Minimization of energy consumption using various mechanisms in WSN

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***Abstract*—Wireless Sensor Network is an emerging technology that consists of several numbers of sensor nodes to sense various parameters in its workspace. These batteries are operated with the help of batteries, wherein most of the cases they are not replaceable. Hence during the design of such networks it is essential that the sensor nodes consume as less energy as possible. Three transmission mechanism, such as; 1.Cooperative Communication, 2. Coalition-Based Data Transmission Mechanism and 3. Cluster-Based Data Transmission, are discussed in this paper which allows an energy-efficient and at the same time a reliable data transmission from the source node to the destination node. The first mechanism depends on two parameters, namely the number of cooperative nodes and the E2E error probability. The second and the third mechanisms depends on the number of cooperative nodes required. Both the mechanisms are studied and their corresponding results are simulated.**

***Index Terms*—Wireless Sensor Networks, Cooperative Communication, Coalition, Cluster, Data Transmission Mechanism, Energy-Efficiency.**

I. INTRODUCTION

Wireless Sensor Networks are networks that consists of tiny sensing devices (down to the size of a grain), called as sensor nodes. These sensor nodes are used to monitor parameters like the temperature of any particular region and then transmits these sensed information to another sensor node or any other device in the network. Hence in order to transmit these sensed information, the node requires some amount of energy. This energy is supplied to the nodes by means of batteries which maybe replaceable or non-replaceable or in some cases these batteries may also be rechargeable, depending on solar power for recharging. In most of the applications it is not possible to replace these batteries and hence it is important that these nodes consume as less power as possible during transmission of data. By doing so, the lifetime of the nodes will be increased which in turn will also increase the lifetime of the network as the lifetime of a network solely depends on the lifetime of the nodes present in the network.

Thus while designing a network it is essential to satisfy two important criteria, such as prolongation of network lifetime and energy-efficient data transmission. Hence the main aim of this project is to reduce the energy consumed by the network during the transmission of data and at the same time provide an energy-efficient and reliable data transmission. Three mechanisms are discussed in this paper and the best out of the three techniques are used to transmit the data in the network.

The conventional data transmission mechanisms such as the SISO, MISO and MIMO may be used but their energy consumption characteristics vary depending upon the distance between the source and the destination. In SISO, the energy consumed for short distance communication is less, but as the distance starts increasing, the energy consumption also increases. Thus for long distance communication, MIMO serves better as it requires less energy for long distance communication and at the same time provides more channel capacity. But due to the practical limitations (i.e. the small size of the nodes), it is not possible to mount several antennas in a single node.

Hence another technique where several nodes are used to provide the same efficiency as MIMO technique is proposed. This mechanism is called Cooperative Communication (also referred to as Cooperative MIMO/MISO). Here the source node transmits the data to the nodes that are present close by to the source node, called cooperative nodes, and then the source node along with the cooperative node will transmit the same data to the next cluster head of the next cluster. A simple Cooperative Communication is shown in Fig.1. The energy consumed in this mechanism depends on two important parameters, they are the number of cooperative nodes and the E2E error probability. With the help of the simulation, the optimal number of cooperative nodes and the best value of E2E error probability maybe obtained.

The second mechanism is called the Coalition-Based Data Transmission Mechanism. It provides data transmission in a cooperative manner. The neighboring sensor nodes to the source node form coalitions and each coalition elects one sensor node as the coalition header (CH). Four stages are involved in the transmission of data from the source node to the destination node of the next coalition head. They are as follows:

1. Firstly, the sensor nodes within a coalition send their sensed data to the CH which carries out data aggregation.
2. The CH along with the sensor nodes broadcasts the aggregated data to the CH in the next coalition.
3. Before data transmission, the next CH will broadcast the pilot symbol so that the SN within the coalition can estimate its channel attenuation coefficient and adjust its sending power.

This model uses CDMA for inter-coalition data transmission to avoid interference and uses TDMA for intra-coalition data transmission. This mechanism also reduces the total energy consumed for data transmission.

