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A Spanning Tree for Enhanced Cluster Based Routing in Wireless Sensor Network

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***Abstract*—**Wireless Sensor Network (WSN) clustering architecture enables features like network scalability, communication overhead reduction, and fault tolerance. After clustering, aggregated data is transferred to data sink and reducing unnecessary, redundant data transfer. It reduces nodes transmitting, and so saves energy consumption. Also, it allows scalability for many nodes, reduces communication overhead, and allows efficient use of WSN resources. Clustering based routing methods manage network energy consumption efficiently. Building spanning trees for data collection rooted at a sink node is a fundamental data aggregation method in sensor networks. The problem of determining Cluster Head (CH) optimal number is an NP-Hard problem. In this paper, we combine cluster based routing features for cluster formation and CH selection and use Minimum Spanning Tree (MST) for intra-cluster communication. The proposed method is based on optimizing MST using Simulated Annealing (SA). In this work, normalized values of mobility, delay, and remaining energy are considered for finding optimal MST. Simulation results demonstrate the effectiveness of the proposed method in improving the packet delivery ratio and reducing the end to end delay.

***Keywords*—**Wireless sensor network, clustering, minimum spanning tree, genetic algorithm, low energy adaptive clustering hierarchy, simulated annealing.

I. Introduction

CLUSTERING, partitions data set into subsets called clusters so that each subset's data, share common properties. Clustering divides a WSN into interrelated substructures, called clusters, with a cluster having many Sensor Node (SN) headed by a CH, which coordinate the substructure. Cluster formation benefits routing as CH and cluster gateways are responsible for inter-cluster routing, thereby restricting, creating, and spreading routing information. Local changes like nodes changing cluster are updated in corresponding clusters. No update is required by entire network, which reduces information stored by a mobile node greatly [1].

Dividing sensor networks into manageable units is clustering. Clustering improves network scalability and is important to achieve energy efficient routing of data. Clustering schemes offer less communication overheads and efficient resource allocation decreasing overall energy consumption and reducing interferences among SNs. Many clusters fill an area with small size clusters, which exhaust CH with messages from cluster members. Low-energy Adaptive Clustering Hierarchy (LEACH) protocol is clustering based hierarchical routing, which finds optimal clusters in WSNs to save energy and enhance network life [2].

Typical WSN clustering routings protocols include:: Hybrid Energy-Efficient Distributed clustering (HEED), LEACH, Distributed Weight-based Energy-efficient Hierarchical Clustering protocol (DWEHC), Two-Level hierarchy LEACH (TL-LEACH), Position-based Aggregator Node Election Protocol (PANEL), Unequal Clustering Size (UCS), Energy-Efficient Uneven Clustering (EEUC) algorithm, model, Energy Efficient Clustering Scheme (EECS), Algorithm or Cluster Establishment (ACE), Power-Efficient Gathering in Sensor Information Systems (PEGASIS), Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN), Threshold sensitive Energy Efficient sensor Network protocol (TEEN), Two-Tier Data Dissemination (TTDD), Concentric Clustering Scheme (CCS), and Hierarchical Geographic Multicast Routing (HGMR). Clustering routing is an active WSN branch of routing technology due to various advantages like more scalability, data aggregation/fusion, less energy consumption, fewer loads, and more robustness [3]. Fig. 1 shows a Cluster Protocol Model.

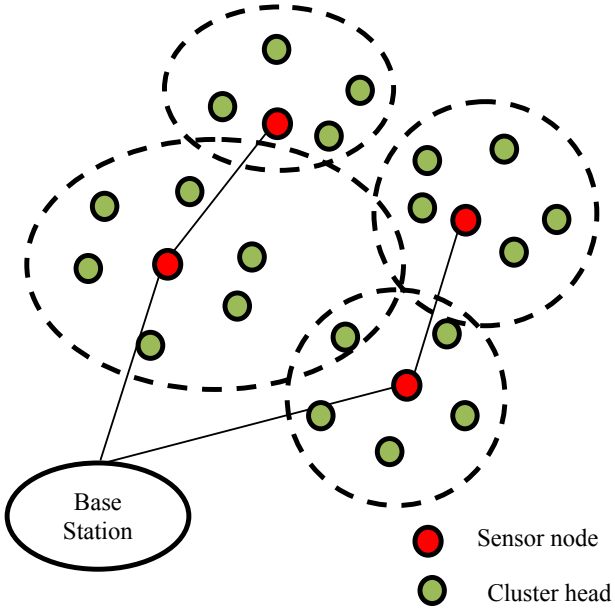

Fig. 1 Cluster Protocol Model

Clustering advantages and WSN clustering objectives are:

