MMSTC: MODIFIED MINIMUM SPANNING TREE CLUSTERING SCHEME ENERGY EFFICIENT HETEROGENEOUS WIRELESS SENSOR NETWORK

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ABSTRACT

A wireless sensor network (WSN) is consisting of a set of sensor nodes with a limited energy stored in their batteries. Generally, replacing or charging the battery is hard and inefficient. Further, the main critical aspect of applications based on wireless sensor networks is their lifetime. Therefore, judicious power management with optimized routing protocols can effectively optimize the energy consumption of sensor nodes and thus extend the network lifetime. In this paper, an optimized routing protocol for wireless sensor nodes is proposed. We are interested in constructing an efficient routing spanning tree that minimizes the energy consumption among all nodes in the network and fit for WSN with reduced energy for achieving a longer lifetime. The main idea of this algorithm comes from the Minimum Spanning Tree (MST) graph theory. The MMSTC focuses on the minimal hop count of each node to reach the destination (sink node) within an optimal path in a heterogeneous wireless sensor network.

Keywords: Wireless Sensor Networks; Network lifetime; Energy consumption; Routing protocols; Minimum Spanning Tree

INTRODUCTION

Wireless Sensor Networks (WSNs) have been widely used in numerous real-life applications, such as health care, pollution monitoring, target tracking, fault detection, or environmental measuring (temperature, humidity, pressure, position, vibration, sound, etc.). Every single node mainly includes various components such as a radio transceiver with an antenna, a microcontroller and an energy source typically a small battery difficult to recharge or replace due to the unattended and harsh environment, which makes it constrained in energy for long-term deployment. Routing in WSN is a very important task that determines how the routes are discovered and how to efficiently deliver data from source to destination even if the routes in between are broken, so to establish a communication. So, many routing protocols have been proposed by researchers or industries in order to optimize the energy consumption and to maximize the network lifetime. Energy consumption, node deployment, scalability, coverage and security are main challenges of routing protocols for WSNs [1].

In this paper, an improved routing algorithm is proposed. It can effectively improve the network lifetime and ensure minimal power consumption. The proposed protocol utilizes a "minimum hop distance to reach the destination" as path selection criteria in every node belonging to a minimum spanning tree (MST) network. As in [2], the path selection criterion is a measure used by a routing protocol for selecting the best path among all the possible paths between a pair of nodes (source and destination). The path selection criterion is usually based on weights, which can be either the sum of distances cost along the communication path, or the number of hop to reach the destination node. In this paper, energy efficiency is demonstrated on the basis of minimum hop count-based algorithm.

The rest of this paper is organized as follows: Section II proposes a global presentation of the multi-hop communication for WSNs, as well as the MST graph theory that our work is based on, and some related works. The proposed approach is presented in section III and the simulation results of the routing algorithm are provided. Finally, a conclusion and a discussion are presented in Section IV.

BACKGROUND

A. Multi-Hop Communication

Wireless sensor nodes can communicate in two ways: single-hop or multi-hop communication, as seen in Fig. 1. In multi-hop communication, a packet has to go through different nodes in order to reach its final destination address. In a Single-hop communication, all the sensors (blue circles in Fig. 1) can send the collected information, directly to the sink node (red circle in Fig. 1). In the case of a multi-hop communication, the sensors send their data to one of their neighbor node, to reach the base station.