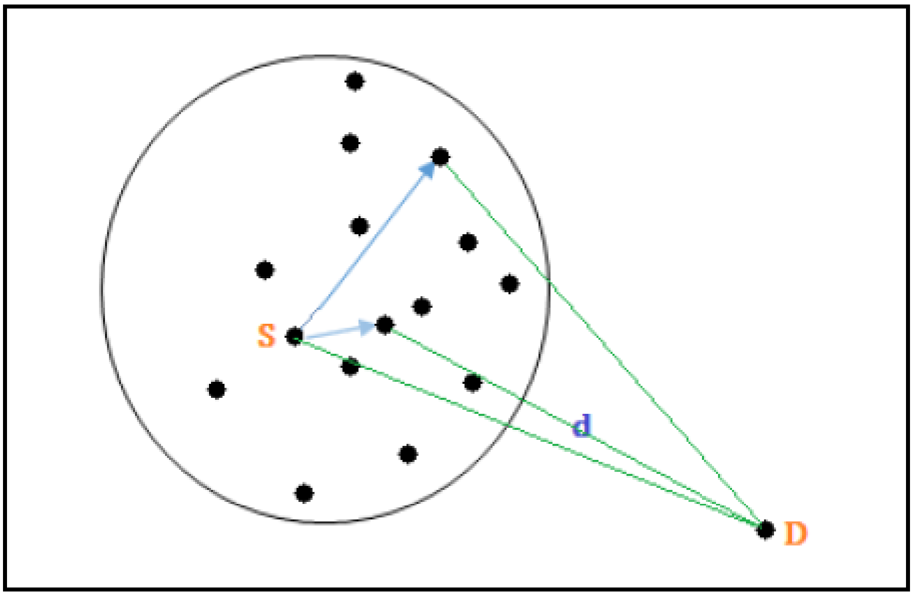

Fig 1 Cooperative Communication

II. ENERGY MODEL:

Energy consumption is one of the most important factor that determines the performance of a wireless sensor network. The three mechanisms are discussed below in detail.

A. Cooperative Communication

The energy consumed for cooperative communication is mainly because of data transmission and due to the circuit.

(1) Energy Consumed for Data Transmission

As mentioned before the total energy required for the transmission of data depends on two main parameters. The number of cooperative nodes chosen for CC plays a major role. The total energy required for CC transmission comprises of two types, such as:

- Broadcasting transmission (local transmission): From source node to cooperative nodes.
- Long haul transmission: From cooperative nodes to the sink.

The total energy for cooperative communication depends on the following factors for an efficient transmission:

- Number of cooperative nodes(Ncn)
- Broadcasting probability (pb)
- Cooperative transmission probability (pc)
- Broadcasting distance ( ). k br

With reference to [8] and [10], the following equations are derived. The equation for the CC energy consumption is given by (1),

$$E_{CC} = E_b(N_{cn}, p_b) + E_{CT}(N_{cn}, p_c) \tag{1}$$

where E_b denotes the energy required for local transmission and is given by (2),

$$E_b(r_b^k, p_b, N_{cn}) = E_T(r_b^k, p_b, 1) + (N_{cn} - 1)E_R \tag{2}$$

and E_{CT} denotes the energy required for long haul transmission and is given by

$$E_{CT}(\mathrm{d}^k, p_c, N_{cn}) = E_T(\mathrm{d}^k, p_c, N_{cn}) + E_R \tag{3}$$

and E_T denotes the energy required for data transmission in general and is defined as

$$E_T(\mathrm{d}^k, \mathrm{p}_e, N_{cn}) = C.(\mathrm{N}_0 . \mathrm{d}^k / p_e^{1/N_{cn}}) + (\mathrm{P}_{ct} / \mathrm{R}_b) \tag{4}$$

k denotes the pathloss exponent whose value depends on the environment through which the data is transmitted. For free space its value is 2 and in multipath fading environment the pathloss exponent value is 4.

(2) Circuit energy

The nodes consists of several components for processing the sensed data such as the ADC, processor unit, transceiver, location finding unit and so on. Hence the circuit in the node also consumes some part of the energy during processing of the data. This energy consumed depends on the number of cooperative nodes chosen for the data transmission. The relation between the circuit energy consumption and the number of cooperative nodes is given in (5) as,

$$E_{circuit} = N_{CN}.E_R + (N_{CN} + 1).P_{ct} / R_b \tag{5}$$

B. Coalition-Based Data Transmission Mechanism

Another type of cooperative communication is the Coalition-Based data transmission mechanism. The network consists of n number of sensor nodes and one sink (such as a base station). The network consists of M number of coalitions and ni is the number of SN in the ith coalition, such that

$$\sum_{i=1}^{M} n_i = n \quad (6)$$

The inter-coalition and inter-coalition communication are assumed to take place in an AWGN channel. Each SN generates data of $H0$ bits with a transmission rate R. the energy consumption model is based on the delay (energy consumption=power x delay). All SN have a fixed receiving power . The analysis of energy consumption consists of three parts: Inter-Coalition Data Transmission, Intra-Coalition Data Gathering and Intra-Coalition Data Broadcast.

