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Energy Efficient Routing in Random Deployment of Wireless Sensor Networks

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Abstract—

Wireless sensor networks are composed of large number of tiny sensor nodes that are used to observe, monitor and collect data about a certain phenomenon of interest. Wireless sensor networks are often deployed randomly due to the harsh environments and their hard to reach locations. The sensor nodes used in wireless sensor networks are energy constrained. Energy efficiency is thus the main concern of the network. Energy efficiency depends upon the routing mechanism that is used to forward packets from the sensor nodes to the base station. Cluster based hierarchical routing protocol; LEACH is most conventionally used for energy efficient routing in wireless sensor networks. LEACH protocol has undergone many enhancements and improvements over the years to improve the energy efficiency of the network. In this paper we address the key issue of energy efficient routing where the sensor nodes are deployed randomly. We propose to enhance LEACH protocol to reduce the energy consumption and also verify and validate the enhancement by using MATLAB.

Keywords—Energy Efficiency, Hierarchical Routing, LEACH, Node deployment, Wireless Sensor Networks.

I. INTRODUCTION

Recent technological advancements in Micro-Electro-Mechanical System (MEMS) have paved way for manufacturing of smaller and more compact sensor nodes [4]. The miniscule sensor nodes work in collaboration via RF communication to form a WSN (Wireless sensor network). WSN can be defined as a infrastructure-less, self configured wireless network where the sensor nodes monitor a particular phenomenon or some environmental conditions to cooperatively propagate data to a base station or sink where the data can be further processed and analysed. Typically a sensor network consists of hundreds and thousands of sensor nodes that are placed in a random or predetermined manner. The sensor nodes are also highly resource constrained in case of energy and computational capabilities. Thus energy conservation emerges as an important issue for WSN.[7]

A sensor node used in a wireless sensor network comprises of a sensing unit, processing unit, transceiver unit and a power unit as shown in the figure. The sensing unit has specific sensors for which it is designed, eg. heat, temperature etc. The output of sensor is an analog signal and is analog in nature. Thus an analog to digital converter (ADC) is used to transform the signal to digital form for communication with microcontroller. The processing unit comprises of storage alongside the processor. Data collected from the area being sensed is then processed and stored in this unit. It also consists of a timer for sequencing tasks. The transceiver unit resides both the transmitter and the receiver. On the basis of the application for which it is suitable, different methods such as optical, infrared or radio communication is used. Most importantly the power unit consists of the battery (or a power generator) which is needed to provide energy to the sensor node for monitoring the environment and sensing purposes. The life of a sensor node depends on the battery (power resource) connected. Efficiency of battery increases by the efficient use of power unit.

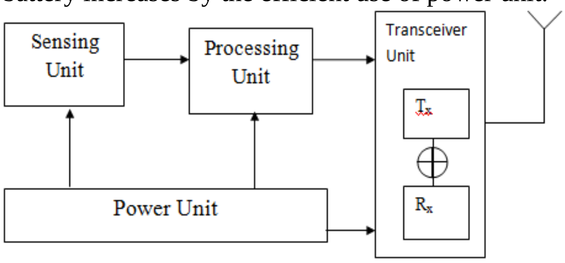

Fig 1: Sensor Node Structure

WSN is a hot topic of research for applications in everyday life. Recent developments in technology have also given new direction for WSN deployment in various civil and military applications. The emerging use of these networks has also procured new innovations in this field. Research has been proposed in data routing, data compression, data aggregation, efficient clustering mechanisms for reducing the energy consumption of the sensor network as the energy source is often incapable of replenishment. Thus research pushes WSN towards wide range of applications and helps it become more versatile. Routing in WSN is important as the sensor nodes have to route packets and information that is sensed from the environment. Also, most of the energy is expended in transmitting or routing the information among the sensor nodes. [16]

In the following sections of the paper we discuss the node deployment models and propose an enhancement in LEACH protocol to address the energy efficiency issue for routing packets in WSN. Finally simulation results are used to show the effectiveness of the proposed scheme.

II. NODE DEPLOYMENT MODELS

The deployment of nodes for observing and monitoring the interested phenomenon is done in different ways. The node deployment models used in wireless sensor networks are classified mainly into following two categories:

A. Random Node Deployment

The sensors that are deployed in random deployment have an equal probability of being placed at any given location inside the sensor field. In case of random deployment of the nodes, they are scattered from the air. Thus the nodes are viable to be placed at locations which are uncertain. The node density in case of random deployment of sensor nodes is not even in the network. This strategy is sometimes considered cost effective but only if it provides a desired coverage which is of course very rare due to unequal density of sensor nodes. This model finds application in locations that are often inaccessible and have harsh environmental conditions such as seismic zones, military applications, volcanoes etc. [10]

