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MINIMIZING ENERGY CONSUMPTION USING UNEQUAL CLUSTERING IN WIRELESS SENSOR NETWORKS

Nihal Das, Ravi Raj, Mrinmoy Choudhury, Karthika Sundaran and Ganapathy Velappa
School of Computing, Department of Information Technology, SRM University, Chennai, Tamil Nadu, India
E-Mail: ganapathy.v@ktr.srmuniv.ac.in

ABSTRACT

Wireless Sensor Network (WSN) is becoming a very important area of research in today's world and contributes a lot in the field of technology. Reducing energy consumption and improving the network lifetime is the key factor to be considered. In this paper, we propose a new protocol namely Minimizing Energy Consumption Using Unequal Clustering (MECUC). MECUC attempts to improve energy efficiency using duty cycling and unequal clustering concepts. The inclusion of duty cycling in MECUC is expected to provide a better balancing of energy amongst the sensor nodes. Selection of relay CH in MECUC is based on (i) distance to BS (ii) residual energy of the nodes and (iii) node proximity. Performances of MECUC are compared with the performances of the existing protocol EADUC and the obtained results show that operation of DTUCFA is found to be better than EADUC in terms of delay, energy consumption, packet loss ratio and packet received ratio.

Keywords: clusters, cluster head, node energy, duty cycling, unequal clustering,proximity.

INTRODUCTION

In Wireless sensor networks (WSN), sensors are distributed to monitor the physical and other environmental conditions, such as temperature, pressure, etc., and transmit their data through a network to a central location [1]. WSN applications have excelled in the areas including health care, utilities, and remote monitoring. In health care, wireless devices make a significant contribution in monitoring health issues and implementing various new technologies. Another advantage is that the wireless sensor networks are scalable. Moreover a dense wired set up will prove to be very costly. On the other hand, wireless sensor nodes can easily be deployed without any hustle. [2]

Limited computation, short lifetime of batteries, communication resources, etc., are some of the disadvantages in wireless sensor networks. They also have other disadvantages like limited storage, prone to security attacks and limited bandwidth to communicate. Despite these disadvantages, sensor networks are widely used and considered to be the backbone of wireless communication. In wireless sensor networks, nodes which have shortest distances to other nodes form clusters. Within a network many clusters are formed and each cluster has a Cluster Head (CH). CHs are elected on the basis of maximum threshold energy and least node proximity of the nodes. CHs are responsible for accumulating the data from the nodes and transmitting them to the Base Station (BS).

By combining the sensors in the sensing field, the number of long distance transmissions can be reduced and hence saving energy [3]. Duty cycling is a concept which allows nodes to consume less energy by putting them to sleep state or active state depending upon the energy the node possesses and the activities of the member nodes. This activity scheduling is executed largely through a schedule which is based on TDMA [4]. Also clustering involves data aggregation in CH by reducing the transmitted data packets.

The intention is to develop a new protocol namely Minimizing Energy Consumption using Unequal Clustering (MECUC) by improving the existing Energy Aware Distributed unequal Clustering Protocol (EADUC). Objective of the Proposed Protocol is to minimize the energy consumption of the nodes which are located in the sensing field, to work on the efficient selection of CHs in the network and to extend the lifetime of the nodes. The node which is to be elected as a tentative Cluster Head is determined based on its distance from the Base Station (BS) and the Energy of the node. The final Cluster Head is selected from the nodes which possess maximum energy and closer to the base station. The concept of duty cycling is introduced to minimize energy consumption i.e., switching the node from sleep mode to active mode and vice-versa. Other improvement in the proposed protocol is selection of a relay node based on highest energy, lowest distance from BS and high node proximity.

RELATED WORKS

An earlier research work taken up in the field of clustering algorithm has been based on cluster heads rotation in every cycle and electing cluster heads (CH) based on nodes which have more residual energy. The first protocol available in this category is low-energy adaptive clustering hierarchy (LEACH) protocol [5]. It works on the principle of single-hop communication between base station and the nodes. This makes it unreliable for large-scale networks. There are various other modified LEACH protocols which are improvements over the LEACH protocol. Some of the modified protocols are a multi-hop variant (M-LEACH), LEACH-DT, C-LEACH and MOD-LEACH [6].