(1) Inter-Coalition Data Transmission

With reference to [11], the total power required to send the data in the i^{th} coalition is given by (7),

$$P_T = \frac{P}{n_i^2} \sum_{j=1}^{n_i} \frac{1}{\lambda_{ik}^{(j)2}} \quad (7)$$

where $\lambda_{ik}^{(j)}$ denotes the channel attenuation of the j^{th} node and P denotes the power required for transmission and is expressed as P=γN007A. The noise is considered to be Gaussian noise with zero mean and square error, N (noise power). The energy consumption is given by (8),

$$e_{transmit} = \frac{H_i}{R}\left[\frac{P}{n_i^2} \sum_{j=1}^{n_i} \frac{1}{\lambda_{ik}^{(j)2}} + P_R\right] \quad (8)$$

Assuming that every node in the i^{th} coalition has the same channel attenuation, (8) becomes,

$$e_{transmit} = \frac{H_i}{R}\left[\frac{P}{n_i^2 \lambda_{ik}^2} + P_R\right] \quad (9)$$

(2) Intra-Coalition Data Gathering

The energy consumed at this phase is given by (10),

$$e_{gather} = \frac{H_0}{R}(n_i - 1)\left[\frac{P}{\lambda_c^{i2}} + P_R\right] \quad (10)$$

where λ_c^i denotes the lowest channel attenuation coefficient from the n_i number of nodes to the cluster head CH_i.

(3) Intra-Coalition Data Broadcast

CH_i broadcasts the aggregated data of H_i bits to $(n_i - 1)$ nodes within the coalition and the energy consumed for such a process is given by (11)

$$e_{broadcast} = \frac{H_i}{R}\left[\frac{P}{\lambda_c^{i2}} + (n_i - 1)P_R\right] \quad (11)$$

Thus the total energy consumed by the Coalition-Based data transmission mechanism is given by (12),

$$e_{coalition} = e_{broadcast} + e_{gather} + e_{transmit}$$

$$e_{coalition} = \frac{H_i}{R}\left[\frac{P}{\lambda_c^{i2}} + (n_i - 1)P_R\right] + \frac{H_0}{R}(n_i - 1)\left[\frac{P}{\lambda_c^{i2}} + P_R\right] + \frac{H_i}{R}\left[\frac{P}{n_i^2 \lambda_{ik}^2} + P_R\right] \quad (12)$$

It is evident from (12) that the energy consumed for Coalition-Based data transmission depends on the number of sensor nodes that sends data to the cluster head.

C. Cluster-Based Data Transmission Mechanism

The energy consumption consists of two parts: Intra-cluster data transmission and Inter-cluster data transmission. The energy consumed by the intra-cluster data transmission is same as that for Coalition-Based data transmission mechanism and is given by (13)

$$e'_{gather} = \frac{H_0}{R}(n_i - 1)[\frac{P}{\lambda_c^{i2}} + P_R] \quad (13)$$

As mentioned above Inter-cluster data transmission is a point-to-point process and hence the energy consumed by such a process is given by (14),

$$e'_{transmit} = \frac{H_i}{R}[\frac{P}{\lambda_{ik}^2} + P_R] \quad (14)$$

Thereby the total energy consumed by the Cluster-based data transmission mechanism is given by (15),

$$e_{cluster} = e'_{gather} + e'_{transmit}$$

$$e_{cluster} = \frac{H_0}{R}(n_i - 1)[\frac{P}{\lambda_c^{i2}} + P_R] + \frac{H_i}{R}[\frac{P}{\lambda_{ik}^2} + P_R] \quad (15)$$

D. Energy Gap

Comparing the energy consumed between the two mechanisms: Coalition-based data transmission mechanism and Cluster-based data transmission. The difference between the energy consumed between the two mechanisms is known as the gap of energy and is given by

$$\Delta e = \frac{H_i}{R}[\frac{P}{\lambda_{ik}^2} - \frac{P}{n_i^2\lambda_{ik}^2} - \frac{P}{\lambda_c^{i2}} - (n_i - 1)P_R] \quad (16)$$

III. SIMULATION AND RESULTS:

The main aim of this work is to reduce the energy consumed during the transmission of data from source node to destination node. Our work is to analyze the performance of the network and the energy consumption, by varying one or more factors. Depending on how these factors affect the transmission energy we find out the optimal value for these factors such that the transmission of data is done in an energy-efficient and in a reliable manner.

