

Comparative Performance Analysis of Routing Protocols in Wireless Sensor Network

Ramkrishna Ghosh*

Haldia Institute of Technology, West Bengal, India

Abstract

Wireless Sensor Networks (WSNs) and Wireless Multimedia Sensor Networks (WMSNs) consist of wirelessly interconnected sensor nodes which can collect, deliver and process information in different application areas. Power Consumption in these networks is a major problem. Some of the applications include landslide detection, glacial monitoring, wildlife tracking, health care, military applications, environmental monitoring and a large number of applications to robotics, "internet of things" projects. This paper will illustrate the fundamental characteristics of WSN followed by different power consumption protocols. Here we have performed the comparative performance analysis of different power consumption protocols.

Keywords: WSN; LEACH; MODLEACH; SEP; TSEP; Cluster Head (CH)

Introduction

Wireless Sensor Network (WSN) provides many advantages such as portability, flexibility, increased productivity, deplorability, mobility and lower installation costs. Wireless Sensor Networks (WSNs) are distributed network of all tiny and light weighted nodes which can sense physical parameters such as temperature, pressure, relative humidity. Each node of the sensor network consists of three subsystems.

- i. Sensor subsystem: Which sense the environment?
- ii. Processing subsystem: Which can perform computation on the sensed data?
- iii. Communication subsystem: It is answerable for message exchange with neighbouring sensor nodes.

Communication in Wireless Sensor Network (WSN) happens in three different ways:

- i. Clock driven: Sensors sense and gather data at constantly and periodically distribute.
- ii. Event driven: Communication is triggered by an event.
- iii. Query driven: Communication happens in reply to a query.

A Wireless sensor node has a small amount of memory for storing programs and data. In WSN, many sensors are linked together via radio frequency communication links (Figure 1). Different types of Dos attacks can affect a network. If affected node continues to exchange information with neighbouring nodes and lead to diminish its power then the node is declared as dead node which is worst case.

There are four parts of sensor network: i) Sensors; ii) Network connecting different sensors; iii) Centralized information gathering store; and iv) Resources performing computation which include data mining, data correlation etc. [1,2]. Routing in wireless network is somewhat different from other wireless networks due to sensor nodes which have constraints of energy, processing activities, transmitting collected data from multiple nodes to a single sink. In WSN unique global address is not possible due to random deployment of nodes Main objective of routing protocols is to reduce the power consumptions and increasing network life time [3]. Network life time can be increased by implementing routing protocols that consume less energy, choose path

between sensor nodes and base stations. There are three different types of routing protocols based on the network architecture [2].

Flat protocol

Here nodes are placed uniformly and do the same work i.e., every node is at the same level inside the network.

Hierarchical protocol

Here nodes are arranged into clusters and the nodes which have maximum energy are known as Cluster Head (CH). Cluster head is responsible for collecting data from nodes of their cluster and removing redundancy among collected data to reduce energy requirement for transmitting of data packets from cluster head to base station e.g., LEACH, SEP, TEEN, APTEEN, etc. [4].

Location based protocol

Nodes are differentiated based on their location inside network. Distance among sensor nodes are calculated based on signal strength, higher the signal strength lesser the distance between nodes. Some protocols based on location allow nodes to enter into sleep mode if there is no activity is going on at that particular node.

Among the categories of routing protocols of WSN, FLAT protocols have minimum overhead to maintain resources [5]. Main aim of this paper is to review the hierarchical energy efficient routing protocols along with the modifications over some of these protocols.

Hierarchical Protocols

In hierarchical routing protocols, nodes organize the network into a group of clusters. Each cluster is managed by a selected cluster head [5]. Cluster head is answerable for collecting data from member

*Corresponding author: Ramkrishna Ghosh, Haldia Institute of Technology, Haldia, West Bengal, India, Tel: 03224 252 900; E-mail: ramkr.ghosh@gmail.com