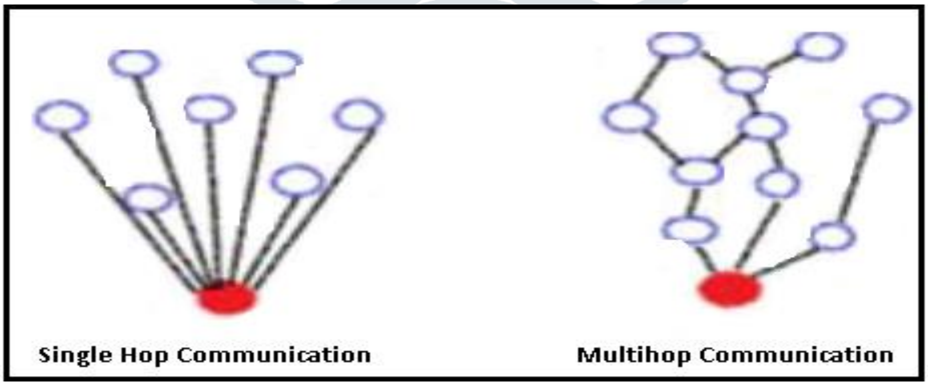


fig. 1: single-hop and multi-hop communications in wireless sensor network

The design of each type of communication is based on energy conservation of the sensor node. In this paper, a multi-hop network topology has been adopted. Our purpose is to optimize the energy consumption of each sensor. To do so, we propose to find the shortest path of transmission that costs the minimal number of hops to deliver the packets between the source and its destination.

As a result, aggregated data is efficiently transmitted along the shortest path through multiple hops from nodes towards the sink, helping to reduce the number of individual transmissions.

B. Minimum Spanning Tree

The proposed WSN can be modelled as a connected graph G = (*VG*, E), where *VG* is the set of N fixed sensors, and E is the set of wireless links. This work is based on the minimum spanning tree (MST) concept of graph theory, for finding the shortest path to connect all the nodes in the network. By constructing the MST with a given set of nodes, we can route in an efficient manner the data from all sensor nodes to the sink with a minimum number of hops in a short time.

A MST of an undirected and connected graph is a sub graph that connects all the vertices of that tree with a minimal overall edge weight. A single graph can have many spanning trees. The overall weight of a tree is the sum of weights of its edges. Obviously, different spanning trees will have different weights [3].The MST is constructed using either the Kruskal's algorithm [4] or the Prim's algorithm [5]. The location of the root node is not taken into consideration in these algorithms. The MST is constructed using the Prim's algorithm.

With the purpose of optimizing energy consumption during communication, the metric of optimal hop number or corresponding individual distance is preserved as the main issue. Indeed, it influenced on many network metrics like energy consumption, latency, routing overhead, etc. [6].

In [7], the authors studied different energy models under general wireless network environment. The authors in [8] presented the selection of transmission manner from probability point of view. They presented a probability of Pi to transmit data through multi-hop manner and a probability (1-Pi) to transmit through single hop manner to sink node. Also, the energy consumption by using single-hop or multi-hop transmission is studied by authors in [9]. They confirmed that choosing multi-hop or single hop routing protocols is subject to the reception cost and the distance between source and sink.

In [10], the author suggested a Multi-hop/Direct communication scheme to divide data traffic into two branches. He used in his work multi-hop transmission to optimize energy consumption and enhance the performance of the network lifetime. In [11], the authors proposed a distance-based energy aware routing (DEAR) algorithm in order to reduce energy consumption and prolonging network lifetime. In [12], the passive optical devices may be used in wireless optical networks.

Routing based on the Minimum Spanning Tree (MST) graph theory is frequently used by researchers for networks energy efficiency issues, but it doesn't takes into account both the minimum cost of edges and the average of the residual energy of nodes during the construction of the spanning tree.

In this work, we proposed a novel approach for constructing an energy efficient spanning tree based on the minimum hop-count to route the data from sensor nodes toward the sink node and the maximal residual energy of each node.

PROPOSED ROUTING PROTOCOL

A. Network Model

Let a node s ∈ *VG* a sink node *sk* ∈ *VG*. Let Path (*s*1, *sk*) be the sequence: *s*1, *s*2...*sk*. We define Hop count (*s*1, *sk*) as the number of hops along the Path (*s*1, *sk*). We recall that Hop count (*sk*)=0.

