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Energy Efficient Duty-Cycling for Mobile Sensor Networks

S.Navaraj[#1] and G.Raja[*2]

[#] M.E Computer Science and Engineering(2nd year), Dhanalakashmi Srinivasan Engineering College, Perambalur,Tamil Nadu, India.

[*] Assistant Professor, Dhanalakashmi Srinivasan Engineering College, Perambalur,Tamil Nadu, India.

***Abstract*— Mobile Sensor Networks (MSN) energy of the battery operated nodes is the most vulnerable resource of the MSN. In a clustering approach,the Cluster Head node looses a significant amount of energy during transmission tobase station. So the selection of Cluster Head is very critical. In this work a centralized protocol for Cluster Head selection in MSN is discussed, which is run at the base station, thus reducing the nodes' energy consumption and in- creasing their life-time. The primary idea is implemented using a fuzzy-logic based selection of Cluster Head from among the nodes of network, which is concluded depending on two parameters, the current energy of the node and the distance of the node from the base station. The simulation results show increasing the network lifetime.**

Index Terms*— Mobile Sensor Networks(MSN), Clusted Head, Duty Cycling, Energy Efficient.

I. Introduction

Mobile Sensor Networks (MSNs) are networks that comprise of sensors that are distributed in an ad hoc fashion over a defined geographical area, aimed at sensing some predefined information from the surrounding, processing them and transmitting them to the sink station. The sensors work with one another to capture some physical event. The data assembled is then transformed to get important outcomes. Remote sensor systems comprise of protocols and algorithms with self-arranging capabilities. MSNs can be widely divided into two types-Unstructured MSN and Structured MSN. While Unstructured MSN have a large collection of nodes, put up in an ad-hoc fashion; Structured MSN have few, scarcely distributed nodes with pre-planned deployment. The Unstructured MSNs are difficult to maintain, but it is relatively easy to maintain Structured MSNs.Mobile wireless sensor networks have received considerable attention in recent years. These networks are starting to be used for wildlife tracking, livestock monitoring, Nadimi et al., , medical , human centric and pervasive applications. Energy is a critical factor in most real deployments of sensor network applications. Many mobile applications, such as environmental monitoring ones, require months of unattended operation of large number of small battery-operated nodes. Due to slow advancements in battery technology, energy efficiency will remain an important issue. Since the introduction of lead-acid cells in 1950s the energy density of these types of batteries have only doubled, with expected rise of only 10-20% in the near future. Energy-harvesting solutions are attractive, with photovoltaic, vibrational and thermoelectric techniques being the most promising sources of energy. The relatively low efficiency of those devices means energy efficiency will still remain an important factor for a long time. Since radio communication is a major source of power consumption in wireless sensor network applications, power management often reduces to duty cycling the radio, a process where the radio module is turned on and off while making sure the network achieves its aims. Many duty cycling approaches exist for fixed wireless sensor networks. The majority of these focus on energy efficient channel access and arbitration with the general goal of obtaining an optimal trade-off between latency and power consumption. The approaches can be grouped into synchronous and asynchronous categories. Synchronous approaches assume global time synchronization either with precise clocks or by periodically resynchronizing through network time synchronization protocols. Asynchronous approaches and do not assume the presence of precise clocks, and the nodes duty cycle asynchronously and independently from each other. However, current approaches are not applicable to mobile wireless sensor networks, which are characterized by intermittent connectivity of the nodes. In addition, in sparse mobile networks, the nodes can be isolated but whenever a new node comes into communication range it has to be detected in timely manner in order to initiate communication. Thus, mobile applications cannot be simply built on top of a power efficient MAC layer designed for fixed networks. These MAC protocols usually perform a neighbour discovery only once during configuration phase, and then schedule the nodes to be active during certain timeslots and sleep at any other time. This leads to network partitioning and failure to timely detect new neighbouring nodes, and consequent inability of a networking protocol to deliver messages. The crux of the problem is that the nodes have to be discovering neighbours while spending the minimum amount of time in active mode, in mobile networks this is excercebated by the dynamics of the nodes. Wireless routing protocols such as DSR [Johnson and Maltz, 1996], AODV [Perkins and Royer, 1997], OSPF [Moy, 1998] [Vahdat and