Hybrid energy-efficient distributed (HEED) clustering algorithm, where the CHs are selected depending upon the residual energies of the nodes and the cost of communication for intra-clusters. For communication in inter-cluster, use of multi-hop

communication comes effective. It is effective in prolonging the lifetime of the node. It lacks in balancing the load as nodes close to BS die quickly [7]. Clustering is one of the solutions for better energy conservation in the process of communication in WSN. A new clustering algorithm named Unequal Clustering Algorithm (UCA) is implemented to eradicate the overheads of the cluster head which is situated near the sink because of the traffic from the other CHs. Enhanced Unequal Clustering Algorithm (EUCA) [8], tries to reduce the traffic between clustering by eradicating the competition between the nodes competing to be the Cluster head (CH).

Simulation studies clearly show the efficiency of EUCA in terms of energy consumption. Lowering the overheads in collecting the data is used to decrease the energy-hole problem. Unequal sized clusters are used for creating the clusters in this protocol [9].

Sink Mobility based Energy Balancing Unequal Clustering (SMEBUC) is a protocol with distribution of nodes, which elects its Cluster Head which has maximum energy amongst all the nodes. The nodes are distributed into clusters of various size with an improved algorithm called as the Shuffled Frog Leaping Algorithm (SFLA). Greedy algorithm is used to elect the relay node which is optimal for transmission of data between the Cluster Head and Sink node. [10]

In the proposed work, we are attempting to improve the existing protocol namely Energy Aware Distributed Unequal Clustering (EADUC) protocol. We are using a multi-hop approach to solve the energy-hole problem [11]. The energy-hole problem is the one where the clusters near the Base station (BS) lose more energy than the clusters which are sitting far away from the Base station (BS). A new approach is implemented that will make the network more efficient by electing alternate cluster head from rest of nodes after each transmission. A Cluster head (CH) selection algorithm is implemented that considers the distance between the sensor node and the Base station (BS) and accordingly balances the consumption of the energy in the nodes

Our attempt in this paper is to implement a protocol which is an improvement over the existing protocol (EADUC). The agenda is to propose a new protocol called Minimizing Energy Consumption using Unequal Clustering (MECUC). MECUC attempts to solve the energy-hole problem more efficiently by improving on the network parameters such as reducing delay, reducing energy consumption, improving the packet received and finally decreasing packet loss. Duty cycling, which involves putting a node to sleep or active state depending upon its energy, is also implemented so as to reduce the amount of energy consumed.

METHODOLOGY

Energy consumption model

The transmitter runs the radio and amplifier electronics circuitry, as a result it consumes a lot of energy where the energy consumption in receiver is only radio electronics part. Also, based on the transmission distance, both the multipath fading εmp and the free space εfs channel models are used [12]. If the distance is too large than the threshold level, the multipath model is used otherwise the free space model is used. When transmitting l-bit data to a distance d, the ratio of energy expenditure is according to Equation. (1).

$$E_T(l,d) = \begin{cases} l E_{elec} + l \varepsilon_{fs} d^2, & d < d0 \\ l E_{elec} + l \varepsilon_{mp} d^4, & d \geq d0 \end{cases} \quad (1)$$

When receiving the l-bit data, the radio expends energy according to Equation. (2).

$$E_R(l) = l E_{elec} \quad (2)$$

MECUC functioning

The following assumptions are used for developing the new protocol MECUC by enhancing the existing protocol EADUC.

- The network is based on N nodes placed in MxM sensing field.
- The energy in the node is heterogeneous which means all the nodes have different energies.
- Each node has the complete idea of where the base station (BS) is located.
- Each node starts broadcasting the data to every other node.

a) Neighbor node discovery and CH selection

Sink node plays a vital role in the neighbor node discovery. Sink node starts the process by sending the message *brdcst_msg* to all nodes in the network. After receiving the message *brdcst_msg*, each node can calculate its distance between the node and sink node based on received signal strength. MECUC uses the basic principle of LEACH to form clusters in the network [13]. Using the Equation. (3), each node in the network generates a random number. If the random number is above the threshold energy value (THE), MECUC assigns that particular node as a tentative CH.

$$THE = \frac{P}{1-(P*rmod\left(\frac{1}{P}\right))} \quad (3)$$

where desired percentage of cluster heads and current round number are represented by P (e.g., P = 0.05) and r respectively. Each tentative CH uses its distance to BS and its residual energy for calculating the competition radius. The tentative CH sends a message *req_info* to all the nearby nodes. The neighbor node which sends the information back to the source node which is the tentative CH stores the information into Neighbor Information Table (NIT). If the tentative CH energy is greater than the energy of all the other neighbor nodes, then the tentative CH becomes Final CH. Based on various distances of nodes from BS and available residual energies, MECUC

forms unequal clusters in the network. MECUC uses duty cycling concept to improve the lifetime of network. Duty cycling can be defined as: if the node energy is less than that of the Threshold Energy (THE), it is put to sleep or if it is more, in that case it is put into active mode. In each cluster, CH can put the nodes into sleep states if the nodes energies are lesser than the threshold energy value. The active nodes in each cluster can transmit data to their corresponding CH.