First order radio model is used for the calculation of energy consumption. In this simple radio model, it is assumed that the energy dissipated to run the transmitter circuitry *Eelec* is the same as the receiver circuitry. An illustration of the first order radio model is shown in Fig. 2. Let *ETx* and *ERx* the energy consumed during the transmission and the reception respectively. In our work, we assume that all transmissions over the network have data packets of the same size.

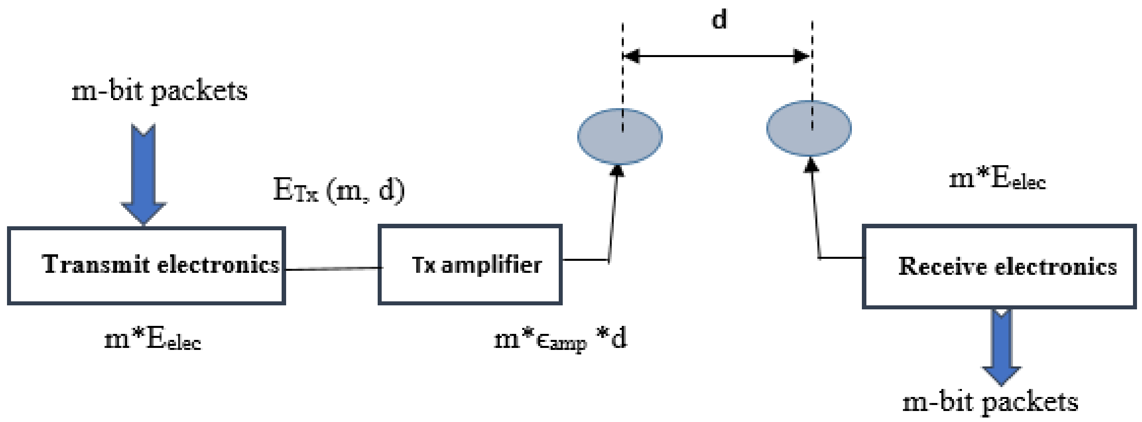


fig. 2: first order radio energy dissipation model

B. Proposed Protocol Description

Problem Statement: A network is composed of N static nodes randomly deployed in an uncertain area, each node having a communication range of radius R. The N static nodes communicate data to a single sink node which has fixed coordinates in advance and presents the final recipient of all the sensed data. The aim is to transfer the data between nodes and the sink node, by calculating the shortest path using the minimum number of hops between the intermediate nodes and the sink node.

Each iteration considers the lowest cost edge (minimum number of hops or minimal distance in addition to the minimal energy consumption for the transmission) within its communication range R to extend the tree with one more node within a cluster. Based on the adjacent matrix that shows the number of hops of each node to reach the sink and on values of energy consumption per node, the algorithm calculates a cost for every edge connected to the sub tree, chooses the lowest cost edge and adds the node in the tree. Then, it determines all optimal routes between nodes and the sink within the tree. In order to ensure the establishment of an optimal path that minimizes energy consumption during data transmission, we aim to minimize count of nodes involved in N transmission (i.e. number of hops).

The sink maintains a route table containing all the shortest routes, i.e. those with a minimum Hop count and maximal residual energy RES(s, r) per node, to all nodes in the network.

RESULT ANALYSIS

MATLAB platform has been used to evaluate the results. Some assumptions are made to simulate the results as shown in table1.performance metrics chosen for above scenarios are network lifetime, packets transmitted to BS, number of CHs per round, number of dead normal nodes per round, no. of dead advance nodes, no. of alive nodes per round.