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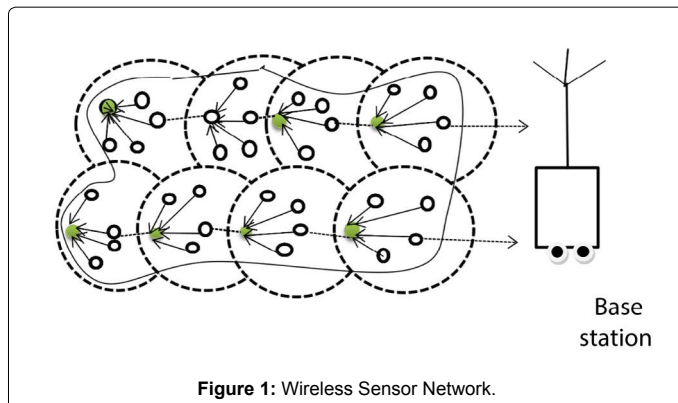


Figure 1: Wireless Sensor Network.

nodes of their cluster, compresses it and then removes duplicity among collected data to minimize number of transmissions between cluster head and base station [6].

LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH is a routing protocol that collects and sends data to base station with following main objectives:

1. Increase Life time of the network.
2. Decrease energy dissipation of sensor nodes.
3. Reduce the number of communication messages.

To fulfil the aforementioned objectives the nodes organize themselves into clusters. As shown in the Figure 2, member nodes of a cluster send their respective data to cluster head which is answerable for sending the collected data from all its member nodes to base station.

This results in saving large amount of energy as aggregated data is sent over a single hop. LEACH operates in two phases including setup phase and state phase. The set up phase is categorized as cluster head selection and cluster formation [7]. Cluster head ensures that cluster head selection moves among all sensor nodes. Selected cluster head lasts only for a round. Selected cluster head will not die soon. For cluster head selection, node 'n' generates a random number between 0 and 1 and compare it with the cluster head selection threshold $T(n)$. A node will be cluster head if the generated random number less than a threshold $T(n)$. Node which acts as a cluster head in last $1/p$ rounds are not selected as cluster head [8]. To satisfy these requires threshold is set as

$$T(n) = p/1-p \times (r \text{ mod } 1/p) \text{ if } n \in G$$

$$0 \text{ otherwise}$$

Where r is the current round and G is set of nodes that have not been selected cluster heads in the last $1/p$ rounds. After cluster creation each cluster head creates and distributes TDMA schedule among each member of their cluster [9]. This ends set up state phase and starts state phase. During steady state each node transmits its sensed data to cluster head during its allocated time slots.

Different LEACH Variations

Non uniform distribution of cluster head is the drawback of LEACH that leads to early fading of battery of cluster head and hence lowers the network life time. The limitation is overcome in descendants of LEACH protocols.

C-LEACH (Centralized LEACH)

In LEACH every node takes its own decision to become a cluster head but the main limitation is that there is no guarantee for cluster head position and number of nodes in each cluster. It may decrease the overall performance during some rounds. C-LEACH, a central control algorithm is used to clusters in such a way that cluster heads are scattered throughout the network. This algorithm is implemented at base station which selects nodes to make them cluster head for current round [10]. Every sensor node sends their current location (using GPS) and residual energy to the BS. Base station calculates then average node energy and nodes that have energy less than average cannot become cluster head for that round. In C-LEACH, every node sends their data to cluster head and cluster head after doing data aggregation sends compressed data to BS. Overall, C-LEACH performs better than LEACH because it considers position of nodes inside the network.

MODLEACH

It is another cluster based algorithm differs from LEACH mainly on two points; firstly, there is no need to change cluster head until and unless it has more energy than certain required threshold. Secondly, MODLEACH did not amplify all the signals to the same level. In LEACH, cluster head is changed every round but in MODLEACH current cluster head is replaced by new one only if current cluster head does not have energy less than the required threshold [11]. It saves energy consumed in cluster formation and forwarding the routing packets for searching another new cluster head. There are three communication categories based on MODLEACH: 1) Intra cluster communication; 2) Inter cluster communication; and 3) Data transmission from cluster head to BS.