- More Scalability

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- Data Aggregation/Fusion
- Less Load
- Less Energy Consumption
- More Robustness
- Collision Avoidance
- Latency Reduction
- Load Balancing
- Fault-Tolerance
- Guarantee of Connectivity
- Energy Hole Avoidance
- Maximizing of the Network Life
- Quality of Service

Building spanning trees for data collection rooted at a sink node is a fundamental data aggregation method in sensor networks. But, due to sensor networks nature, a spanning tree should be formed in a decentralized way. A distributed algorithm determines minimum weight spanning tree for an undirected graph by combining small fragments into larger ones. A spanning tree fragment is its sub-tree. This algorithm's time complexity is O(NlogN). It is presumed that SNs are distributed randomly and densely over an area to be monitored and that the sensor field can be mapped into a 2-dimensional space. Also, all SNs have identical and fixed transmission ranges and hardware configurations [4].

The key cluster formation process is election of the coordinator for the cluster. Information delivery here is by Cluster Configuration Message (CCM). CCM is a 4-tuple: <Type, ID, HTT, State>, where ID is node identifier that started the message, HTT and State fields store HTT and State node value with identifier ID separately. At the start, all event nodes are eligible. A node that detected an event sets its role coordinator, constructs CCM message and sends it [5]. A node with shortest Hop-Tree path becomes the coordinator. When many nodes have smallest HTT value that with the best state is the victor. Other nodes in event area are collaborators.

MST is a sub-graph spanning all graph vertices without any cycle. It has minimum sum of weights over all included edges. In MST-based clustering, each edge weight is considered as Euclidean distance between end points forming that edge. So, an edge connecting 2 sub-trees in MST must be shortest. In such clustering methods, inconsistent edges, usually longer, are removed from MST. The MST connected components obtained by removing edges are treated as clusters. Elimination of longest edge results into 2-group clustering. Removal of next longest edge results in 3-group clustering.

The problem of determining CHs optimal number is an NP-Hard problem. A proof of NP-hardness is minimum energy broadcast in metric space. But, in their minimum energy broadcast problem interpretation, they restrict a node to select a transmission radius from a set of integers, which catch very few problem instances in metric space. The polynomial time algorithm's execution time grows slowly with increasing input size to run on a computer, but if execution time grows exponentially the algorithm is used only for smallest inputs. An accepted way to prove a problem is hard is to prove it is NP-complete. When an optimization problem is NP-complete, it is certain that it cannot be solved optimally in polynomial time [6].

Planar networks MST with no mobility, which graphs node positions, may be fixed during communication. This result implies that computing an MST of a (planar) network with mobility is NP-Hard [7].

A study of "Stochastic MST and Related Problems" conducted by Pegah et al., (2011) resulted in the following findings: they investigated MSTs computational complexity and maximum flows in a simple stochastic networks model where a node or an undirected master graph edge can fail with an independent and arbitrary probability [8]. They showed that computing MST's expected length or max-flow value is NP-Hard, but that for MST it can be nearly exact within O(log n) factor for metric graphs.

Theorem (NP-hardness): Finding one source of minimum cost broadcast tree in an evolving graph is NP-hard, even when nodes are static in a Euclidean plane and cost function on edges is square of their Euclidean length.

Proof: The Steiner minimum cost tree problem in a planar graph is reduced with Euclidean distances, to this problem. In Steiner problem, a planar graph G = (V, E), is given and a set of vertices X ⊂V. The problem consists in finding a tree in G containing all vertices in X so that the sum of its edges costs is minimum. The cost of an edge is square of its length in the plan.

WSNs dynamic nature and changing CHs in every network activity round have led to their modeling being tough with classical mathematical methods. Due to the influence of various parameters on increasing WSN life, an intelligent technique with high flexibility is a good alternative for mathematical systems. Fuzzy logic, an artificial intelligence technique, can make real time decisions, even with incomplete information [9]. Merging different environmental parameters according to pre-defined rules to make a decision based on the result is another important fuzzy logic application.

A stochastic optimization approach suggests an alternative formulation and solution for distance-based localization problem using combinatorial optimization notions and tools [10]. Issues of WSN life optimization are based on population-based optimization techniques. These naturally inspired or bio-mimic algorithms are recent suitable methods for global optimization. Selection of proper bio-mimic or meta-heuristic algorithms that propose the best solution to any problem efficiently is very critical. So, there is no single algorithm that ensures reaching the best solution for all problems; there are many optimization algorithms including ACO, Genetic Algorithm (GA), PSO and Bat Swarm Optimization (BSO).

In this paper, we present SA for optimized routing for WSN with MST. Rest of this paper is summarized as follows: Section II deals with the related works have done in literature and Section III explains the methods involved in this work. Section IV discusses the experiment and results then Section V concludes the proposed work.