Network Lifetime may be defined as the time interval from the start of operation to death of the last alive SN. As the energy of SNs is drained out, the communication will end up. Fig. 3 (a), (b), (c), (d), (e), (f), (g) shows that MMSTC outperforms the other existing protocols such as LEACH and LEFCA protocols. This improvement in network lifetime is due to efficient use of clustering method, awareness in terms of energy heterogeneity and using multi-hop MST pattern used for communication between CH and BS.

table 1. parameters

Network Area Dimensions	100m x100m
Number of SNs	1000
Rounds	10000
Electronic energy	50 nJ / bit
Data aggregation energy	5 nJ / bit
Initial energy	0.5 J
Size of the message	4000 bits
Probability	0.05
Energy level for Advance nodes	3
Energy level for Intemediate nodes	1.5
% of nodes to be Advanced and Intemediate	0.2,0.3
BS Location	(50,50)

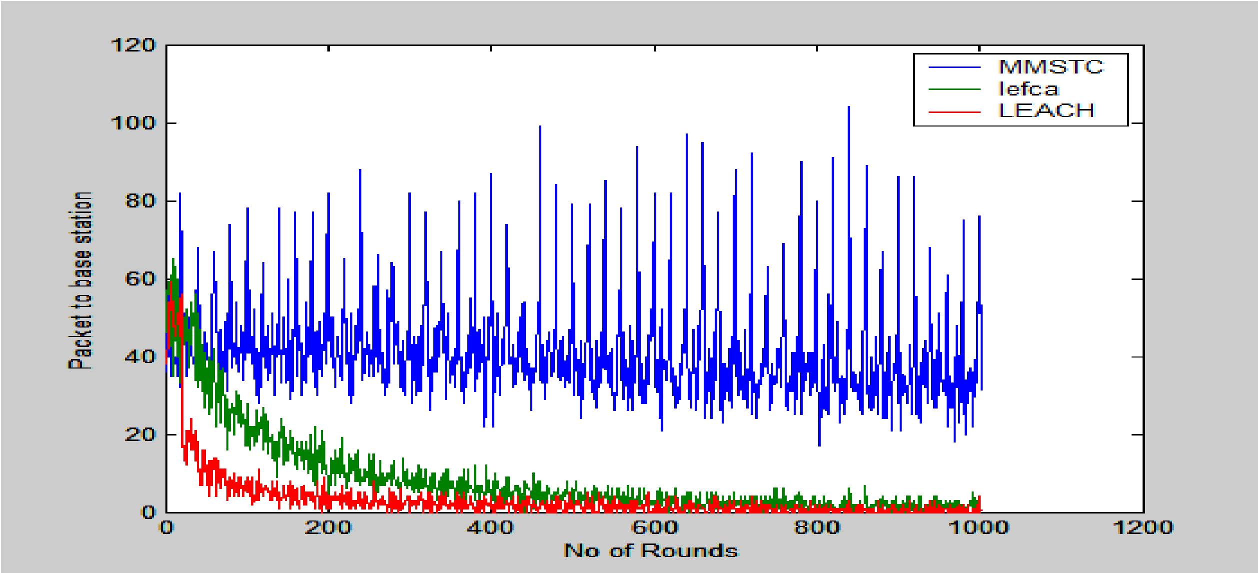


Figure .4(a). Packet to base station vs. rounds

Fig.4 (a) shows that number of packets sent to base station are approaching to zero in around 600 rounds in LEACH and LEFCA whereas in MMSTC packets count is sustained up to 1000 rounds.