SEP (Heterogeneous LEACH)

In LEACH every sensor node is initialized to same energy level but in SEP there are two types of nodes: 1) Normal nodes; and 2) Advance nodes. These nodes have different initial energy. There are m advance nodes in a network with α additional energy. Advance nodes have energy $E_0 \times (1+\alpha)$ where E_0 is the energy of normal nodes. Advance nodes are made cluster head more often than normal nodes because advance nodes have more energy as compared to normal nodes [12]. In SEP, Initial energy is increased by $\alpha \times m$ and hence overall performance/network life time increases so instability period decreases.

Improvement over Hierarchical Routing Protocols

DFCA (Distributed fault Tolerance Clustering Algorithm)

IN DFCA, gateways have more energy than normal node and made as cluster heads. These special nodes are battery operated and hence limited life time. Hence their proper use in the network increases the

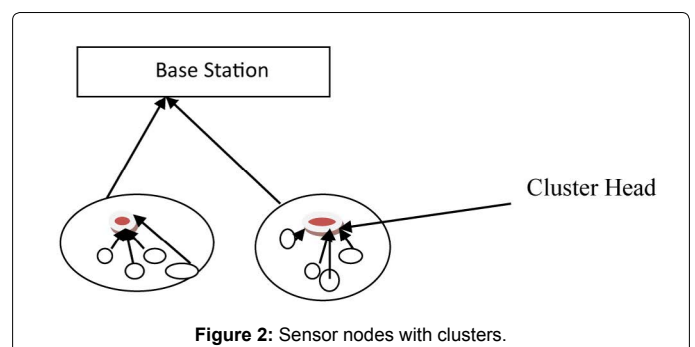


Figure 2: Sensor nodes with clusters.

network life time. DFCA implemented fault tolerance to maintain the death of gateways. In DFCA base station assigns unique identity to all nodes including gateways in the network and then sends HELLO message to each gateway.

An improvement over DFCA is EDFCA in which whole area is divided into grids. Main advantage of this approach is it increases the covered node and decreases broadcast messages sent by uncovered nodes for finding new gateway. EDFCA decreases routing overhead and reduces energy consumption for routing [8].

TSEP (Threshold Stable Election Protocol)

It is a reactive protocol in which nodes continuously sense the environment but transmit only when threshold of different parameters is reached. It has three different types of nodes—normal nodes, intermediate nodes and advance nodes. Nodes having maximum energy are called advance nodes and nodes having minimum energy are called normal nodes [4]. TSEP selects cluster head based on the principle of LEACH. If generated value is less than the threshold then node becomes Cluster Head (CH). But threshold is calculated on the following formula:

$$T_{nrm} = \frac{p_{nrm}}{1 - p_{nrm} [r \cdot \text{mod} 1 / p_{nrm}]} \text{ if } nrm \in G'$$

0 otherwise

$$T_{int} = \frac{p_{int}}{1 - p_{int} [r \cdot \text{mod} 1 / p_{int}]} \text{ if } int \in G''$$

0 otherwise

$$T_{adv} = \frac{p_{adv}}{1 - p_{adv} [r \cdot \text{mod} 1 / p_{adv}]} \text{ if } adv \in G'''$$