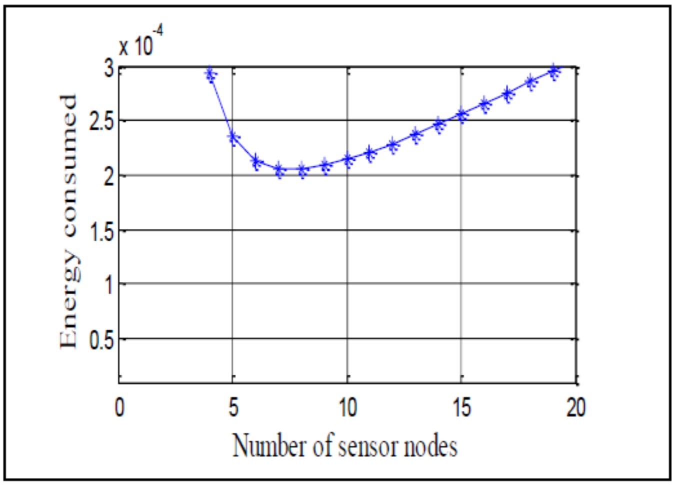

Fig.2. Energy consumed by Cooperative Communication

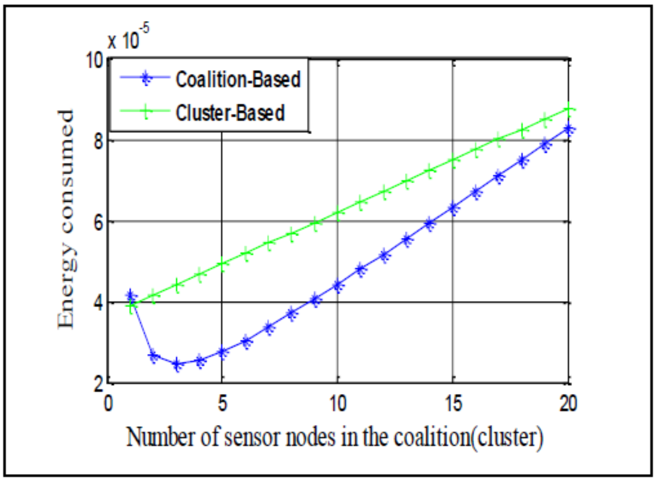

Fig.3. Comparison of energy consumed using the two mechanisms

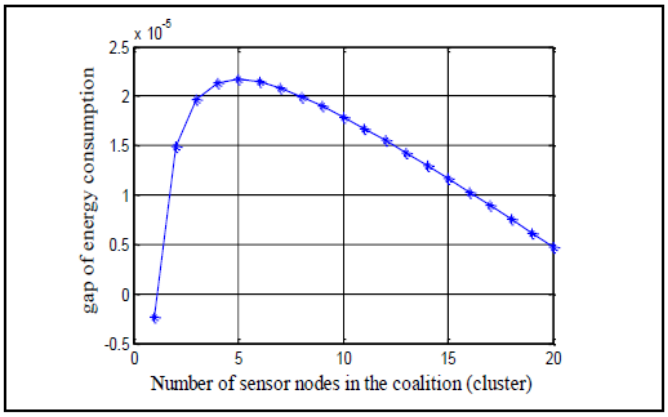

Fig.4. Gap of energy

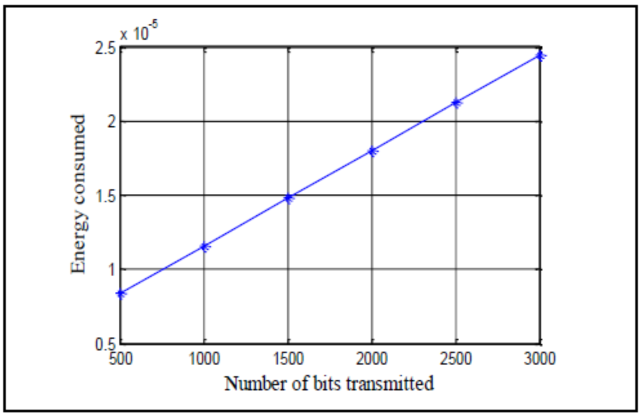

Fig. 5. Energy consumption based on the number of bits transmitted

A. Energy consumption using Cooperative Communication:

From (1), (2) and (3), it can be seen that the energy consumed depends on the distance between the source and the sink node, the number of cooperative nodes and also the E2E probability. The nodes are distributed within the network and the entire network is divided into clusters, and each cluster consists of a cluster head which is responsible for forwarding the data to the next cluster head or to the destination node. The nodes are placed at fixed locations in the network and the distance between the nodes are also fixed. Let us assume that the distance between the source node and the destination node is 100m (the energy consumption characteristics will be the same even at larger distances) and the E2E probability is $1x10^{-3}$. In order find out the optimum number of cooperative nodes required to perform an energy efficient data transmission, a graph is plotted between the number of cooperative nodes and their corresponding energy consumption. Fig.2. shows the energy consumed by the network using Cooperative communication. From the graph it can be observed that the optimum number of cooperative nodes required to perform cooperative communication is 8.

B. Energy Consumption comparison between the three Mechanisms

The energy consumption between the two mechanisms: Coalition-based data transmission mechanism and Cluster-based data transmission mechanism, are plotted using (12) and (15). Fig.3. shows the comparison between the two mechanisms. Fig.4. shows the gap of energy consumption plotted against the number of cooperative nodes. Fig.5. shows the energy consume on varying the number of bits transmitted from the source node and the destination node. Fig.6. gives a comparison of the energy consumed by all the three mechanisms.