Becker, 2000] [Lindgren et al., 2003] rely on periodically sending broadcast packets to advertise the node's presence and discover other nodes. This assumes all the nodes have to be listening most of the time to be able to timely discover other nodes or be discovered by other nodes. This is problematic for modern radios where the cost of idle listening is approximately comparable to the cost of transmitting or receiving [TexasInstruments, 2008]. In the worst case, a node would have to be awake all the time, waiting for a contact with other nodes, which would limit the useful lifetime of a typical node to just 30 days1. There have been a number of recent attempts to apply duty cycling to mobile wireless networks. Most of these approaches focus on node discovery functionality, but do not deal with channel access and duty cycling in connected states. Some of these protocols have been evaluated in a simulator with a number of assumptions about the hardware. The approaches are based on generating a certain sequence of states between listening, transmitting and idle states, which are designed to maximize the probability of overlapping between the active states of asynchronously duty cycled nodes. Looks at energy efficient node discovery after sensor nodes are deployed in the field. Investigate an efficient way for mobile nodes to discover neighbours using birthday protocols.

In our work, we design a Group based super node for energy efficiency of the network. The impulse behind this work is to trim down the energy consumption of sensor node. From the nodes the data packets are routed to super node through the CH, then super node transmits these data to the BS. The rest of the paper is organized as follows: section 2 brief about the related work. In section 3, LEACH protocol is described. Proposed Scheme is defined in Section 4. Simulation and performance parameters are described in Section 5. Section 6 describes the simulation results of our proposed work. Finally, section 7 concludes the paper.

II. RELATED WORK

Some of the related works for Distance based node selection for energy efficient routing in WSN (DNER) are as follows:

A two layer hierarchical routing protocol which attempts to minimize energy consumption evenly across all nodes is discussed in [5].Survey on recent routing protocol for sensor networks and classification for various approaches are explained in [6]. The three main approaches discussed are data centric, hierarchical and location based routing. Depending upon some weight factors the super cluster head is elected among the existing clusters. Weight factors are evaluated based on distance and remaining energy considerations is discussed in [6]. CH is responsible for not only the general request but also assisting the general nodes to route the sensed data to the target nodes. The power-consumption of a CH is higher than of a general (non-CH) node. Therefore, the CH selection will affect the lifetime of a WSN is discussed in [7]**.**The powerful competitive learning algorithm, self splitting competitive learning which is able to find the natural number of clusters based on the one-prototype-take-one-cluster paradigm is given in [8].The first breakdown energy consumption for the components of typical sensor node and main directions to energy conservation schemes in Wireless sensor networks are presented in [9]. Comprehensive and fine grained survey on clustering routing protocols proposed in the literature for WSNs. The advantages and objectives of clustering for WSNs, and develop a novel taxonomy of WSN clustering routing methods based on complete and detailed clustering attributes[10].A systematic and comprehensive taxonomy of the energy conservation schemes are also given. The work given in [11] explains several multihop flat based routing protocols like flooding, gossiping, and a cluster based protocol, multi hop-LEACH intra-cluster multi hopping using TinyOS and TOSSIM simulator. The information about energy status can be used to notify about resource depletion in some parts of the network. It can also be used to perform energy-efficient routing in WSNs.

A. With this survey we have some common criticisms as below:

- Number of cluster heads in a network is not defined. Since in each round a node becomes a cluster head with uncertain probability, it is possible that network may have large number of clusters will congest the area with small size clusters. If less number of clusters will exhaust the cluster head.
- Multi hop Routing model must be used to increase the energy efficiency.

To avoid these criticisms we have proposed routing scheme for WSNs. A distance based super node is elected among the nodes as; distance always affects the energy of the nodes. Directly communicating of CHs to BS decreases the energy efficiency so a super node which is nearer to BS which sends all the data packets to BS

B. Our Contribution

1) Development of nodes randomly over the network environment.
2) Optimal cluster heads are computed.
3) Clustering is done by threshold probabilistic method as in LEACH.
4) Selection of super node is done depending upon the minimum distance from base station.

III. LEACH PROTOCOL

LEACH [5] –Low Energy Adaptive Clustering Hierarchy protocol by Heinzelman is the most famous clustering protocol. This protocol is used as a basis for many clustering protocols. It is hierarchical and probabilistic protocol. All nodes are homogeneous and energy constrained.