0 otherwise

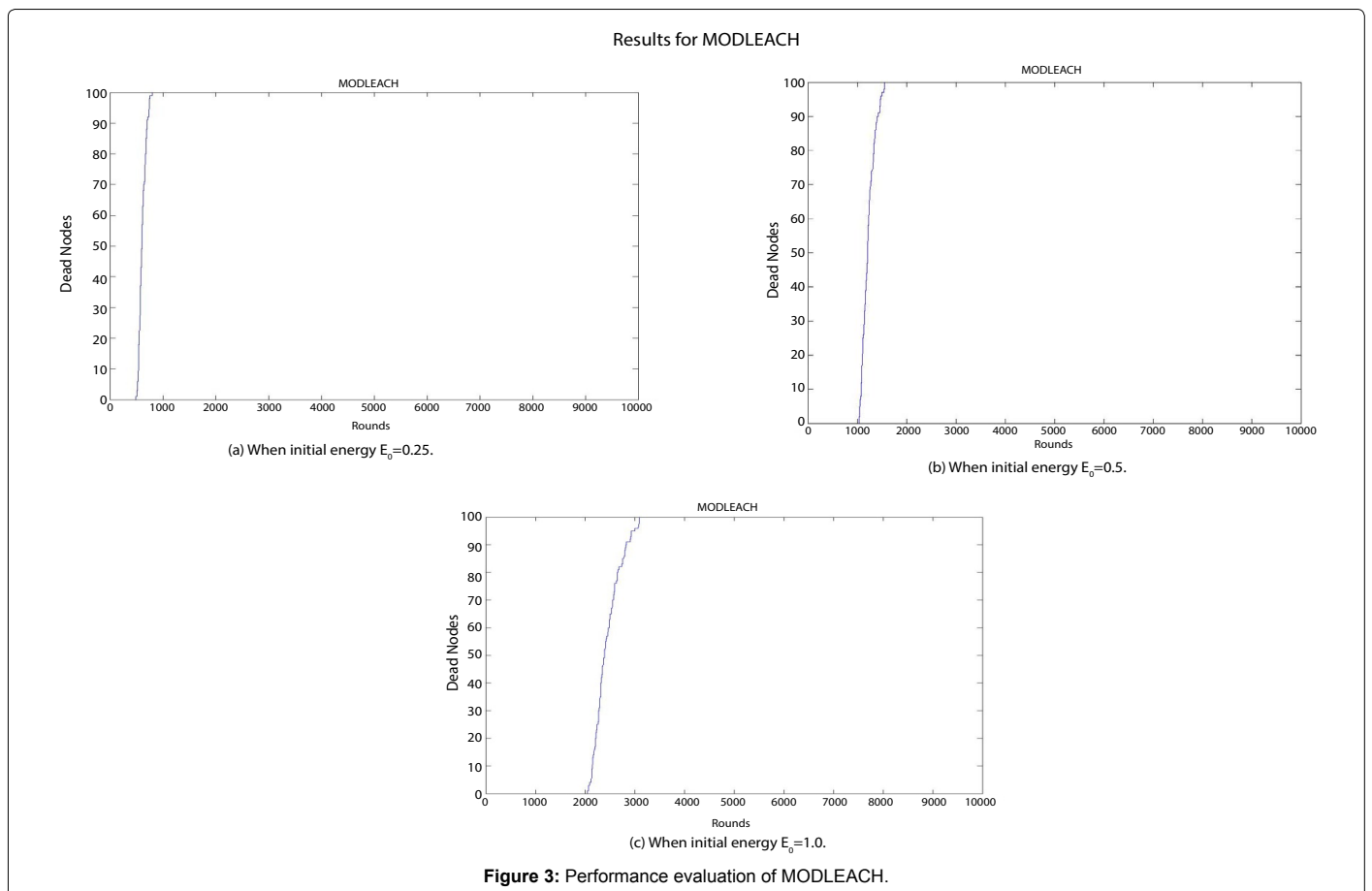
Where G' , G'' , G''' are normal, intermediate and advance nodes that have not become cluster head in previous rounds. After cluster head selection cluster head broadcasts two values—hard threshold and soft threshold. Nodes will not transmit data until and unless sensed value does not reach hard threshold [5]. Soft threshold reduces the number of transmissions that results in energy saving.

