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Energy Efficient Wireless Sensor Network Using Cooperative Communication

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Abstract—A network like sensor networks have energy constrained devices. The energy consumed by the nodes need to be less which prevents the earlier death of the sensor nodes due to drained energy level. Several techniques, methods are proposed and used to reduce the energy consumed by the sensor nodes. Thus lifetime of the network, one of the recent and significant research area in sensor network plays a vital role when deploying a sensor networks in real time applications having harsh environments where there is the chance for battery replacement is difficult or impossible. This work focuses on improving the lifetime of the sensor network using cooperative multi-input multi-output (CMIMO) transmission strategy. The nodes in the network cooperate with each other and then perform the transmission of data from source to the base station. So that the energy consumed by the nodes also reduced. Furthermore the cuckoo search optimization algorithm is used for cluster formation so as to make the clustering to be more energy efficient.

Keywords: Wireless Sensor Network, cooperative communication, clustering, routing, lifetime.

I. INTRODUCTION

A wireless sensor network is a type of ad hoc network having small light weight and portable wireless nodes deployed in large number to monitor the environment or system to measure the physicalparameters such as temperature, pressure, or relative humidity, wind direction and speed, sound intensity, pollutant levels, vibration intensity and some vital body functions. Each node in the sensor network consists of three subsystems. They are sensing sub system (to sense the environment), processing subsystem (performs local computations on the sensed data), communication subsystem (responsible for message exchange with neighboring nodes). The potential applications of sensor networks include industrial automation, automated and smart homes, robot control, environmental monitoring, traffic monitoring, video surveillance, air traffic control and medical device monitoring. The important operations in the sensor networks include Data Dissemination (propagation of data/query throughout the network) and Data Gathering (collection of observed data from the individual sensor nodes to sink). The major issues that affect the design and performance of the Wireless Sensor Networks are as follows: Hardware constraints of sensor nodes, Wireless Radio Communication Characteristics, Medium Access Schemes, Calibration, Data Aggregation and Data Dissemination, Database centric and Querying, Middleware, Programming models for WSN, Quality Of Service (QOS), Security. The nodes in the wireless sensor networks are battery powered. If the sensor nodes are deployed in any disaster area then it is difficult to reach them. In addition, if the network contains more number of sensor nodes then making the process of collecting those nodes for recharging is an expensive and time consuming process. Hence improving energy efficiency is always a research area in Wireless Sensor Networks. Several approaches have been proposed to make the energy efficient WSN. The possible approaches are Controlling the transmission power, Clustering the nodes which reduces the communication across the networks, Some nodes are put in sleep mode according to their duty cycles, Multi Input multi Output (MIMO). MIMO(Multi-input multi-output) is based on the antenna arrays which significantly reduces the transmitting power by utilizing the spatial diversity under fixed performance requirements such as throughput and PER(Packet Error Rate) in fading channels. However, the nodes in the WSN usually have small operation platform and are not practical to equip with multi-antennas due to size limitation. Thus the technology called cooperative MIMO (CMIMO) is introduced and become an active research area in WSN. The concept of CMIMO is that, multiple adjacent nodes with single antenna form a virtual antenna array to achieve spatial diversity. Hence the sensor nodes in the WSN become energy efficient when compared to direct transmission. Cooperative communication is one of the fastest growing areas of research, and it is likely to be a key enabling technology for efficient spectrum use in future. The key idea in cooperation is that of resource-sharing among multiple nodes in a network. The reason behind the exploration of cooperation is that willingness to share power and computation with neighboring nodes can lead to savings of overall network resources. Cooperation is possible whenever the number of communicating terminals

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greater than or equal to two. The cooperative communication can avoid the difficulties of implementing actual antenna arrays and convert the single-input single- output system into a virtual multiple-input multiple-output system. In this way, cooperation between the users allows them to exploit the diversity gain and other advantages of MIMO system in a SISO wireless network.

A. CMIMO

Cooperative communication is an improvement of direct communication by asking other neighbor nodes for cooperation. Usually it means a packet forward by an intermediate node so as to gain spatial diversity at the receiver side, which also means at least one more transmission will have to be made than before.