II. Literature Survey

Tan and Viet [11] proposed Sleep Scheduled and Tree-Based Clustering approach routing algorithm (SSTBC) for energy-efficiency in WSN. SSTBC preserved energy by turning off radio (entering sleep mode) of either impossible or unnecessary nodes, which observe almost the same information, based on their location information to remove redundant data. The simulation results showed that the network lifetime with using the proposed protocol can be improved about 250% and 23% compared to LEACH and PEGASIS, respectively.

Ramasamy and Balakrishnan [12] proposed a Velocity Energy-efficient and Link-aware Cluster-Tree (VELCT) scheme for data collection in WSNs which would effectively mitigate the problems of coverage distance, mobility, delay, traffic, tree intensity, and end-to-end connection. The proposed VELCT constructed the Data Collection Tree (DCT) based on the CH location. The designed VELCT scheme minimized the energy exploitation, reduced traffic and end-to-end delay of CH in WSNs by competent usage of the DCT. Simulation results have demonstrated that VELCT provided better QoS in terms of energy consumption, throughput, end-to-end delay, and network lifetime for mobility-based WSNs.

Karthickraja and Sumathy [13] presented a survey of the state-of-the-art routing technique and a novel energy efficient hybrid routing based on Rapid Spanning Tree (RST) and Cluster Head Routing (CHR). Many-To-One: A hybrid protocol based on RST and CHR used clustering, which included partitioning stage and choosing stage, namely, partitions the multi-hop network and then chose cluster-heads. Then all cluster-heads will construct a rapid spanning tree to prolong network lifetime, save energy, and shorten path. RST provided faster spanning tree convergence after a topology change, thereby minimizing the energy consumed.

Chauhan and Gupta [14] proposed an algorithm using least spanning tree to transmit data to sink. Using LEACH algorithm to elect CHs, the cluster formation is done by checking the cluster member's information similarity to the CH. By using the sleep scheduling and least spanning tree algorithm, repetitious data transmission and energy consumed in the network is reduced. Simulation results showed that network lifetime has increased effectively in comparison to other clustering algorithm such as LEACH.

Chatterjee et al. [15] proposed a transport protocol using cluster-based single hop tree topology for congestion avoidance in WSNs under noisy environments. The CHs pass on the received data to their parent nodes hop-by-hop until the sink node is reached. Simulation results showed that a rapid convergence coupled with the cluster-tree topology, leads to congestion avoidance and energy minimization in the WSN. Analysis revealed that this protocol scheme is appropriate for both continuous and event based monitoring and can be made adaptive to changing requirements.

Kim et al. [16] proposed a novel Tree-Based Clustering (TBC) approach for energy efficient WSNs. Computer simulation showed that the proposed scheme effectively reduced and balanced the energy consumption among the nodes, and thus significantly extended the network lifetime compared to the existing schemes such as LEACH, PEGASIS, and TREEPSI.

Guo et al. [17] constructed a cluster-based routing tree, which makes balance between tracking quality and energy consumption. It could provide reliable data transmission, meanwhile makes guarantee of energy savings. The protocol validated using TOSSIM. Comparing with existing methods, the proposed method obtained better performance in term of tracking quality and energy savings.

Zhang and Yu [18] compared the performance of cluster-based and tree-based routing protocols. Two kinds of operations were considered: aggregation and acquisition. The performance of cluster-based and tree-based topologies analyzed and found for energy efficiency in aggregation cluster-based topology is better than tree-based topology. However, for energy efficiency in acquisition tree-based topology is better than cluster-based topology. The above analysis was verified using HEED and MintRoute routing protocols.

Yang et al. [19] presented Cluster-Tree Data Gathering Algorithm (CTDGA) to decrease the energy consumption to gather data when a WSN is used. In CTDGA, to decrease transmission energy in a cluster, the architecture of cluster is used to get data from the nodes sensed interesting event to CH. Next, a special CH is used to get the data from other CHs transferred to base station. This is done using the architecture of tree as this protects the CHs with low residual energy. The simulation results showed that CTDGA could improve energy efficiency, and thus prolong network lifetime.

Law and Okeke [20] proposed a novel lifetime extending heuristic (MLC-X) for tree-based multi-level clustered WSN. Duties of nodes at bottlenecks in tree were modified for sustaining longer network lifetime. And the simulation results indicated that the heuristic could successfully extend life spans of sensor networks.

Abusaimeh and Yang [21] proposed a novel technique to define the number of clusters and to choose the appropriate CH in WSN based on the energy level of wireless SNs. Simulation results showed that the suggested technique improved lifetime of WSN by 50% in average when compared to lifetime of the cluster-tree network.