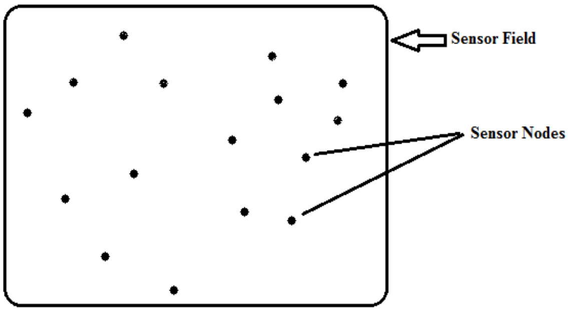

Fig 2: Random Node Deployment

B. Deterministic Node Deployment

The senor nodes in case of determined deployment have a predetermined and predefined location for them to be positioned. The position of the sensors is calculated so as to provide a maximum coverage with the use of minimum number of sensor nodes. The number of sensor nodes used in deterministic node deployment is less in comparison to the random node deployment model. It is thus more preferred than random deployment, wherever possible. The deterministic node deployment finds applicability in those situations where the area to be monitored is physically reachable. [10]

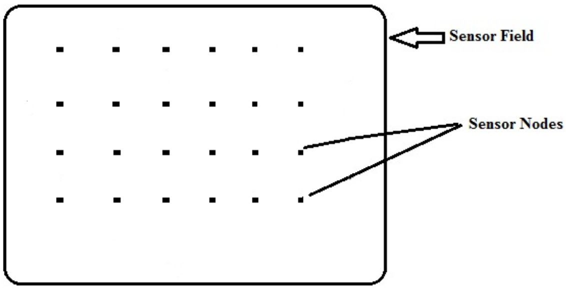

Fig 3: Deterministic Node Deployment

III. PROPOSED WORK

The energy consumption is mainly due to the transmission of data packets in a wireless sensor network. Thus to increase the energy efficiency of the network we need to lay emphasis on transmission and receiving of packets in WSN. The most conventional and popular routing protocol used in WSN is LEACH (Low Energy Adaptive Clustering Hierarchy). LEACH uses hierarchical routing for packet transmission in the network. LEACH also balances energy in the nodes and the nodes die randomly when LEACH is used. LEACH proceeds in rounds. Each round is comprises two phases viz. Setup and Steady phase. Setup phase comprises of clusters of nodes formed (as shown in the figure) and a cluster head selection done according to a stochastic probabilistic calculation based on the following formula:

$$T(n) = \begin{cases} \dfrac{p}{1 - p \times (r \bmod p^{-1})}, & \forall n \in G \\ 0, & \forall n \notin G \end{cases}$$

Where n is a random number between 0 and 1, p is the cluster head selection probability and is the set of nodes that have not been CH for previous rounds. After Cluster Head is selected, advertisement of CH takes place. Then the nodes join the cluster based on RSS (Received Signal Strength). Cluster head then makes TDMA (Time Division Multiple Access) schedule in which each node is provided a slot for data transfer. Thus the setup phase completes. Then steady phase follows by the transmission of data. Steady phase is kept longer than the setup phase for energy efficient routing. [1],[4],[7]

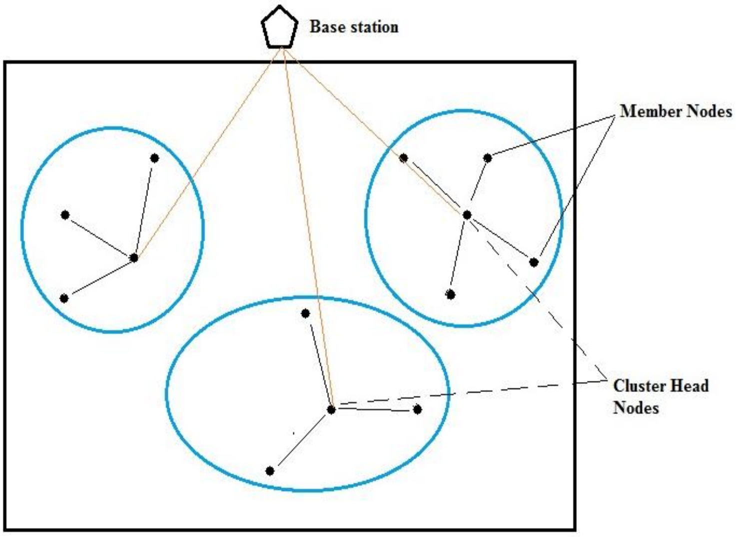

Fig 4: LEACH protocol architecture.

Now to address most important problem of energy dissipation we propose a scheme to suppress the data transmissions within the cluster. As we know the sensor nodes that are placed in vicinity collect data that is correlated. This data is mostly unnecessary in most of the situations. The correlated data is then transmitted to the CH node and further to the base station. In our proposed scheme we group nodes that come in close geographical proximity to form a virtual correlated cluster (VCC). Then during the transmission all the nodes in the VCC are given one TDMA schedule. Thus only one of the nodes is allowed to send data to the Cluster head. This leads to lesser number of correlate data transmissions which increases the energy efficiency of the overall sensor network.