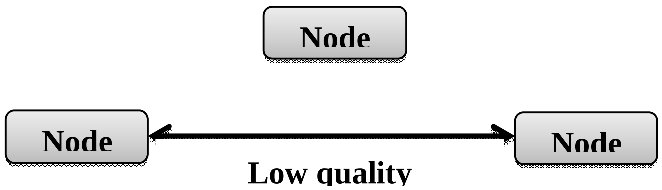

Fig. 1. Data transmission without cooperative communication

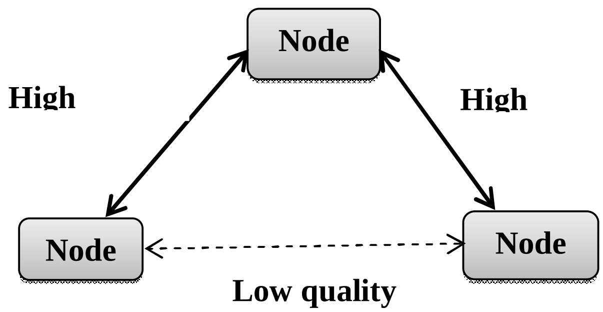

Fig. 2. Data transmission with cooperative communication

B. Direct Transmission

A regular transmission can be one or more hops. i.e. it can be unicast or broadcast, or it can be multi hop. They set the address of next hop in packet header without considering the performance of connections. To be specific, in direct transmission a packet normally will go through all the network layers when sending out, go up to some certain layer when forwarding (depends on which layer is responsible of forwarding) and then go down again, and while receiving go through all the network layers again but with an opposite way of sending. Figure 1 shows the direct transmission between the nodes. Figure 2 shows the cooperative transmission between nodes.

II. BACKGROUND

Wireless Sensor Network has energy efficiency as an important issue since the sensor nodes are battery powered. Lee and Heesan proposed an energy-efficient cooperative communication method which forms clusters and establishes inter cluster routes directly or via relay nodes [1]. Bin Li et al studied CMIMO energy consumption in a random wireless sensor network where the nodes are distributed randomly. The clusters are formed to transmit the packets to the relay clusters using CMIMO [2]. In the [3] done by, Cui et al proposed MIMO for WSNs, where MIMO is based on Alamouti diversity schemes and it is extended to individual single antenna array nodes. The array nodes cooperate with each other to form multiple antenna transmitters or receivers. By receiving and sending information jointly, a lot of energy can be saved. MIMO system outperforms SISO (Single Input Single Output) after a certain distance. Zhang and Dai focus on energy efficiency of the data collector nodes in the wireless sensor networks. The data collectors are equipped with antenna arrays (VMIMO) and superior processing capability [4]. In [5] Chu et al focused on the MIMO-based ad hoc network. This paper exploits the use of cooperative relay transmission. Cooperative relay transmission is used when the direct transmission cannot successful. In [6] proposed an energy-efficient virtual multiple-input multiple-output (MIMO)-

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based communication architecture for distributed and cooperative wireless sensor networks. In this paper semi-analytic techniques are used. Suresh and Selvakumar proposed a clustering algorithm to provide efficient energy consumption in such networks [7]. The main idea of this article is to reduce data transmission distance of sensor nodes in wireless sensor networks by using the uniform cluster concepts. In order to make an ideal distribution for sensor node clusters, they calculate the average distance between the sensor nodes and take into account the residual energy for selecting the appropriate cluster head nodes. The lifetime of wireless sensor networks is extended by using the uniform cluster location and balancing the network loading among the clusters.

III. SENSOR NETWORK LIFETIME

Lifetime is the amount of time that a wireless sensor nodes would be fully operative. In other words lifetime is the time at which the first network node runs out of energy to send a packet, because to lose a node could mean that the network lose some functionalities. The lifetime of the network is calculated using the following expression.

Lifetime=((initial energy/consumed energy by the node)*simulation time)/(time in seconds)

Moreover in some scenario network life is considered as the period until the entire region discovered. Several metrics for network lifetime are defined, e.g., N-of-N lifetime, K-of-N lifetime and m-in-K-of-N lifetime. N-of-N lifetime means the time duration until first gateway dies. K-of-N lifetime means survival of the network until K gateways out of N are alive and m-in-K of N lifetime means the time duration until all m supporting gateways and overall a minimum of K gateways are alive.

IV. SYSTEM MODEL

The system model involves sensor nodes are deployed randomly in a field. The senor nodes are grouped into clusters based on the distance. The data sensed by the nodes are transmitted to the cluster head. The cluster head then choses the cooperative nodes to transmit the aggregated data to the base station. Thus the overall design contains the clustered wireless sensor networks having the cluster members, cluster heads, cooperative nodes and the base station. Figure 3 depicts the system model.

