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AN ENHANCED MULTI HOP LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY USING ENERGY AWARE MINIMUM SPANNING TREE

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ABSTRACT

Wireless Sensor Networks (WSNs) are intelligent network application systems autonomously collecting, integrating and transmitting data. An emerging information acquisition technology which integrates the latest technological achievements in micro-electronic network and communications. WSNs are used in the military, environmental monitoring, industrial control and urban transportation. Due to the wireless node's limited power supply, energy efficiency is crucial to broadcast protocol design. A node adjusts its transmission power to minimize energy consumption while delivering data to other network nodes. Minimum energy problem is NP-Complete. In this paper, we proposed a multi hop Low Energy Adaptive Clustering Hierarchy (LEACH) using energy aware minimum spanning tree.

Keywords: *Wireless Sensor Network (WSN), Clustering, Low Energy Adaptive Clustering Hierarchy (LEACH), Minimum Spanning Tree (MST).*

I. INTRODUCTION

WSNs include spatially distributed autonomous sensors monitoring physical/environmental conditions. A wireless sensor node's task is to sense and collect data from specific domains, process and transmit it to a sink where the application lies. But, ensuring direct communication between sensor and sink can force nodes to emit messages with high power quickly depleting their resources [1, 2]. Sensors life is limited in WSNs as they are only self-alimented with a battery, and so have to use limited power to reduce energy consumption.

Sensors have the ability to sense, process data and wirelessly transmit collected data to base stations through a multiple-hop relay. Sensors supply necessary operations with limited battery energy. Network life in a sensor network is important for applications [3]. A sensor's energy consumption affects the network operational life. WSN's characteristics include [4]: ability to cope with node failures, node mobility, scalability to large scale deployment, withstanding harsh environmental conditions, ease of use, unattended operation, power consumption, dynamic network topology, communication failures and nodes heterogeneity.

Routing protocols find/keep network routes. A particular routing protocol's rightness relies on nodes potentialities and on application prerequisites [5]. Routing protocols should conserve energy, be scalable, robust, fault tolerant and self-organizing. Routing protocol is a key component WSNs. The characteristics of routing protocol research put forward new technical problems. An important goal of designing a routing protocol is to reduce node energy consumption and prolong network life [6].

Most routing protocols classification is based on structure like data-centric, hierarchical and location- based. Data-centric protocols are query-based depending on naming desired data, which eliminates redundant transmissions. Hierarchical protocols cluster nodes so that cluster heads can indulge in data aggregation and reduction to save energy. Location-based protocols use position information to relay data to desired regions. Low Energy Adaptive Clustering Hierarchy (LEACH) is a classic cluster-based, hierarchical routing algorithm for fully distributed WSNs

[7]. LEACH randomly chooses a cluster head, and through it distributes the entire network's energy to all sensor node evenly, uses data fusion and compression to process data and reduce traffic.

Clustering is a WSN mechanism for energy efficiency and effective data communication. Clustering provides a network scalability and robustness; allowing spatial bandwidth reuse and simpler routing decisions. It results in decreased energy dissipation of the entire system minimizing nodes that participate in long distance communication [8]. Clusters are WSNs organizational units. Cluster heads are a cluster's organization leader. They often organize activities in a cluster including data-aggregation and the cluster's communication schedule [9].

Clustering schemes offer reduced communication overheads and efficient resource allocations reducing overall energy consumption and interferences among sensor nodes. Many clusters congest an area with smaller clusters and very small clusters exhaust the cluster head with numerous messages transmitted from cluster members [10].Selecting cluster heads is a hard problem. Most clustering approaches use random scheme to select cluster heads. Different clusters use different approaches to choose CH/form clusters. Clustering's advantages include [11, 12 & 13]:

- Reducing routing table size
- Reducing the redundancy of exchanged messages
- Conserves communication bandwidth
- Prolonged battery life of individual sensor
- No topology maintenance overhead
- Reduce rate of energy consumption
- More Scalability
- Data Aggregation/Fusion
- Less Load
- More Robustness
- Collision Avoidance
- Latency Reduction
- Load Balancing
- Fault-Tolerance
- Guarantee of Connectivity
- Energy Hole Avoidance
- Quality of Service

Protocols are broadly classified into two categories based on routing structure: tree-based protocols and mesh-based protocols. There is a single path between a sender-receiver pair in tree-based protocols which have the advantage of high multicast efficiency. A different routing protocols group is based on spanning tree idea. Protocols in this category are Direct Spanning Tree (DST) routing protocol, Spanning Tree, Shortest Path Tree (SPT), Minimum Energy Spanning Tree (MEST) and Gathering Load Balanced Tree (GLBT).