b) Relay node selection and data transmission

In each cluster, CH establishes a TDMA connection with its cluster members. Only CH can aggregate and transmit data to BS. In each cluster, CH responsibilities can be rotated among the nodes to conserve energy. For selecting a relay CH, the source CH considers all the nodes distances from BS, residual energies and their proximities to the CH. Each CH broadcasts a request message *relay_select*to neighbor CH nodes to get information about their distances from BS, residual energies and their proximities to the CH. Selection of relay CH in MECUC among the neighboring set of nodes is based on the parameter $S_{relayCH}$ and calculation of $S_{relayCH}$ is based on the condition stipulated in Equation. (4).

$$S_{RELAYCH} = \{S_j | RE_{energy}(s_j) > THR_{energy} dist(s_i, s_j) \leq TH_d; dist(s_j, BS) < dist(s_j, BS)\} \quad (4)$$

The first condition in Equation. (4) ensures that the *residual_energy* of node s_j should be larger than the threshold residual energy value. The second condition makes sure that the considered relay CH has its distance within the threshold distance TH_d from the source CH. TH_d determines the maximum possible distance between the current CH and the relay CH. The current CH will send data directly to BS, if there is no relay CH which satisfies the first condition then $S_{RELAYCH}$ will be an empty set. MECUC combines the above mentioned three conditions for the selection of relay CH in the network. Figure-1 shows the flowchart of the proposed protocol.

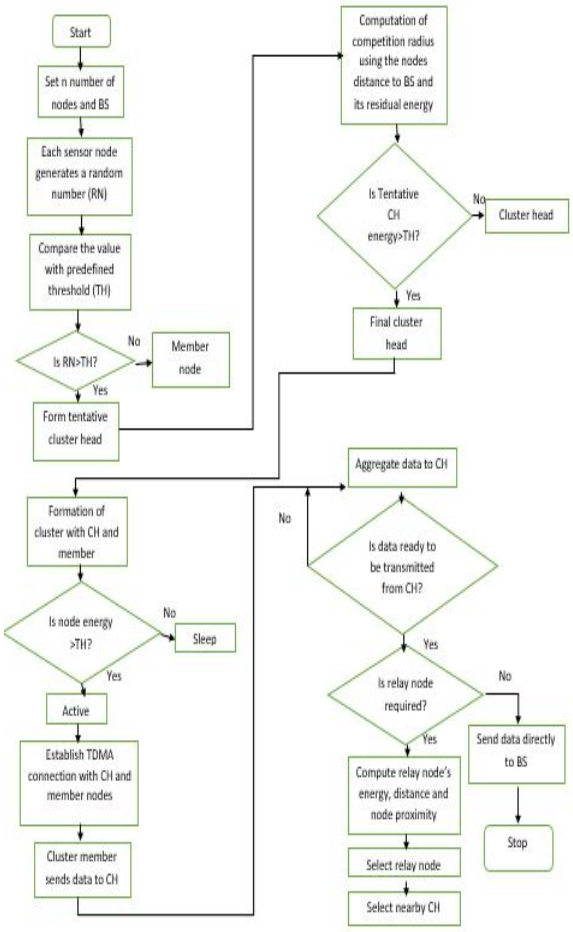

Figure-1. Flowchart of the proposed protocol (MECUC).

SIMULATION RESULTS

The proposed methodology of Minimizing Energy Consumption using Unequal Clustering (MECUC) is implemented using the network simulator NS-2. 56 nodes are uniformly deployed over an area of 900 x 900 m2 as shown in the Figure-2.

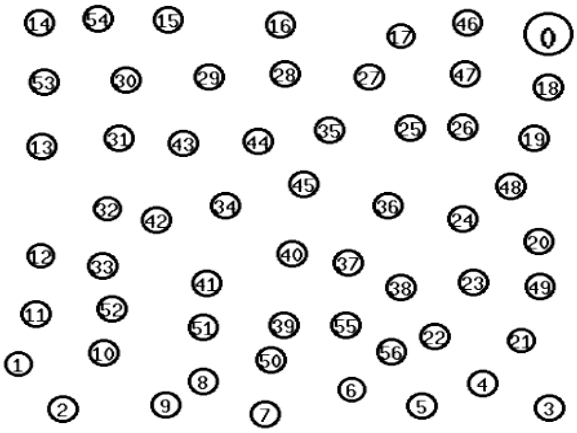

Figure-2. Node sensing field.