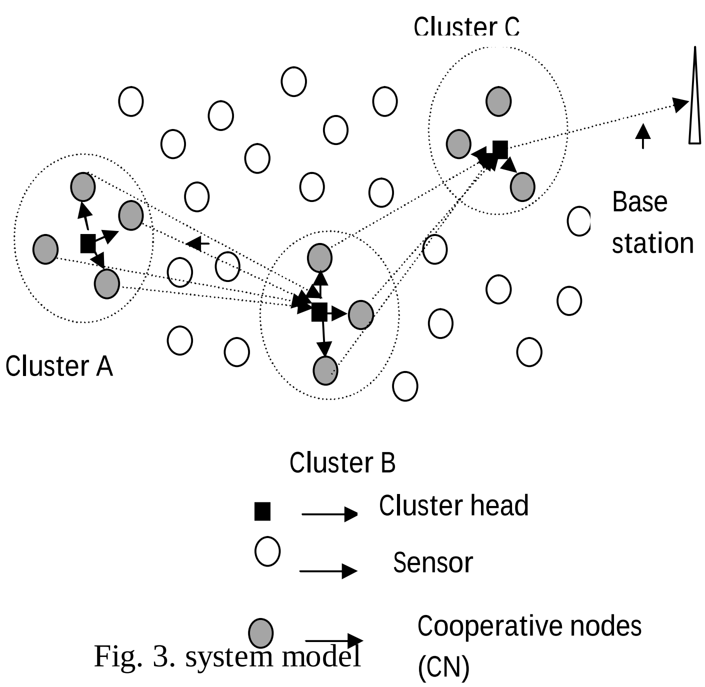

Fig. 3. system model

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III. ENERGY EFFICIENT CLUSTERING AND RELAY SELECTION

WSN have energy constraint wireless sensor nodes. Maintaining an energy efficient WSN is a complex task and hence become an active research area. In WSN most of the energy is consumed during transmission. Many techniques are available to reduce the transmission energy. Clustering is one such a method used to reduce the number of transmissions. But it is not energy efficient in real time WSN applications. Hence clustering should need to be an energy efficient process. In addition, inorder to reduce the transmission energy cooperative transmission is performed. i.e. nodes in the network cooperate with each other. So that the network resources are shared among them. The cooperative nodes are selected. This work includes the broadcasting phase, clustering phase, data transmission phase, inter cluster cooperative node selection phase and end phase. In broadcasting phase, the BS (Base Station) triggers all other sensor nodes. In clustering phase, CH (Cluster Head) and CM (Cluster Member) are selected. Based on their residual energy, number of neighboring nodes and the distance between the CH and CM. data collection and data aggregation is performed in the data transmission phase. The cooperative nodes are selected in the inter cluster cooperative node selection phase. Finally the collected data packets are transmitted to BS. The following gives the brief description of these phases.

Broadcasting phase: this is the initial phase where the BS sends start message to all sensor nodes in the network.

Clustering phase: this phase involves CH selection and CM selection. After the start message sent by the sensor nodes, the values of T is calculated based on the sensors remaining energy and the number of neighbors. This T value is transmitted to the neighbors. The sensors receives the value of T from neighbors and compare it with their T value. The node having largest T value selects itself as CH and selects sender of start message as its higher- level CH. After CH selection, CM selection is based on the computation of T_{CH} which is based on the sensors remaining energy and the distance to its CH. This can be represented as

T = sensors remaining energy + number of neighboring nodes

T_{CH} = sensors remaining energy + distance to its CH

After this CH create a TDMA scheduler according to Cluster members.

Data transmission phase: the data sensed by the sensor nodes are sent to the CH. CH aggregates the collected data. Finally it transmits that data to higher level CH.

Inter cluster cooperative node selection phase: this phase can be done in two steps. Cooperative nodes(CN) candidate selection step and deciding cooperative nodes step. CH T broadcasts a CN-candidate-signal packet within a certain range, which is the distance between CH Tx and CH Rx. CMs of cluster R, which received a cooperative-candidate-signal packet from CH Tx, become a CN of CH Tx. relay candidates of cluster R transmit their own information to CH Rx. CH Rx broadcasts a cooperative-candidate-signal packet within a certain range, which is the distance between CH Tx and CH Rx. CMs of cluster T, which received a cooperative-candidate-signal packet from CH Rx, become a CN of CH Tx. relay candidates of cluster T transmit their own information to CH Tx transmit their own information to CH Tx. CH Rx transmits gathered information to CH Tx. CH Tx receives information from CH Rx. CH Tx decides a CN using the gathered information from the cooperative candidate nodes of CH Tx. CH Tx transmits a cooperative-signal packet to the CN of CH Tx. the relay candidate node received a cooperative node-signal becomes the CN of CH Tx. Otherwise this phase ends.

End phase: this is the final phase where the data packets are transmitted to the base station with the help of the cooperative nodes. Figure 3 shows all the phases that are explained.

