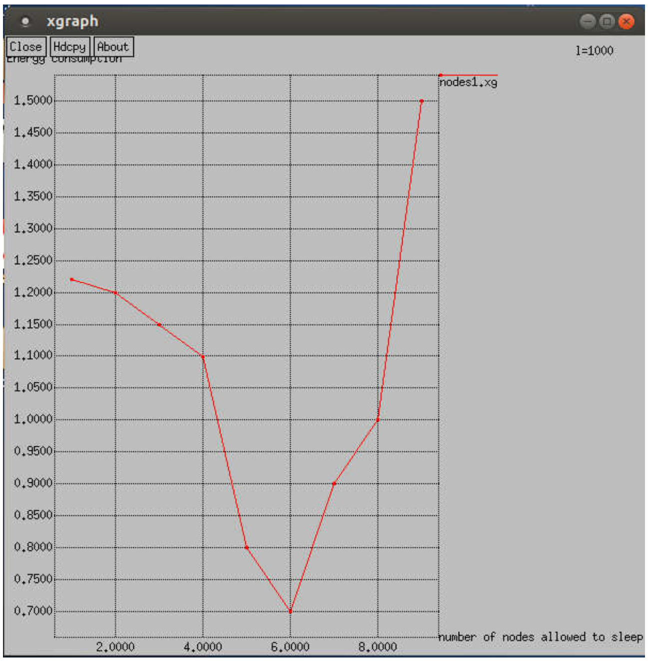

Fig.10. Energy consumption vs number of nodes allowed to sleep for distance =1000m

VII. CONCLUSION

In this paper, we analyzed the performance of a cooperative communication scheme in a clustered random wireless sensor network. Here, the overall energy consumption can be minimized by cooperative transmission of sensor nodes by increasing node density. Simulation results shows that for larger distances the energy consumption is more and it can be minimized by cooperating more number of nodes in transmission. Simulation results also addresses the optimal number of nodes needed for transmission with different distances. The energy conservation can be improved by sensor node sleep strategy. The sleep nodes are selected based on the highest residual energy. Furthermore, in future works, we can consider other network parameters to minimize the total energy consumption.

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