For such routing protocols, networks are formed by construction a tree covering the interested area rooted at a Base Station (BS). Tree construction is from selected nodes meeting specified criteria to be a member [14, 15]. Sender nodes choose best available nearby node to forward sensed data and then the data is directed similarly to BS through spanning tree.

Energy-Aware Distributed Aggregation Tree (EADAT): Energy-Aware distributed heuristic algorithm constructs/maintains Data Aggregation Trees in WSNs where tree formation is by broadcasting a control message forwarded among sensor nodes till a node broadcasts the message once, the result being an aggregation tree rooted in base station. After receipt of a message for the first time, sensor nodes set up their timer counts. When its communication channel is idle, a sensor node chooses a node with higher residual power and shorter sink path as its parent during the process.

Greedy Incremental Tree (GIT): GIT routing is a heuristic distributed algorithm constructing a Steiner tree on a hop-count basis based on directed diffusion (DD), a data-centric routing for sensor networks. Routing assumes perfect aggregation. A source finds the shortest hop from self to existing path tree or sink, one by one [16]. A GIT routing exploratory message involving an additional attribute is considered, to realize a process denoting the additional cost (hop-count) from source to current node.

An algorithm based on minimum spanning tree is proposed in this paper to improve the network's energy efficiency. Section 2 discusses related work. Section 3 explains the methodology. Section 4 describes the results and Section 5 concludes the paper.

II. RELATED WORK

Energy-Aware Routing Based on Beaconing (EARBB) which ensures reliable and energy-efficient routing scheme for information collection and dissemination with beaconing packets exchanged between nodes and their neighbors was introduced by Ya et al., [17]. Simultaneously, EARBB supports node-to-node routing besides node-to-sink routing. Simulation showed that EARBB established a reliable network which quickly recovers from node failure. During downstream data transmission, 80% less packets are sent using EARBB than with flooding. Its average life is at least 20% longer than a collection tree protocol (CTP).

Problems which affect WSN performance while computing a path from source to base station was addressed by Sujeethnanda et al., [18]. Parameters explored by designing software/hardware integration, directly impacts power conservations during path computation. The new protocol provides a path from source to base station consuming less energy based on dynamic TDMA schemes using local/global fusion algorithms.

An energy aware learning automata-based routing protocol, ICLEAR, for WSN that adopted a new approach to increase network life was presented by Navid & Javadi [19]. Energy consumption decreased to increase network life and manage routing discovery to find best route in energy consumption through an irregular cellular learning automata concept. The cellular learning automata model was introduced where learning automata adjusted cellular automata's state transition probabilities. Then irregular cellular learning automata was used for network routing problems. Finally, the new routing protocol, ICLEAR was simulated/evaluated with other learning automata based routing protocols by the Glomosim simulator.

A LEACH-SM protocol which modified LEACH protocol providing an optimal energy-saving spare management, including spare selection to extend WSN life was proposed by Bakr & Lilien [20]. LEACH-SM added a spare selection phase to LEACH. A quantitative comparison of energy consumed and WSN life was presented for both protocols.

A clustering protocol based on Chaos-PSO to reduce nodes energy consumption and prolong WSN life proposed by Liu et al., [21] improved cluster-head selection mechanism which was nodes residual energy, distance to sink node and clusters range. It optimized cluster-head selection by Chaos-PSO. Then other nodes decide whether join cluster by comparing advertisement message's signal strength with a predefined threshold, and restricted cluster range. Simulation proved that compared to LEACH, the new protocol saved energy and prolonged WSN life.