Bandral and Jain [22] proposed different energy efficiency based protocols Tier Based Energy Efficient Protocol (TBEEP) and Cluster Based Energy Efficient Protocol (CBEEP). In TBEEP, the nodes are separated into 3 different groups subject to their distance from base station known as tiers. MST is generated. Energy is equally circulated among all SNs in the network. Next, a CH is selected from every tier depending upon the maximum energy which will be able to send data to base station. In CBEEP, relay nodes which are Fully Functional Device (FFD) are selected as CH to send data to base station using relay nodes that are closer to base station. Simulation results calculated lifetime of a network and energy consumed and using random and uniform deployment results were compared between the suggested protocols and LEACH.

Sahoo et al. [23] presented TREE-CR, a trust based secure and energy effective clustering algorithm in WSN. TREE-CR can defend the WSN from various types of malicious nodes. Also, TREE-CR proposed accurate prediction of network life time, and the proposed algorithm could also detect malicious nodes in the network. The proposed algorithm TREE-CR was compared with LEACH.

III. Methodology

Tree based routing has lower control packet overheads but suffers from approximation error compared to cluster based routing that ensures better energy savings compared to tree based techniques. This work proposes to combine cluster based routing features for cluster formation and CH selection and use MST for intra-cluster communication. Ideal clusters are formed when network parameters like energy spent, life, Packet Delivery Ratio, and end to end delay are optimized. As most network parameters are additive, optimization problems are NP-hard. The tool used in this approach is SA, a generalization of the Monte Carlo method in combinatorial optimization. An SA property is its robustness against converging to false local minima. SA is a kind of global optimization technique which finds the global minimum using stochastic searching technology from the means of probability. This algorithm has a strong ability to find the local optimistic result and it can avoid the problem of local minimum. So SA is chosen for proposed technique.

A. LEACH

LEACH is a cluster-based protocol using distributed clustering formation algorithm. LEACH algorithm is a cluster routing based data aggregation algorithm that works in rounds so that every round has: a setup phase and a steady state phase [24]. In setup phase, p% of n sensors are randomly chosen to be CHs based on a threshold as shown in (1):

$$T(n)=\begin{cases}\dfrac{p}{1-p(t \bmod (1/p))}, & \text{if n} \in \text{G} \\ 0, & \text{otherwise}\end{cases} \quad (1)$$

where p is desired number of CHs, t is current round, and G is a set of nodes that have not been CHs in last 1/$p$rounds. This ensures that a sensor chosen to be CH is not chosen in next rounds till other network sensors become CHs. This leads to fair energy consumption and increases network life. The algorithm does not consider non-uniform networks as the CHs are chosen randomly. After all CHs are chosen, clusters are dynamically defined so that every non-CH becomes a member of the cluster in the nearest CH. In the steady state phase, a CH collects data from sensors in its cluster, based on Time Division Multiple Access (TDMA). CHs compress collected data and forward it to a BS.

The large number of SNs in LEACH is divided into many clusters. A SN is selected as a CH for a cluster. The CH selection is based on predetermined probability. Other non-CH nodes choose nearest cluster to join by receiving the advertisement message strength from CH nodes. A non-CH node only monitors the environment and sends data to its CH node that is responsible for collecting information of non-CH nodes in the cluster. It then processes data and sends it to the BS. As a non-CH node cannot send data directly to BS, data transmission distance of SN shrinks. So, energy consumption in WSNs is reduced. But, random selection of CH node may result in a poor clustering setup, and CH nodes may be redundant for some rounds. The CH nodes distribution is not uniform, and so SNs transfer data through a longer distance and so energy is depleted in WSNs [25].

LEACH is a hierarchical routing approach for sensor networks. Formation of clusters in this algorithm is based on received signal strength. LEACH aims to ensure data aggregation for sensor networks. Total nodes are divided into small groups or clusters for equal distribution of power consumption in a network in LEACH protocol.

LEACH's advantages are as follows:

- Outperforms conventional routing protocols
- Is completely distributed, and does not require control information from BS
- No global network knowledge required.

LEACH also suffers from many drawbacks like:

- Extra overhead for dynamic clustering.
- CH selection is random without considering energy consumption
- Unable to cover large area.
- CHs are not uniformly distributed [26]

Election of CH node in LEACH has deficiencies like:

- Some very big clusters and very small clusters exist in network simultaneously.
- Unreasonable CH selection where nodes have different energy.
- Cluster member nodes deplete energy after CH dies.

The algorithm does not consider nodes location [27].

B. Genetic Algorithm (GA) Based Routing

GA based routing's motivation stems from a set of Pareto optimal solutions to choose the best possible solution, depending on the requirements. GA chromosomes have all building blocks to a solution for genetic operators and fitness functions. GA finds a pool of routing paths from sink to each source relay nodes, using a Depth First Search (DFS) algorithm. An initial set of routing trees is constructed, and each is mapped to a string consisting of a sequence of nodes on a path from each source relay nodes to sink. The set of all initial strings constitutes initial chromosome population. The length of a chromosome is equal to number of source relay nodes, but length of genes differs, based on path link count. To calculate objective functions, tree path from each chromosome is derived. Every individual is assigned 3 fitness functions: Energy consumption, Delay, and Reliability [28].