The most important goal of LEACH protocol is to reduce the energy consumption by each node in a network and extend the lifetime of the network. It is also used for data aggregation which reduces the energy consumed by each cluster head. Each Cluster Head in this protocol collects the data from its members or nodes which are associated to cluster. The CH aggregates the data and transmits this data directly to the base station over single hop. Every node can become a cluster head depending on their energy levels and probability values. Cluster Heads are periodically changed in each round to balance the node energy dissipation

The operation of LEACH is divided into two phases:

1. Set up Phase
2. Steady state phase.

LEACH protocol starts with the number rounds. In each round both the phases operation is done. Always cluster formation and selection of cluster head is done in set-up phase. In steady state phase (transmission) TDMA schedule is created, data is aggregated and finally data packets are sent to the Base station.

1. Set up Phase

In this phase cluster formation and selection of cluster head is done. Consider all nodes are not a cluster head these are simply a nodes which is having same energy levels. When current round starts each node decides whether to become cluster head or not. The protocol is probabilistic so selection of the cluster head also had done with a probability function.

Following are the steps to select cluster head

1. Select a random number between 0 and 1 for a current node.
2. If the number is less than the threshold T(n), the node is elected as a cluster head.
3. Form a cluster with its members.

The threshold T(n) is given as

$$T(n) = \begin{cases} \frac{p}{1-p(r \bmod \frac{1}{p})} & \text{if } n \epsilon G \\ 0 & \text{Otherwise} \end{cases} \quad (1)$$

Where,'n' is node, 'T(n)' is threshold value of the node 'p' is the desired cluster head probability, 'r' is current round number and'G' is the set of nodes that have not been cluster heads in last 1/p rounds.

Using the threshold, each node can become cluster head. In round 0 all the nodes have a chance to become a cluster head. After 1/p round, remaining nodes (still not a cluster head) have a more chance to become a cluster head. After completion of the phase, a non-cluster head node decides to which cluster it belongs.

2. Steady State Phase

It is set of frames. Each node must transmit their data packets to the cluster head. So each node sends their data to cluster head at once per frame allocated to them. Duration for each node is constant. After the transmission of data the node goes to sleep mode to save energy. When next transmission slot arrives it awakes and sends the data. The cluster head must keep its receiver ON to receive the data packets from the nodes.

After collection of all data packets, cluster head aggregates the data and form a common single signal. Aggregated data is sent to the base station. An aggregation technique saves energy. The best tools of the LEACH are rotation of the cluster head among all nodes and data aggregation which extends the lifetime of the network and saves energy.

Problems in LEACH are

1. CH selection is random and it does not consider about energy consumption of nodes. Therefore there may be a chance for CH will die earlier than other nodes. When CH dies, the cluster will become useless.
2. It cannot cover large area and CHs are not uniformly distributed.
3. No guarantee about placement and/or number of cluster head nodes in every round.

IV. PROPOSED WORK

In this section, we present a proposed scheme of our work to get more energy efficiency of the network with some modifications in LEACH protocol. Cluster heads will transmit their data packets to base station through super node. Super node is sensor node, which has minimum distance between itself and base station. Distance between transmitter and receiver has more effect on energy of the network. Goal of this proposed work is to make network energy efficient compared to the LEACH. Routing of the data packets from nodes to cluster heads is single hop model. Routing of data packets from cluster head to base station through the super node is multi-hop model.

a. Proposed network model

Following assumptions are made in the proposed work

1. The Base Station (BS) is fixed and its location is far from sensor nodes.
2. All the nodes are static.
3. The nodes are homogeneous i.e. same energy level is applied for all nodes.
4. The nodes always have data packets to sent BS.
5. Optimal number of clusters is selected for each round.