Network quality depending on optimum selection cluster heads in Modified LEACH protocol using new simulator TOSSIM was described by Dutta et al., [22]. Comparison of data packet broadcasting, energy consumption and dead nodes of LEACH/Modified LEACH was discussed and explained. Simulation proved that Modified LEACH performed better than LEACH in extending overall network performance.

A proposal which built the final route in one step calculating the corresponding minimum spanning tree (MST) using a low complexity BDD based algorithm was forwarded by Yanez-Marquez et al., [23].

An algorithm to find a prior Connected Dominating Set (CDS) and using Minimum-Weight Spanning Tree (MST) to optimize result was suggested by Ren et al., [24]. The new algorithm applied effective degree, a new term introduced in the new algorithm, combining ID to determine dominators. Default event was triggered to recalculate and update a node's effective degree after predetermined time. Each node by a 3-hop message relay learns paths leading to other dominators within distance and paths picked by some rules convert into a new weight edge calculating nodes over the paths. A MST is found from the new weight graph induced by prior CDS to reduce CDS size. The new algorithm performed well regarding CDS size and Average Hop Distance (AHD) compared to current algorithms. Simulation showed that new algorithm was more energy efficient than others.

A Data Query Protocol based on Minimum Spanning Tree (QPMST) put forward by Cui & Qin [25], created a minimum spanning tree with sink as root and nodes as descendants. Query tasks were transmitted from sink node, query results were sent to sink from leaf nodes, and aggregated by parents. This protocol reduced redundancy data transmission, saved node energy and enhanced WSN life.

Nearest Neighbor Tree (NNT) algorithms for energy-efficient construction of MSTs in a wireless ad hoc setting were designed and analyzed by Khan et al., [26]. The authors assumed that nodes are uniformly distributed in a unit square showing provable bounds on performance regarding spanning tree quality produced and energy needed to construct them. Specifically, NNT produced a close approximation to MST, and are maintained dynamically with polylogarithmic rearrangements under node insertions/deletions. Simulations of new algorithms was performed and they were tested on uniform random node distributions and realistic node distributions in an urban setting. Simulation validated results showing that bounds were better in practice.

A three-layer topology architecture and a topology control algorithm for its key communication layer for large-scale WSNs was proposed by Fan et al., [27]. The network base station in the algorithm leads the ring periodically to discover minimum power cost links from base station to every sink, and a minimum spanning tree is constructed. The tree is regarded as a routing tree at the monitoring network's top layer. To improve routing efficiency and prolong tree life, the algorithm locates all bottleneck nodes (BN) in tree under an energy consumption estimation model. It eliminates such nodes by introducing movable relay nodes in the tree path. OPNET-based simulation indicated that the topology control algorithm reduced the sinks communication energy consumption significantly in addition to balancing the sinks energy level dynamically.

A new approximation algorithm for Minimum Energy Broadcast Routing (MEBR) problem in ad hoc wireless networks that achieved an exponentially better approximation factor compared to MST heuristic was presented by Caragiannis et al., [28]. Where a minimum spanning tree of a set of stations was guaranteed to cost at most ? = 2 times the cost of an optimal solution for MEBR, the new algorithm achieved an approximation ratio bounded by 2ln?-2 ln 2 + 2. This result was relevant for its consequences on Euclidean instances significantly improving previous results. Experimental analysis confirmed the algorithm's better performance in practice.

A new heuristic approach to search for balanced and small weight routing spanning trees in a network provided by Gagarin et al., [29] was a modification of Kruskal's MST search algorithm and based on hierarchical clusters distributed search. It provided spanning trees with a lower maximum degree, a bigger diameter and was used to balance WSNs energy consumption routing. The approach can be implemented in parallel and in a locally distributed algorithm. Simulation of a realistic WSN scenario was done based on the energy matrix transmission. Simulation results proved that the new approach extended WSNs functional life 3-4 times regarding sensor transmission energy. Possible input network preliminary clustering was also considered.