C. SA for WSN

Based on ideas formulated in early 1950s, SA was introduced in 1983 [29]. SA is a relatively straight forward algorithm that includes the metropolis Monte Carlo method.

The latter suits SA as only energetically feasible states are sampled at any temperature. So, SA algorithm starts at a high temperature with a simulation of the metropolis Monte Carlo algorithm.

SA is an optimization method applied to arbitrary search and problem spaces. Like simple hill climbing algorithms, SA needs a single initial individual as starting point and a unary search operation. In metallurgy and material science, annealing is heat treatment of materials to alter its properties like hardness. Metal crystals have small defects, ions dislocations that weaken the overall structure. By heating metal, ions energy and, thus, their diffusion rate increases. Then, dislocations are destroyed, and the crystal's structure is reformed when the material cools down and approaches its equilibrium state. When annealing metal, initial temperature must not be too low and cooling must be sufficiently slow to avoid the system getting stuck in a meta-stable, non-crystalline, state representing a local minimum energy. Simple hill climbing algorithms create new solution candidates iteratively xi+1 from existing one xi moving on to this new offspring if it has better objective values. SA enhances this by accepting worse solution candidates with a non-zero probability P (Δf) which exponentially decreases with iterations t [30]. Here, objective function is subject to minimization and corresponds to energy level of annealing steel. kB is Boltzmann constant is shown in (2) and (3):

$$\Delta f = f\left(x_{i+1}\right) - f\left(x_i\right) \tag{2}$$

$$P\left(\Delta f\right) = \begin{cases} e^{-\frac{\Delta f}{k_B t}} & \text{if } \Delta f > 0 \\ 1 \quad \text{otherwise} \end{cases} \tag{3}$$

SA begins with a user given solution, evaluates it and performs a small modification on it. SA accepts this and assumes it to be a current solution. If it is not better than the previous one, there is a probability that this new worst solution will be accepted based on cost of every solution and present system temperature [31]. The mathematical expression is in (4):

$$A = e^{\frac{-[c(N)-c(P)]}{t}} \tag{4}$$

where A is a probability of accepting worst solution, c(N) the cost of a new solution, c(P) the cost of present solution and t the temperature. The algorithm uses SA to optimize energy saving is [32]:

$BestEnergy = Objective\ Function\left(Cluster\ Tree\right)$
$For\ \left(i = 0; i < n; i{+}{+}\right)$
{
$if\ \left(E_{mean} - \sigma \leqq Ei \leqq E_{mean} + \sigma\right)$
$For\ (Temperature = T_0; Temperature > Stop;$
$Temperature * grad)$
{
$For\ \left(x = 0; x < Stay\_Time; x{+}{+}\right)$
{
Randomly choose two subtrees to exchange for a new tree
$Energy\_temp = Objective\ Function\left(new\ tree\right)$
$if\ (Energy\_Temp \leqq BestEnergy)$
{
Upgrade new tree
$BestEnergy = Energy\_temp\}$
$if\ (EnergyTemp \geqq BestEnergy)$
{
There is probability $e(-\triangle Z / Temperature)$ *to update new tree and*
$BestEnergy = Energy\_temp\}$
}
}
}
}

The algorithm states that the objective function of cluster tree is to obtain best energy. Initial temperature is set as T_0 and the process is continued till the termination condition achieved. Two sub trees are chosen randomly to exchange the new tree. Then objective function of new tree is assigned as $energy\_temp$. If the $energy\_temp$ is less than or equal to $BestEnergy$ then the new tree gets upgraded and $energy\_temp$ is assigned as $BestEnergy$. Suppose $energy\_temp$ is greater than $BestEnergy$ then *There is probability* $e(-\triangle Z / Temperature)$ and *to update new tree* $energy\_temp$ is assigned as $BestEnergy$.

D. Implementation of SA-MST for CH Selection

WSN network can be considered as a connected undirected graph represented by G=(V,E), where V vertices are made up of $(v_1,\ldots,v_n)$ nodes and E edges represented as $(e_{1,2}, e_{1,3}..,$

$e_{i,j,\ldots,e_{n-1,n}}$) connection between nodes [33]. In this work, normalized values of mobility, delay, and remaining energy are represented by edges. Every edge may be defined by attributes represented in positive real numbers and denoted by $w_{i,j} = w_{i,j}^1, w_{i,j}^2, .., w_{i,j}^m$.