BROADCASTING PHASE

Base station broadcast start message to all sensor nodes

CLUSTERING PHASE

Step 1: calculate T= sensor remaining energy + number of neighbors

Step 2: calculate T_{ch}= sensor remaining energy + distance to CH

Step 3: TDMA scheduling and CM starts sending packets

DATA COLLECTION PHASE

CH receives data from CMs

CH performs data aggregation

CH transmits aggregated data to higher level CH

INTER CLUSTER COOPERATIVE NODES SELECTION PHASE

CN candidates selection

Deciding cooperative nodes

END PHASE

Cooperative nodes sends data packets to Base Station

Fig. 4. Energy efficient clustering and cooperative node selection phase

IV. CONCLUSION

Lifetime of wireless sensor networks is a major issue in WSN. This project focused on improving the lifetime of wireless sensor networks. This can be achieved by using energy efficient clustering algorithm and cooperative transmission. As the transmission distance is reduced the energy consumed by the nodes also reduced. So that they can be in the network for long time. Cuckoo search optimization algorithm will be applied for clustering and ACO will be applied for routing. So that the clustering and routing will be optimized which results in the reduced energy consumption of sensor nodes. The network lifetime also further improved.

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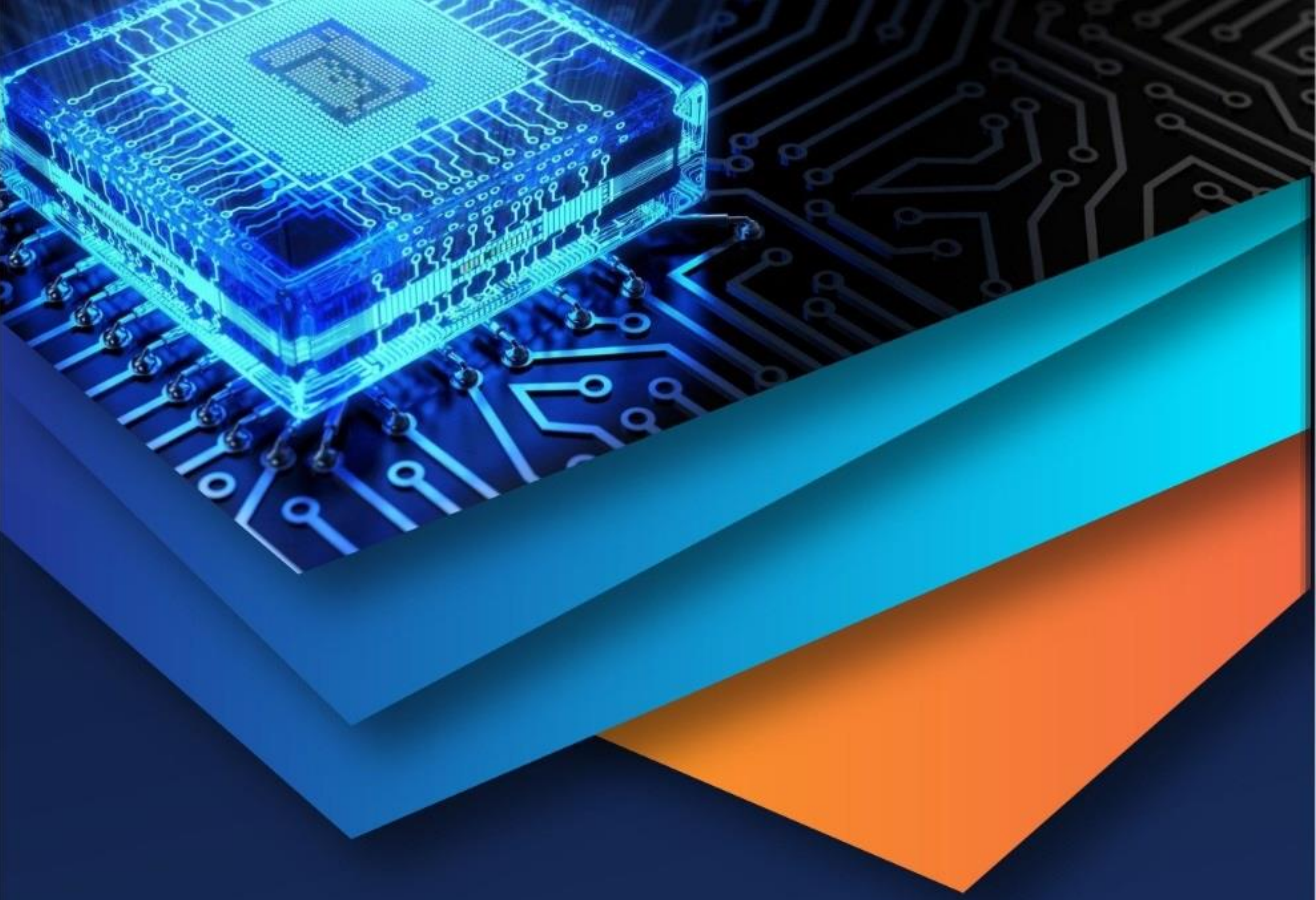

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