Two new localized algorithms were presented by Liu et al., [30]. MST-based multiratecast routing protocol (MSTRC) examined one set of destinations partition at every forwarding step. A new face recovery mechanism handled void areas, when no neighbor provided positive progress to destinations. It constructed current node MST and destinations without progress via neighbors, and, for every set partition of destinations corresponding to an edge e in MST, traversed (with maximal rate among covered destinations) faces with e till a node close to one destinations was found, to ensure greedy continuation. The process was repeated for remaining destinations. Results proved that MSTRC and RoDiF were highly rate-efficient in all scenarios, and, unlike current solutions, were adaptive to destination rate deviations.

III. METHODOLOGY

A tree is represented by a finite set of nodes starting from root node at first period and branching into nodes at next period. Every node has a predecessor node, but many successors. Branching continues up to nodes at final period whose number corresponds to number of scenarios. Insufficient resources result in trees that do not reach all destinations, use more than minimum energy (as only suboptimal trees are constructed), or both [31, 32]. This paper proposes an enhanced multi hop LEACH using an energy aware minimum spanning tree.

LEACH and Multi Hop LEACH
LEACH is a clustering algorithm with distributed cluster formation for WSNs randomly selecting CHs and rotating roles to distribute energy consumed. TDMA/CDMA MAC are used by LEACH to reduce inter-cluster/intra-cluster collisions. Most nodes transmit data to CHs in LEACH which collect and compress data and forward it to base station. In this protocol, nodes organize into local clusters according to procedure, with many acting as CHs and others acting as cluster members [33]. CH node uses more energy than member nodes and runs many rounds in a network‘s life, with each round ensuring cluster formation and cluster steady phases. In the cluster formation phase, many nodes are local cluster-heads with specific probability.

Sensor nodes have same probability to be CHs in LEACH protocol, which makes network nodes, consume energy in a balanced way to prolong network life [34]. In set-up phase, CH nodes are randomly chosen from sensor nodes and clusters constructed dynamically. In steady data transmission phase, cluster member nodes send data to CH, the latter compresses data from member nodes and forwards it to sink node. LEACH protocol elects CH nodes periodically, re-establishing them according to a round time ensuring each node’s energy dissipation is relatively even.

LEACH divides a network into constructed clusters using localized coordination and control to reduce data transmitted to sink and to make routing/data dissemination scalable and robust [35]. LEACH uses randomized high-energy CH position rotation instead of a static selection, to ensure chances for all sensors to be CHs avoiding individual sensor’s battery depletion and death.

A goal of Multi hop LEACH is finding routes for a CH to send a packet using other CHs to save energy [36]. The choice of next CH to get a message must consider its energy level. So, if a CH cannot send a message for another, the node tries to find another based on information in its routing table, according to described ahead.

The higher the signal strength of received packet, i.e., Received Signal Strength Indicator (RSSI), the greater the proximity of node that sent the message. This information is used to build a routing table for a CH. Multi hop-LEACH proposes route establishment using 2 phases [36]:
• Phase 1: CHs are defined as a part of LEACH algorithm. They then broadcast an announcement message and all CHs in transmission ratio take advantage to construct a routing table considering level of signal (RSSI) received. Thus they organize early routes with closest CHs to send packets.
• Phase 2: Then each leader sends initial routes (from routing table) to base station that checks whether a CH is in another’s route. Then, the base station sends its routes back to nodes.

Multi hop LEACH using energy aware minimum spanning tree
Minimum Spanning Tree (MST) of a weighted graph is minimum weight spanning tree of that graph [37]. With classical MST algorithms the cost of constructing a MST is O(mlogn), where m is number of edges in the graph and n the number of vertices. A MST of graph G(V,E) is a tree composed of n − 1 edges of E connecting all vertices of V at lowest total cost [38].