The BS is assumed to be located within the sensing field. The initial energy of each sensor node is 0.5 J. The network is simulated with a bandwidth of 1 Mbps. The size of each data packet is 500 bytes. The parameters used for simulation are listed in Table-1.

Table-1. Simulation parameters.

Name of parameter	Value
Network area	900 x 900 m^2
No. of nodes	56
Initial energy of nodes	0.5 J
Data packet size	500 bytes
E_{elec}	50nJ/bit
ε_{fs}	10pJ/bit/m^2
ε_{mp}	0.0013pJ/bit/m^4
E_{DA}	5/nJ/bit/signal
Control packet size	200bytes

End-to-end delay

End-to-end delay refers to the time taken for the packet to be delivered across a network from the source to the destination. MECUC uses duty cycling to increase the lifetime of nodes. The nodes are put into sleep states, if their energies are below the threshold level otherwise they will be in the active state. Only the active nodes participate in cluster formation and data transmission. The simulation experiments are conducted and the end to end delay evaluated. Figure-3 shows the comparison of end to end delay of the existing protocol EADUC and the proposed protocol MECUC.

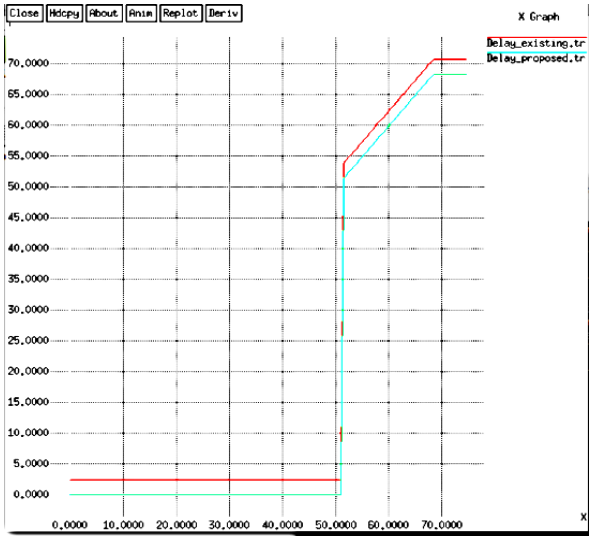

Figure-3. Delay between EUDAC and MECUC.

Energy consumption

Energy Consumption refers to the amount of energy required for the complete functioning of the network. Energy Consumption is reduced by putting the nodes to active or sleep state depending on their energy levels. Only CH is allowed to communicate to the BS either by single-hop or by multi-hop communication. Unequal cluster formation in MECUC reduces energy consumption considerably. Figure-4 represents the comparison between EADUC and MECUC in terms of energy consumption. Figure shows that the network using the proposed protocol (MECUC) consumes less energy than the network which uses the existing protocol (EADUC).

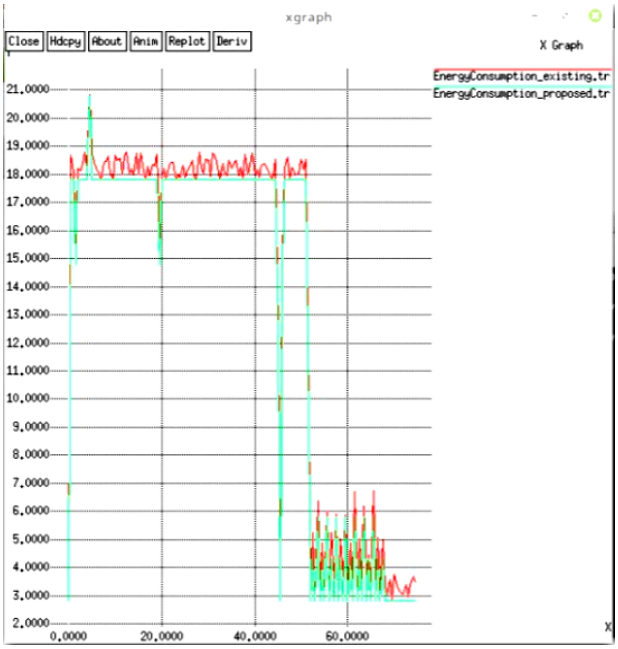

Figure-4. Energy consumption between EUDAC and MECUC.