The figure 2 shows a proposed block diagram:

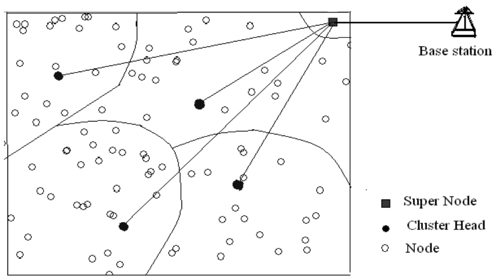

Fig 1: Block Diagram of proposed work

For N=100 nodes, using equations (2) and (3) energy dissipation is calculated for transmitter and for receiver to transmit and receive 'l' packets respectively for each round. Using following equation energy retained in a transmitter is calculated as

Node (i). E = Node (i).E - E_{TX} (l, d) (6)

And energy retained in a receiver is calculated as

Node (i) .E = Node (i).E - E_{RX}(l) (7)

Where, Node(i). E is energy of the current node and 'i' represent current node number

Optimal cluster heads are elected for 'M' area of the network, and distance between transmitters to BS'$d_{to\ BS}$' is calculated [12] using following equation.

$$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}} \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \frac{M}{d^2_{toBS}}. \quad (8)$$

Optimal value for our work is 1<kopt<4.

b. Proposed work algorithm

1. Nodes are randomly deployed in a field of 100 X 100 m^2.
2. Position of a Base station and energy for all nodes is

defined

3. Calculate the optimum value of clusters in a network.
4. Find the distance between all nodes to base station. The minimum distance node is declared as a 'super node'. Save the id of node and define its type as a super node.
5. Initially there is no cluster heads. Define nodes type as a node
6. Cluster Heads are formed as explained in LEACH. Define the type of that node as a 'cluster head'. Save the id of each cluster head.
7. Calculate distance of node to each cluster head. Minimum distance node, join nearby cluster head and declares itself as a cluster member
8. After formation of clusters, check energy level of each node, if it is less than or equal to zero, then count it in dead nodes.
9. Each node starts sending its data packets to associated cluster heads, if the node is not dead.
10. CHs send the data packets to BS through super node.
11. If rounds are not completed again go to step 6.

Routing the packets is done only through the alive nodes, alive cluster heads and alive super node.

V. SIMULATION

The proposed work simulation is done in NS2. Here in the area of 100 X100 nodes are randomly deployed . Optimal cluster heads are 1 to 4. Proposed Network model parameters are defined with their values in following table I

Parameters	**Parameters value**
Network area	100 m X 100m
Base station position	(75m, 150m)
Number of nodes deployed	100
Initial energy of each node	0.5 Joules
Eelec =ETX= ERX	50n J/bit
Eamp	0.0013 pJ/bit/m^2.
Efs	10 n Joules
Length of the data packets, l	4000 bits
No. of rounds	2500
Threshold Probability , p	0.1

TABLE I: VARIOUS PARAMETERS WITH THEIR VALUES

VI. RESULTS

In this section, we discuss various results obtained through simulation. The results include energy consumption, Total number of dead nodes, alive nodes and throughput. Our scheme DNER is compared with existing LEACH.

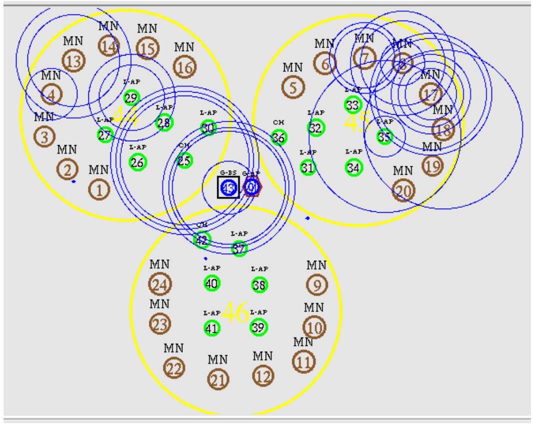

Fig 2: Nodes deployment and created a super node

After simulation various results are obtained.

A. Dead nodes and Alive nodes in a network:

As shown in 3 , in LEACH protocol the First Node Death(FND) at 155th round but in a proposed work the first node dies at 463rd round. So proposed scheme is 19.8% better than LEACH as number of CH is restricted maximum up to 4. Alive nodes are also shown in figure 4.3.Alive nodes are just the difference between total nodes and dead nodes per round.