A MST is constructed by successively selecting edges to include in the tree. After inclusion of new edge, selected edges, X, form a subset of some MST, T. Kruskal's algorithm starts with edges sorted in increasing order by weight. Initially X = { }, and each vertex in the graph is regarded as a trivial tree (with no edges). Each edge in a sorted list is examined and if its endpoints are in same tree, then that edge is discarded; otherwise it is included in X and causing two trees with endpoints of this edge to merge into one tree. The algorithm is given below:

Algorithm Kruskal(G):
Input: A weighted graph G.
Output: A minimum spanning tree T for G.
let P be a partition of the vertices of G, where each vertex forms a separate set
let Q be a priority queue storing the edges of G and their weights
T←Ø
while Q≠ Ø do
(u,v) ← Q.removeMinElement()
if P.find(u) ≠ P.find(u) then
add edge (u,v) to T
P.union(u,v)
return T

Dijkstra's shortest paths algorithm (DSA) heuristic constructs a shortest path from source node s to every other vertex in G. This is done using Dijkstra's shortest paths algorithm. The constructed shortest paths are superimposed to obtain a tree T rooted at s. A sweep is performed over nodes of T where nodes are examined in ascending order of their index (i.e., in the order 1, 2, 3, • • •, n).

The proposed algorithm begins with a tree T comprising only source node s. Remaining nodes are added to T one at a time. The next level nodes (n_{next}) are selected such that it is a neighbor of the node in T and $E(T \cup \{u\}) - E(T)$ is minimum. Once a broadcast tree is constructed, a sweep restructures the tree to reduce energy.

IV. EXPERIMENTAL SETUP AND RESULTS

100 number of nodes used for the experiments and area in the size of 500 sq feet, maximum transmission range of node is 100 m location of Base station is (0,0) and Initial energy of nodes is 1. The proposed Multi hop LEACH using energy aware minimum spanning tree is compared with LEACH and Multi Hop LEACH. The results achieved are tabulated in table 1.

Table 1 Summary of Results

	LEACH	Multi Hop Leach	Energy Aware Multi Hop Minimum Spanning Tree
Number of Hops	10	11	13
End to end delay (sec)	0.003202	0.001984	0.001607
Packet delivery ratio	0.9061	0.9197	0.9326

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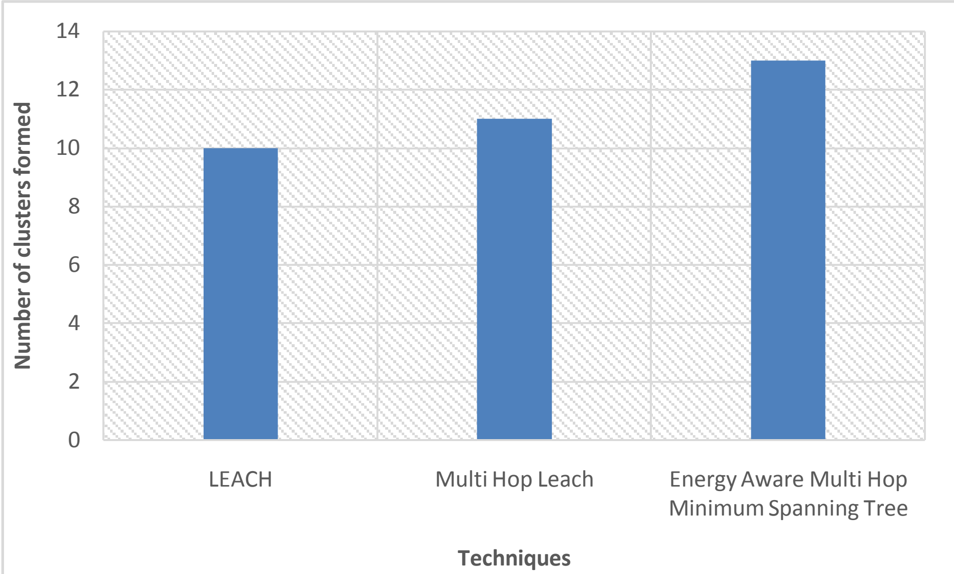

Figure 1 Number of clusters formed

The proposed MST increased the number of clusters formation by 26.09% when compared with LEACH.