We have proposed changes in the setup phase of the LEACH protocol. After announcing the CH status, the CH will find the nodes that are in close proximity. The location would be known to the CH because nodes will send their location to CH during the cluster join phase in form of join_REQ packet. Then CH will find a Threshold Sensing Coverage and group nodes (as VCC) based on their sensing range according to the following calculations:

$$n \times \frac{3\sqrt{3}}{2} \times r^2 = M \times N$$

Where, in our case both M, N= 100, n=100, thus we find out, r= 6.20 m. Then a common TDMA schedule is created for nodes in VCC and finally data is transmitted in the steady phase.

IV. SIMULATION

The simulation parameters are discussed in this section. We show the effectiveness of the proposed scheme using simulation in MATLAB. The base station is kept far away from the network at (50, 195) and other simulation parameters used are given in Table 1.

Table 1: Simulation Parameters

PARAMETERS	VALUES
Simulation Area Size	100 m x100 m
Number of nodes	100
Initial Energy of nodes	0.5 Joules
Percentage of CH (P_{opt})	5%
Data Packet size	4800 bits
Transmission & Receiving Energy (E_{elec})	50 nJ/bit
Free space Transmitter Amplifier Energy (E_{fs})	10 pJ/bit/m^2
Multipath fading Transmitter Amplifier energy (E_{mp})	.0013 pJ/bit/m^4
Data Aggregation Energy (E_{DA})	5 nJ
Type of distribution	Random

V. RESULTS AND ANALYSIS

To perform the analysis we take into consideration the following network performance metrics:

1. *Energy Dissipation by CH Nodes*: Amount of energy dissipated during receiving of packets by Cluster Head nodes with respect to the number of rounds of the network proceeded.
2. *Energy Dissipation by Member Nodes*: Amount of energy dissipated during transmitting of packets by Member nodes (that was sensed) to the CH node with respect to the number of rounds of the network proceeded.

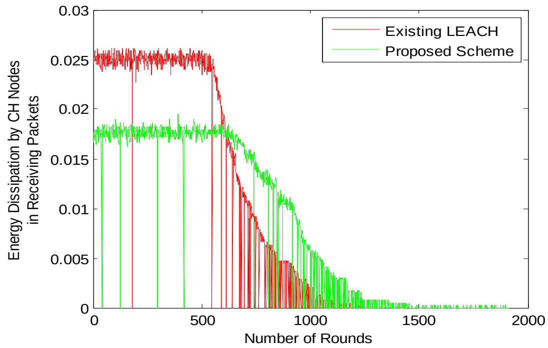

Fig 5: Energy dissipated by CH Nodes Vs Number of Rounds

Fig.5 shows the graph between energy dissipated by CH nodes versus number of rounds. Energy is dissipated in case of receiving the packets from the member nodes. The sensor nodes sensing the environment have to send the data to its cluster head which then forwards the data to the base station or sink for further analysis. As seen from the figure the energy dissipated in case of proposed scheme is lower than the traditional LEACH protocol. However energy consumption is higher after the half life of the network due to the fact that more number of nodes are alive in case of proposed scheme. As we have reduced the energy consumption so the more sensors remain active and send the data to the CH which is consistent with the graph.

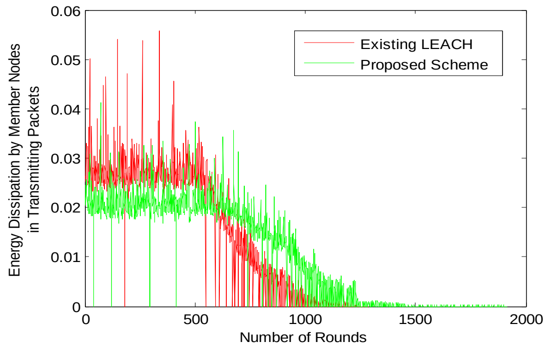

Fig 6: Energy dissipated by Member Nodes Vs Number of Rounds

Fig. 6 shows the graph between energy dissipated by member nodes versus number of rounds. Energy is consumed by the member nodes in case of transmitting data to the cluster head. The sensor nodes observing and monitoring the environment need to send their reported data to the cluster head, as in case of hierarchical routing. The CH nodes then propagate the data to the base station. The energy consumed by member nodes is of importance to us here. The graph clearly shows that energy consumed in case of proposed scheme is lower than the traditional LEACH protocol. It thus validates our enhancement. As seen in fig 5 the energy consumption of the proposed scheme is more than LEACH after half life of the network in this case also. The reason is also same as explained earlier.

VI. CONCLUSIONS

In this paper we have discussed WSN, its working and deployment models, LEACH protocol for routing data packets and proposed an enhancement to the existing methodology for improving the energy efficiency of the sensor network. Energy efficiency is the main concern of WSN as they are mostly deployed in locations that are inaccessible and hostile. Thus its very difficult to replenish the energy source. As seen from the simulation results the energy consumption has been reduced in case of the proposed scheme. Thus the proposed scheme can be very useful for randomly deployed WSN in case of harsh environmental conditions.

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