Let $x = x_{1,2}, x_{1,3}.., x_{i,j,\ldots,x_{n-1,n}}$ be defined as in (5) as the connectivity between node i and j:

$$x_{i,j} = \begin{cases} 1 & if\ e_{i,j} = 1\ and\ is\ selected \\ 0 & otherwise \end{cases} \quad (5)$$

The proposed technique can be formulated as in (6):

$$\begin{aligned} &\min\ f_1(x) = \sum w_{i,j}^1 x_{i,j} \\ &\min\ f_2(x) = \sum w_{i,j}^2 x_{i,j} \\ &..... \\ &\min\ f_m(x) = \sum w_{i,j}^m x_{i,j} \end{aligned} \quad (6)$$

where $f_i(x)$ is objective to be minimized for problem, i=1,…,n-1; j=1,…,n subject to $x \in X$. These objectives are formulated either as a multi-objective function or represented as in (7):

$$\min\ f_i(x) = \alpha \sum w_{i,j}^1 x_{i,j} + \beta \sum w_{i,j}^2 x_{i,j} + ... \quad (7)$$

where $\alpha + \beta + ... = 1$

As node mobility, delay, and remaining energy are used as edge in the graph, objective function is formulated as:

$$\boldsymbol{min}\ f_i(x) = \alpha\boldsymbol{(min(}\text{mobility}\boldsymbol{))} + \beta\boldsymbol{(min(delay))} + \gamma\boldsymbol{(min(}1 - \text{remaining\_energy}\boldsymbol{))}$$

The following assumptions are made for sensor networks:

1. Nodes are dispersed randomly.
2. SNs energy is limited and uniform initially.
3. Nodes are location unaware.
4. Nodes transmitting power varies based on distance to receiver.
5. Approximate distance estimation is based on received signal strength.

MST problem is a commonly occurring primitive in design and operation of data and communication networks. MST, in adhoc sensor networks, is the optimal routing tree for data aggregation. Conventionally, distributed algorithms efficiency is measured by running time, and messages exchanged among computing nodes. Research has been done in designing algorithms that are optimal regarding such criteria [34].

SA is the most commonly used optimization routing technique and MST is most widely used WSN technique and so proposed method consists of SA-MST. An MST-SA based clustering algorithm is used for WSN's weighted graph. The optimized route between nodes and CHs is searched in the entire optimal tree based on energy consumption. CH election is based on energy available to nodes and Euclidean distance to neighbor node in optimal tree. Others concluded that network life does not depend on BS location or node's residual energy. Once the topology is decided, then network life is settled. The author's shows 2 techniques to improve network life: reduce startup energy consumption of transmitter and receiver, and optimize network topology [35].

Node energy model is based on [36] energy dissipated to transmit n bit is given in (8):

$$\begin{aligned} E_{diss\_Tx} = n\boldsymbol{(}&\text{Energy\_dissipated\_tranmitter\_electronics} + \\ \boldsymbol{(}&\text{Energy\_dissipated\_Transmitter\_amplifier} * \\ &\boldsymbol{distance\_squared))} \end{aligned} \quad (8)$$

The energy dissipated to receive n bit is given in (9):

$$E_{diss\_Rx} = n\boldsymbol{(}\text{Energy\_dissipated\_receiver\_electronics}\boldsymbol{)} \quad (9)$$

Power consumed in a time period t can be computed by dividing dissipated energy by time given by (10):

$$\frac{E_{diss\_Rx} + E_{diss\_Rx}}{t} \quad (10)$$

A node's mobility is estimated using Free Space Path Loss (FSPL) model. The relation between FSPL, radio signal frequency, distance between transmitter and receiver are given by (11):

$$FSPL(dB) = 20\log(d) + 20\log(f) + k \quad (11)$$

where d is distance, k frequency and log is logarithm to base 10, k is a constant and equal to 32.44 when frequency is measured in Mhz and distance in Kilometer. Another method to compute FSPL using fade margin is given by (12):

$$\begin{aligned} FSPL = &\text{Energy\_dissipated\_Tx\_electronics} + \\ &\text{Energy\_dissipated\_Tx\_amplifier} + \\ &\text{Energy\_dissipated\_}\boldsymbol{Rx}\text{\_electronics} \end{aligned} \quad (12)$$

Using the two FSPL equations, the distance can be computed by (13):

$$d = 10\left(\text{Free Space Loss} - 32.44 - 20\log(f)\right)/20 \quad (13)$$

To find distance travelled by nodes i and j with respect to each other during time n, distance between nodes are computed at time t and t=n. If High mobility increases clustering process, it also increases energy consumption. The aim is forming clusters based on low mobility leading to lower

energy consumption and lower delays caused by lower link breakages. Node mobility is computed by (14):

$$m = \frac{d_t - d_{t+n}}{D} \begin{cases} > 0.5 \textbf{ implies high mobility} \\ \leq \textbf{ 0.5 implies normal mobility} \\ 0 \textbf{ implies no mobility} \\ \textbf{<0 implies nodes converging} \end{cases} \quad (14)$$

A node stores information about its neighbors in its neighborhood table as shown in Table I. A node broadcasts Ech_Msg, at the start of every round with its residual energy, within radio range *r*. All nodes in cluster range of a node are considered neighbors of this node. On receiving Ech_Msg node updates the neighborhood table.