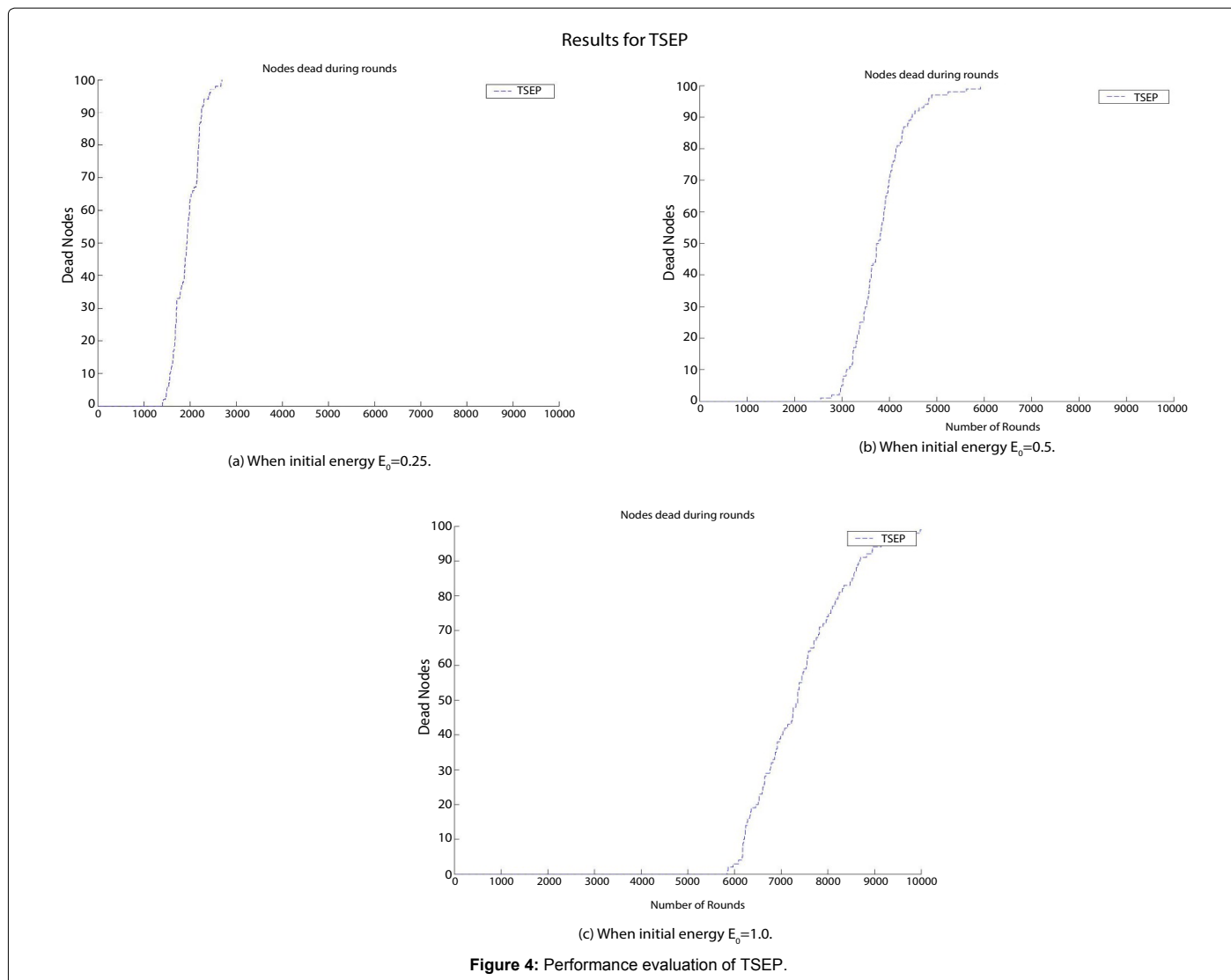
Simulation Results

We have done this simulation using MATLAB. The performance parameters are: At initial energy level 0.25 J first node dies in MODLEACH before 1000 rounds whereas in TSEP first node dies after 1000 rounds. At initial energy level 0.50 J first nodes dies in MODLEACH after 1000 rounds while in TSEP first node dies after 2500 rounds [13]. At 1.0 J first node dies after 2000 rounds whereas in TSEP first node dies near about 6000 rounds (Figures 3 and 4).

Conclusion

In Wireless Sensor Network, nodes are not always homogeneous they might be heterogeneous, which increases network complexity. To decrease energy consumption and increase network life time and stability, clustering is used. In this paper, we have compared





Parameters	Values
Sink location	50, 50
Network Size	100 m
No of nodes	100
CH probability	0.1
Initial Node energy	0.25 J, 0.5 J, 1.0 J
Nodes Distribution	Uniform
Energy Dissipation (Efs)	10pj/bit/ml
Energy for transmission (ETx)	50 nj
Energy for reception (ERx)	50 nj
Data Aggregation	5 nj/bit/signal

Table 1: Different initial energy levels of MODLEACH with TSEP.

MODLEACH with TSEP at different initial energy levels and shown the simulation results (Table 1). We have seen TSEP is giving better performance in terms of network life time and stability.

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