IV. CONCLUSIONS AND FUTURE WORKS

The main aim of this work is to reduce the energy consumption by making use of cooperative communication. In a general SISO technique, the energy consumption increases with the increase in the distance between the source node and destination node, which is a major drawback in this technique. Hence SISO technique serves better only for local communication and it is not suitable for long haul communication. The next technique is MIMO where the energy consumed is lesser than SISO, but the drawback of this technique is the size of the nodes. Hence a better method to have a reliable communication is to make use of cooperative communication, where several nodes are used to transmit the same information from the source node to the destination node.

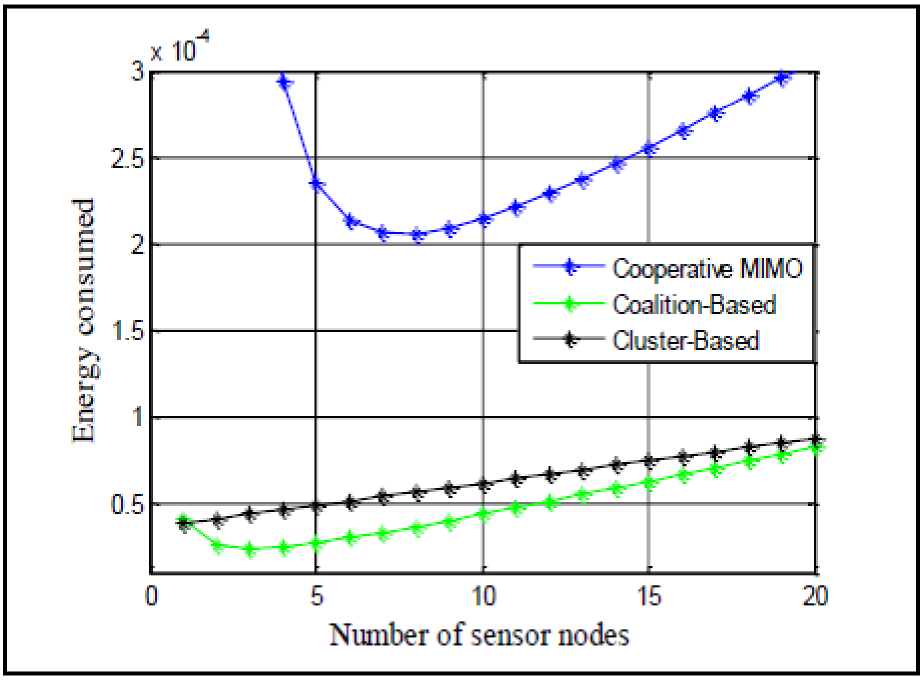

Fig.6. Energy comparison of the three mechanisms

The energy consumption should be as low as possible so that this method is reliable for data transmission. The reduction in energy consumption can be done by varying one or more of the factors that are responsible for transmission in a WSN. The distance between source node and destination node, number of cooperative nodes and E2E probability are some of the factors that influence the consumption of energy in a network. Thus from the Fig.6. it can be seen that out of the energy consumed by the three mechanisms, the energy consumed by the Coalition-based data transmission is lesser than the other two techniques. Although this technique reduces the energy consumed during transmission, it does not involve the E2E error probability. The future work involves the analysis of energy consumption for a cluster based network.

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