Packet loss (PL)

Packet loss is defined as the number of packets that are lost during the data transmission process. The improvement in the proposed protocol MECUC is achieved by the following mechanism. Selection of relay CH in MECUC among the neighboring set of nodes is based on nodes distances from BS, their residual energies and node proximities. Source CH selects a relay CH only if it satisfies the above mentioned conditions. The nodes that are nearer to the BS can directly transmit data to the BS and far away nodes use multi-hop communications. A relay node acts as a via media between the cluster head (CH) and the base station (BS) during data transmission. Simulation results are given in Figure-5 and it is evident that the number of packets lost during the transmission of data in EADUC is more as compared the data packets lost in MECUC for the same experimental set-up.

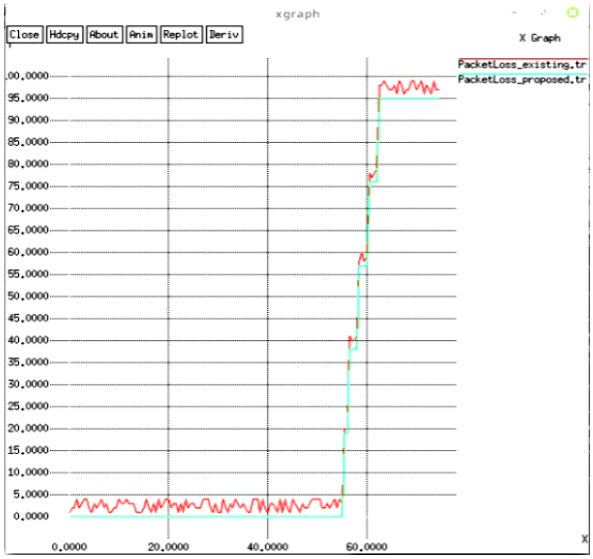

Figure-5. Packet loss between EUDAC and MECUC.

Packet received (PR)

Packet received is the number of packets that are received during a data transmission. In the proposed MECUC, only active nodes are participating for data transmission and relay CH selection. In MECUC, CH selection among the neighboring set of nodes is based on nodes distances from BS, their residual energies and node proximities. Unequal clustering enables the nodes that are nearer to BS to directly transmit data to BS and the far away nodes use multi-hop communication to transmit data. Figure-6 represents the comparison of the number of packets received during the data transmission and shows that the proposed MECUC is able to receive more number of packets as compared to the existing EUDAC.

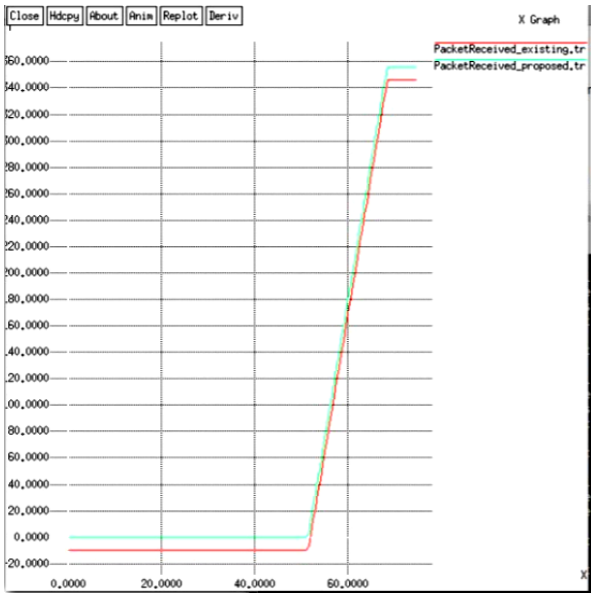

Figure-6. Packet received between EUDAC and MECUC.

CONCLUSIONS

Energy is a vital resource which is required in the functioning of the whole network. Every devices requires energy to complete its particular task that is assigned to it. For a network to be efficient it requires that the energy is utilized optimally. It is necessary to ensure that the energy wastage is limited to a lesser amount. In this paper, to increase the energy efficiency and hence the lifetime of WSN, a new protocol Minimizing Energy Consumption using Unequal Clustering (MECUC) is proposed. MECUC is developed on the existing protocol Energy Aware Distributed Unequal Clustering (EADUC). The proposed protocol MECUC forms unequal clusters in the network by considering nodes distances from BS, their residual energies and node proximities. MECUC uses duty cycling to improve energy efficiency of the nodes by putting the nodes into active states only if their energies are greater than the threshold level. Also relay CH selection is based on 1) distance between the current CH to relay node (2) proximity of the relay node to CH and (3) residual energy of the considered relay node. Simulation were carried out to evaluate the performances of the proposed MECUC protocol and the performances are compared to the existing EADUC protocol. It is observed from the graphical plots that the proposed MECUC has given relatively better performance in terms of reducing delay, improving energy efficiency, reducing packet loss and increasing packet received.

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