IV. Experimental Results

Since both the SA and MST are most widely used technique of optimization and the proposed approach considers the hybrid SA-MST for research. The proposed SA-MST is compared with LEACH and GA. Figs. 2-6 show the average packet delivery ratio, end to end delay, number of hops, lifetime and remaining energy achieved for network of varying size (40 80 120 160 200 240).

TABLE I
Information Maintained in the Neighborhood Table

Parameter	Description
Vi	Node i
Vj	a neighbor node in cluster range of *Vi*
RE ***V i***	Residual energy of *Vi*
Dis ***V j***	Distance between *Vi*and *Vj*
RE ***V j***	Residual energy of *Vj*
Ech_Msg	Elect CH message
Crt_Msg	Create tree message

TABLE II
Average Packet Delivery Ratio for LEACH, GA and SA-MST

Number of nodes	LEACH	GA	SA-MST
40	0.9306	0.9427	0.924648
80	0.8893	0.9018	0.890957
120	0.8818	0.8912	0.883052
160	0.8318	0.8428	0.827057
200	0.7675	0.7827	0.78623
240	0.6706	0.6842	0.753237

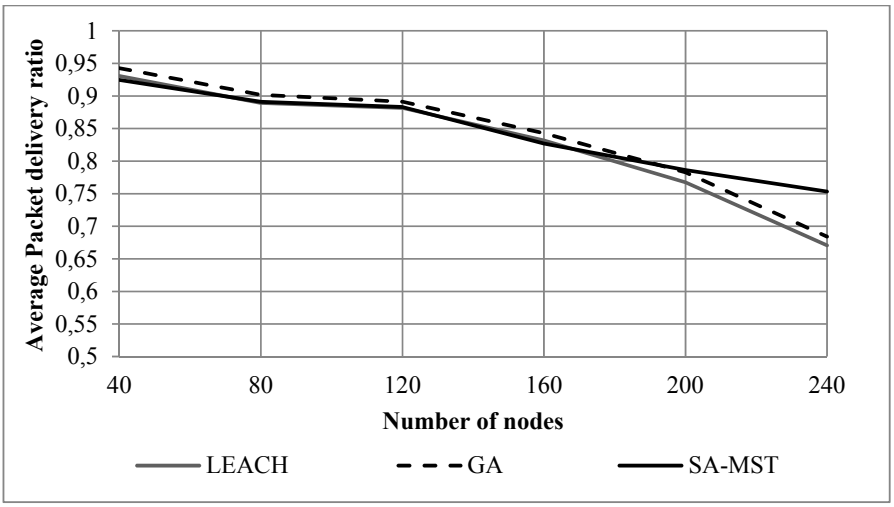

Fig. 2 Average Packet Delivery Ratio for LEACH, GA and SA-MST

Table II and Fig. 2 compares the average Packet Delivery Ratio for SA-MST, GA, and LEACH. Results prove that SA-MST performs better by improving Packet Delivery Ratio than LEACH in the range of 0.19% to 11.61% and improving Packet Delivery Ratio in the range of 0.45% to 9.61% than GA.

Table III and Fig. 3 compare the average End to End Delay for SA-MST, GA, and LEACH. Results prove that SA-MST performs better by lowering End to End Delay than LEACH in the range of 2.14% to 4.0% and lowers End to End Delay in the range of 0.4% to 23.66% than GA.

TABLE III
Average End to End Delay (sec) for LEACH, GA and SA-MST

Number of nodes	LEACH	GA	SA-MST
40	0.00102	0.001	0.000996
80	0.001017	0.001248	0.000984
120	0.009857	0.011485	0.00963
160	0.01658	0.014492	0.015929
200	0.03652	0.031859	0.03554
240	0.03876	0.03399	0.037938