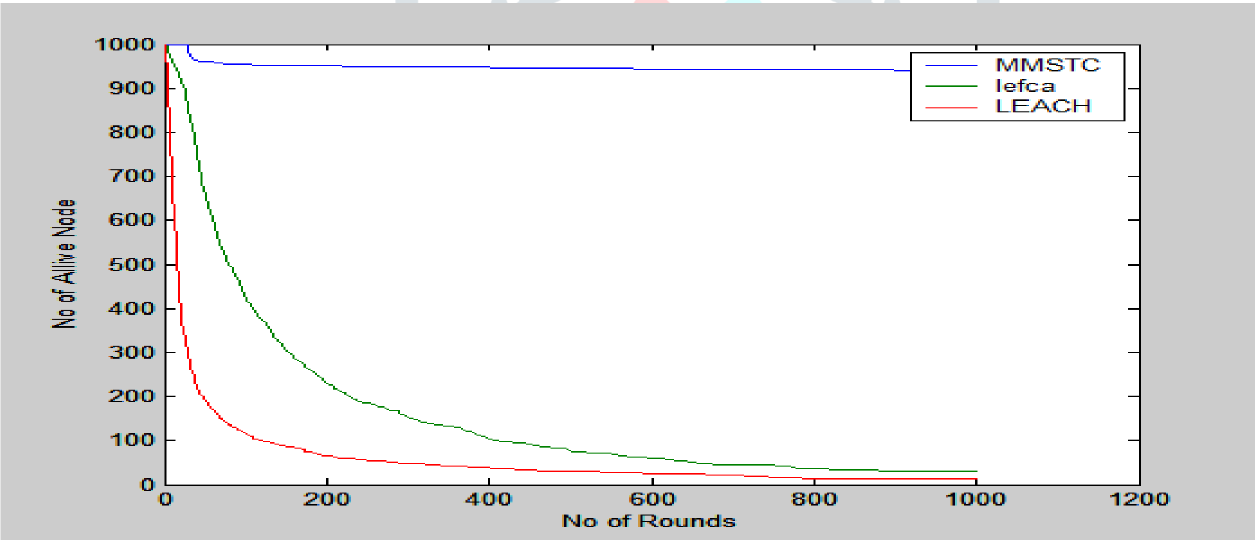


Figure 4(b). Alive nodes vs. rounds

Fig.4 (b) shows that numbers of alive nodes are nearly 5%-10% in 600 rounds in LEACH and LEFCA whereas in MMSTC alive nodes are 90% up to 1000 rounds.