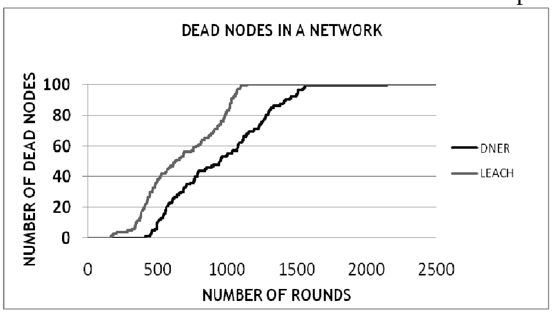

Fig 3: Dead Nodes in the network.

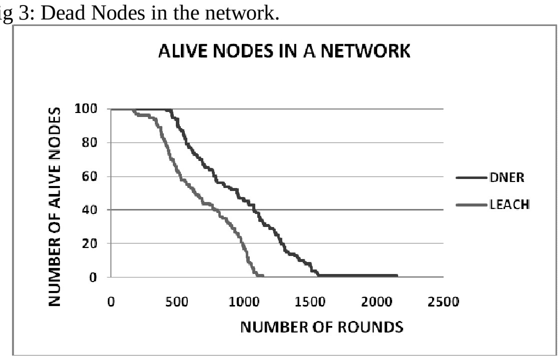

Fig 4: Alive nodes in a Network

B. Throughput of the Network:

Throughput of the network is given in terms of number of packets received at base station. The number of packets received at base station in a proposed work is more compare to the LEACH as shown in figure 6. In a proposed scheme at the end of the last round it sent total 10523 data packets to the base station , but using a LEACH protocol only 7477 data packet are sent. So, proposed scheme is 40.7% better than LEACH.

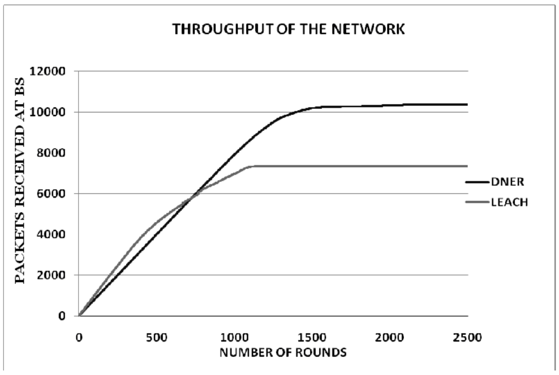

Fig 5: Throughput of the Network

a. Energy efficiency of the network:

The proposed scheme goal is to increase the efficiency of the network. In a Proposed scheme the average energy of the network is 47.9% better than LEACH protocol. The complete energy consumption of the network is zero at 1799th round in a proposed scheme and in a LEACH protocol energy consumption of the network will be lost at 1216th round.

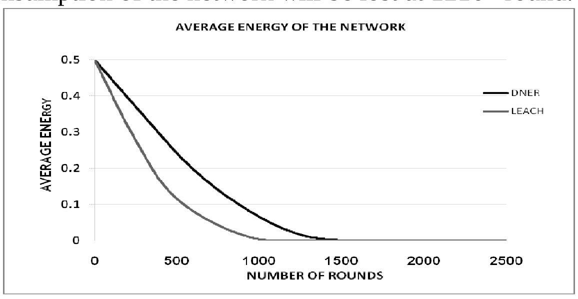

Fig 6: Average Energy of the Network

VII. Conclusions And Future work

Energy Efficient network is a vital problem in this field of MSN. Moreover, in human accessible or in-accessible area, where sensors are not replace in short time gap, people must use some energy efficient clustering strategy and examined for better result. Proposed Scheme is basically a modification of an existing scheme, LEACH. Concept of selection of Super node is to save the energy consumption of network. In each round, it is important to decide the numbers of clusters/CHs that exist in the MSN for maximizing the energy efficiency. For this reason optimal clusters are selected. Optimal cluster increases the network scalability, life time and efficiency.

Energy Efficiency of the proposed scheme is measured against LEACH. Better network lifetime and a better performance is achieved.

As a future extension of this work, the routing technique only through the super node. By applying good data aggregation methods for super node then data aggregated twice and to base station only aggregated data are sent. This may again increases the lifetime of network. In proposed work the network model is homogeneous and all the nodes are static. So the mobile nodes with heterogeneous network can be used.

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