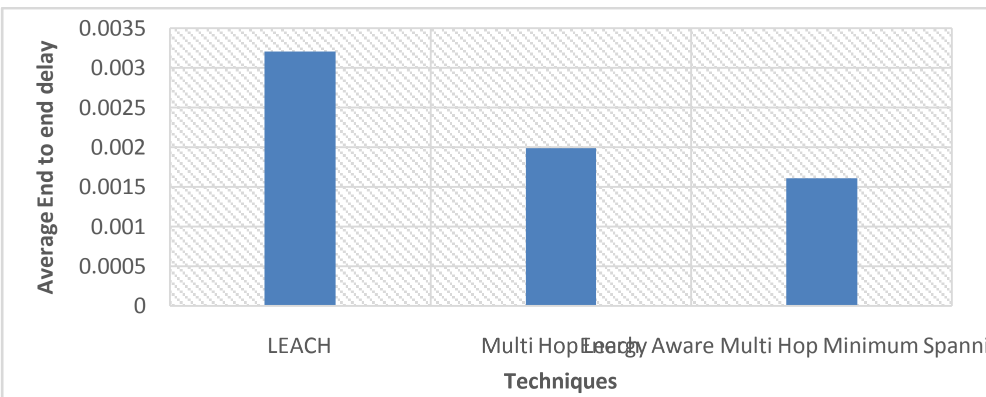

Figure 2 End to end delay

From the above figure is observed that the proposed MST method reduced end to end delay by 21% than multi hop LEACH.

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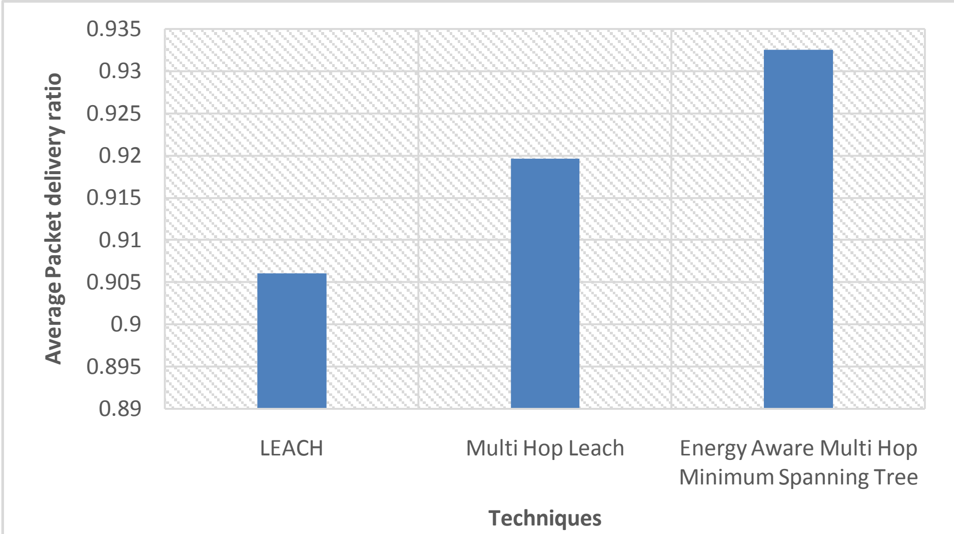

Figure 3 Packet delivery ratio

The proposed MST increased packet delivery ratio by 2.88% when compared with LEACH.

Table 2 Lifetime computation

Number of rounds	LEACH	Multi Hop Leach	Energy Aware Multi Hop Minimum Spanning Tree
0	100	100	100
100	100	100	100
200	78	87	92
300	71	79	84
400	27	56	76
500	12	28	42
600	2	7	14
700	0	0	8
800	0	0	0