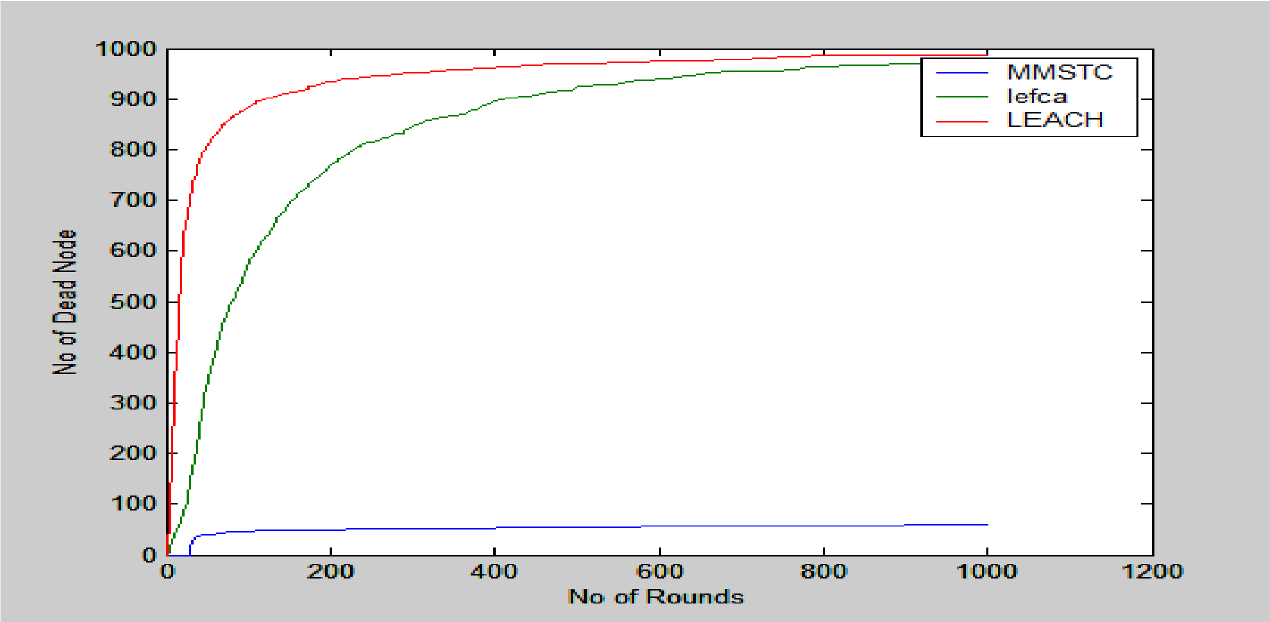
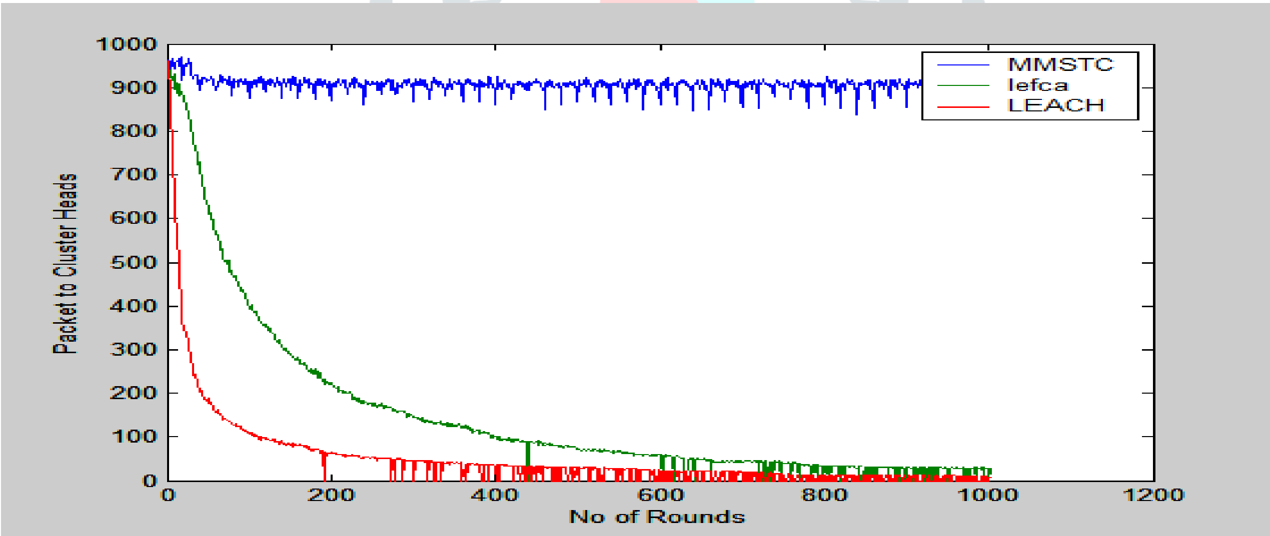


Figure 4©.

Dead nodes vs. rounds

Fig.4(c) shows that approximately all nodes are dead in LEACH and LEFCA whereas in MMSTC dead nodes are 5% in 1000 rounds.



Figure

4(d). Packet to cluster head vs. rounds

Fig.4 (d) shows that Number of packets sent to cluster head are approaching to zero in LEACH and LEFCA whereas in MMSTC packets count is sustained up to 90% in 1000 rounds

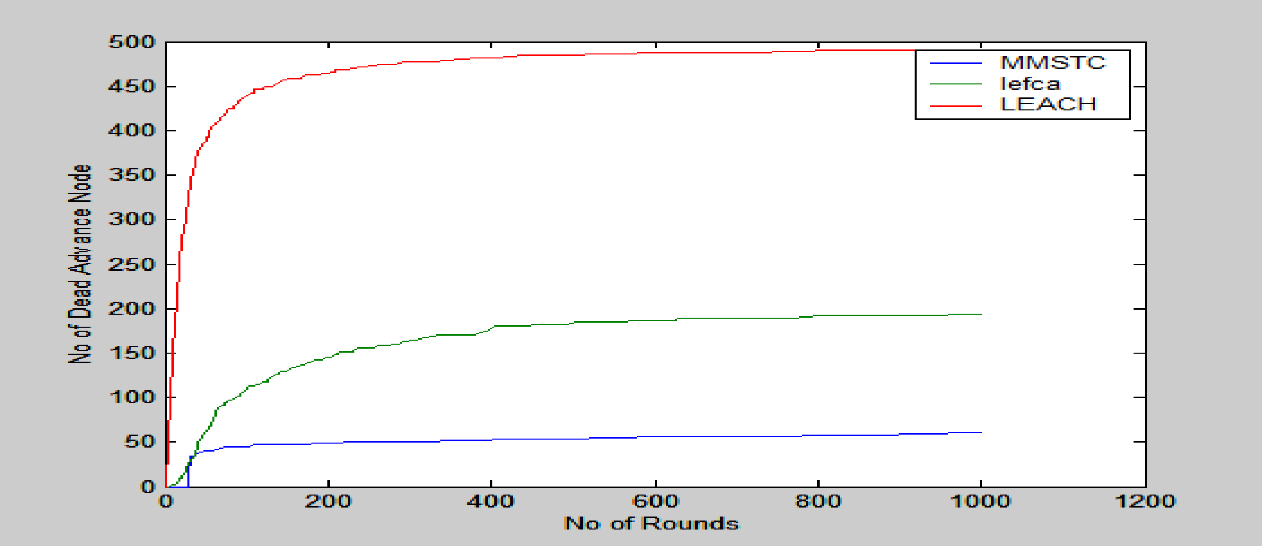


Figure 4(e). Dead Advance Nodes vs. rounds

Fig.4 (e) shows that Around 95% of advance nodes are dead in LEACH, 35% in LEFCA after 600 rounds whereas it is only 10% in MMSTC even after 1000 rounds.

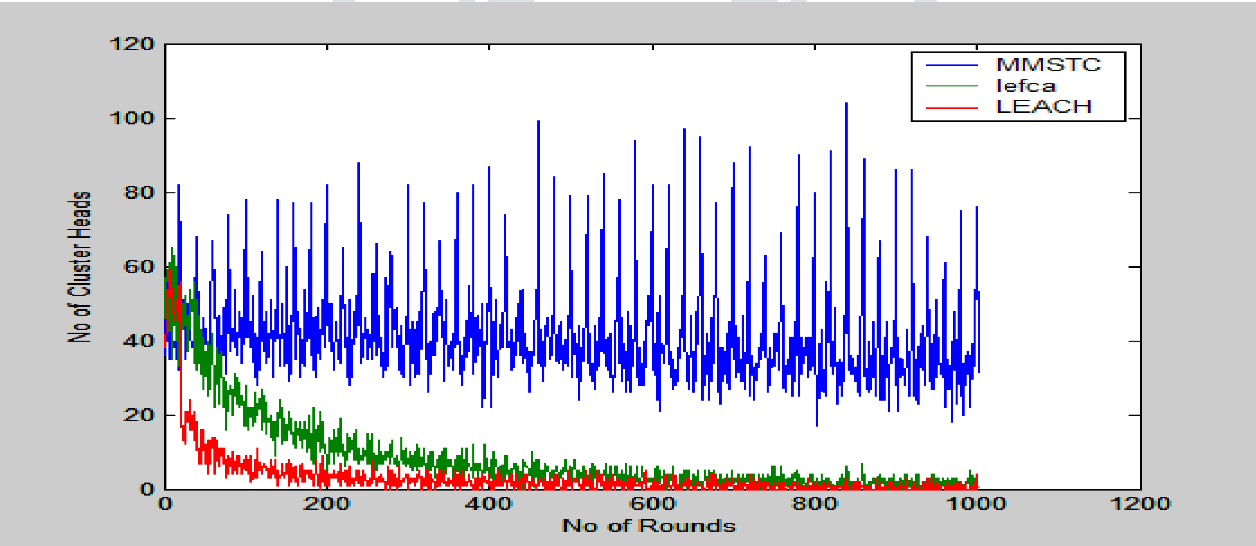


Figure 4(f). No. of cluster heads vs. rounds

Fig.4 (f) shows that numbers of cluster heads are approaching to zero in around 600 rounds in LEACH and LEFCA whereas in MMSTC packets count is sustained up to 1000 rounds.