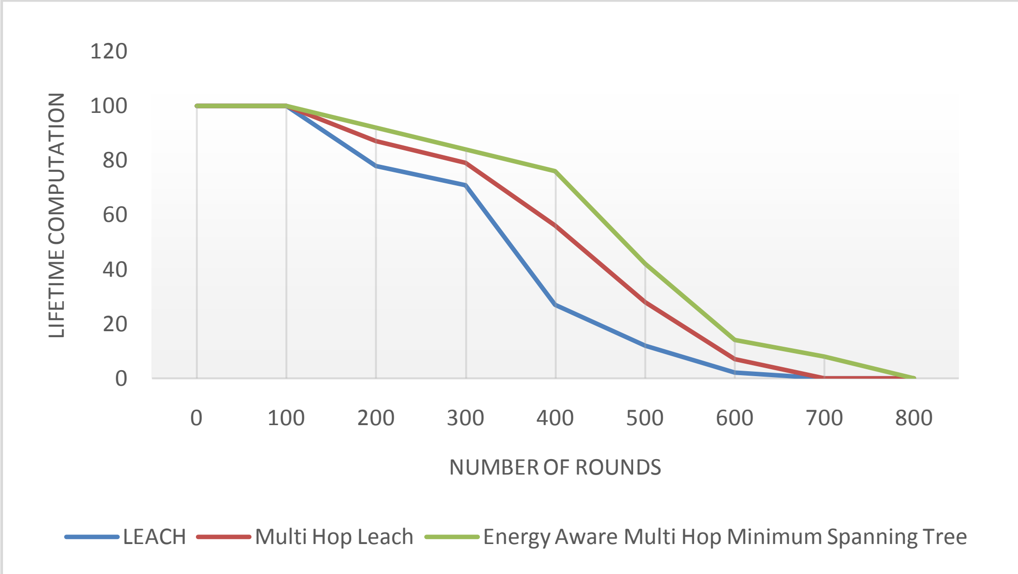

Figure 4 Lifetime computation

The proposed MST method improved the lifetime averagely by 27.81% than LEACH and by 12.13% when compared with multihop LEACH.

Table 3 Remaining energy

Number of rounds	LEACH	Multi Hop Leach	Energy Aware Multi Hop Minimum Spanning Tree
0	1	1	1
100	0.8	0.86	0.86
200	0.46	0.64	0.66
300	0.38	0.54	0.62
400	0.36	0.54	0.6
500	0.24	0.36	0.5
600	0	0.2	0.42
700	0	0	0.18
800	0	0	0

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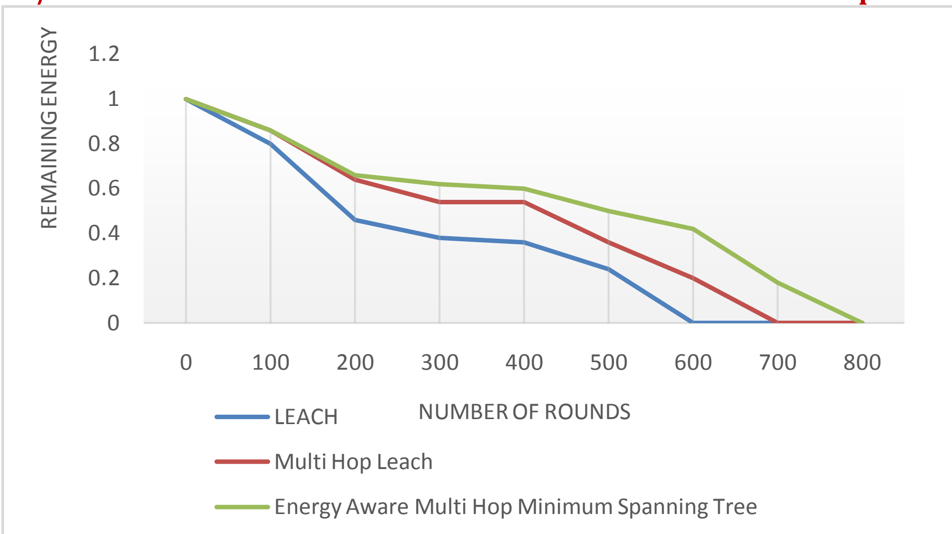

Figure 5 Remaining energy

The proposed method increased the remaining energy by 35.71% than LEACH with 200 numbers of rounds and also increased by 70.27% when compared with LEACH with 500 numbers of rounds.

V. CONCLUSION

WSN technology is based on and different from traditional wireless ad hoc networks. WSN's nodes energy is limited, as is their computing, communication and storage capabilities. Energy saving is essential for reliable operation. Effective energy and resource management is an important technical issue to be considered, and so research on energy consumption has attracted attention. This paper proposes an enhanced multi hop LEACH using an energy aware minimum spanning tree. The proposed algorithm is based on MST. Experiment results show that the new method improved packet delivery ratio and energy efficiency.

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