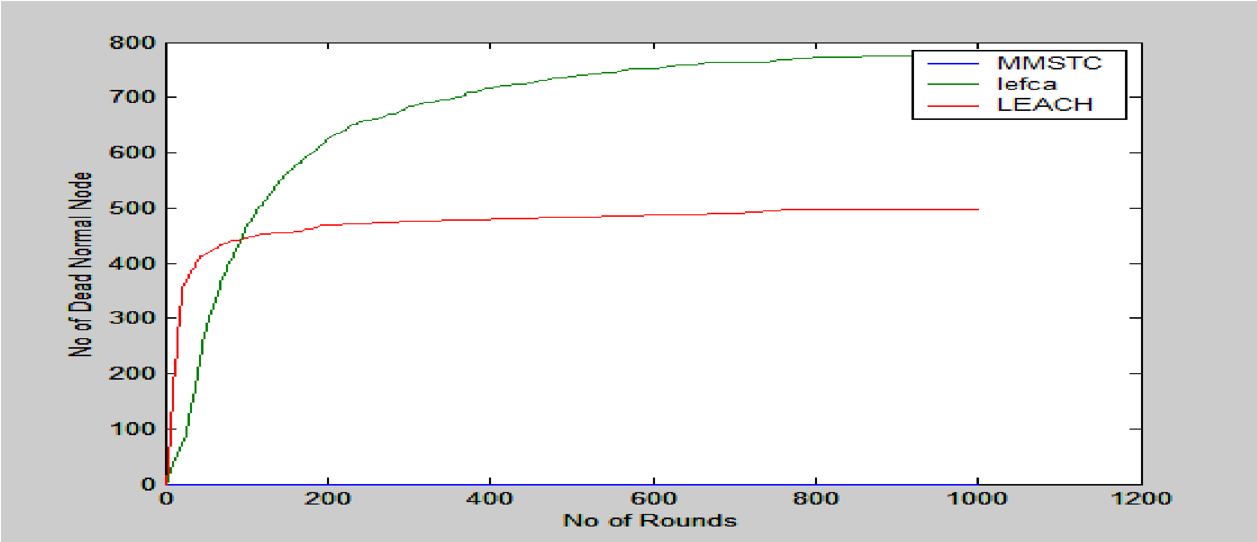


Figure 4(g).

Dead normal Nodes vs. rounds

Fig.4 (g) shows that around 95% of normal nodes are dead in LEFCA, 60% in LEACH whereas no node is dead in MMSTC in 1000 rounds.

This improvement in network lifetime is due to efficient use of clustering method, awareness in terms of energy heterogeneity and using multi-hop MST pattern used for communication between CH and BS.

CONCLUSION

The proposed work offers priority to the higher energy node for the selection of cluster head and uses multihop MST pattern which enhances the energy and lifetime of the network. The simulation results shows that-

- In MMSTC almost 5% advance nodes and normal nodes are dead in 1000 rounds, whereas on the average in LEACH and LEFCA, about 95% are dead (except dead advance nodes in LEFCA, where it is 40%).
- Numbers of alive nodes are nearly 5% in LEACH and LEFCA whereas in MMSTC alive nodes are around 95% up to 1000 rounds
- Numbers of packets sent to base station are approaching to zero in around 600 rounds in LEACH and LEFCA whereas in MMSTC packets count is sustained up to 1000 rounds.

Network Lifetime may be defined as the time interval from the start of operation to death of the last alive SN. Here, MMSTC improves the overall lifetime of the network in comparison to the traditional LEACH and LEFCA protocol.

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