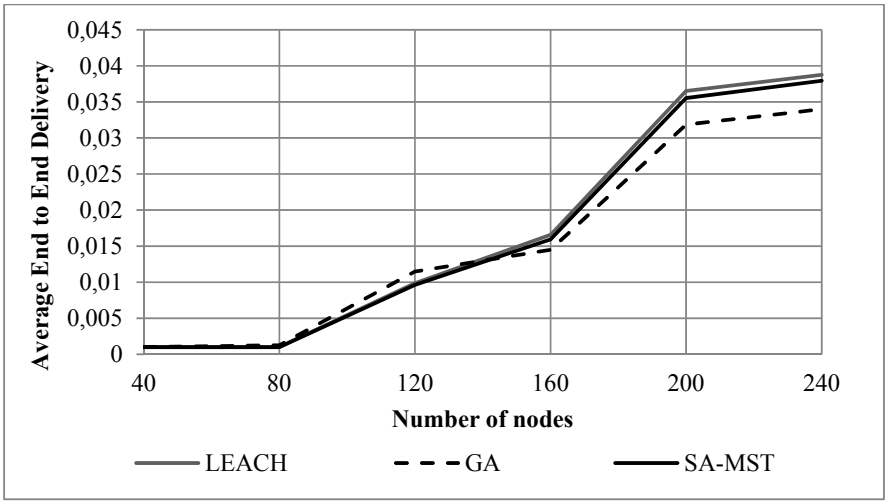

Fig. 3 Average End to End Delay (sec) for LEACH, GA and SA-MST

TABLE IV
NUMBER OF CLUSTERS FORMED FOR LEACH, GA AND SA-MST

Number of nodes	LEACH	GA	SA-MST
40	8	8	8
80	12	12	13
120	17	19	17
160	19	20	19
200	22	22	21
240	26	27	25

TABLE V
LIFETIME COMPUTATION FOR LEACH, GA AND SA-MST

Number of nodes	LEACH	GA	SA-MST
0	100	100	100
100	100	100	100
200	100	100	96
300	90	90	84
400	70	70	68
500	40	50	48
600	20	0	0
700	0	0	0
800	0	0	0

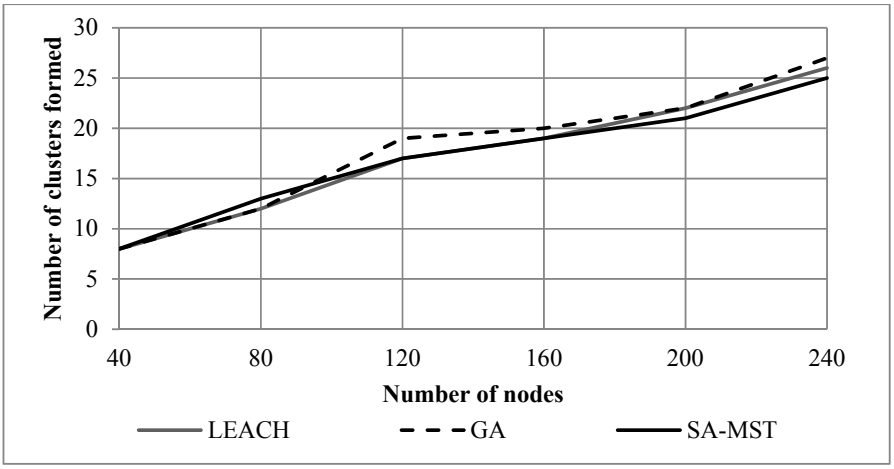

Fig. 4 Number of clusters formed for LEACH, GA and SA-MST

Table IV and Fig. 4 compares the number of cluster formation for SA-MST, LEACH, and GA. Results prove that the SA-MST performs better than LEACH in the range of 0 to 8% and better than GA in the range of 0 to 8%. When the number of nodes increases, LEACH and GA perform better than SA-MST.

From Table V and Fig. 5, it is seen that Lifetime computation for SA-MST is less than LEACH and GA.

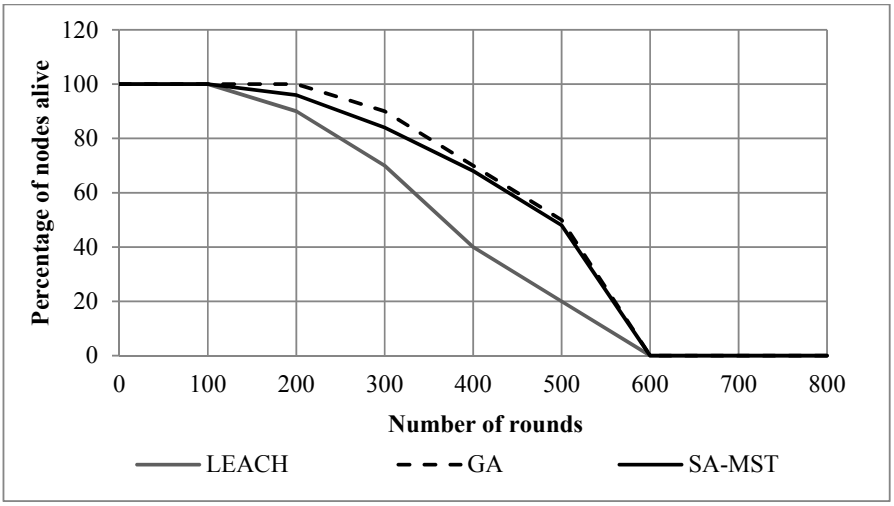

Fig. 5 Lifetime computation for LEACH, GA and SA-MST

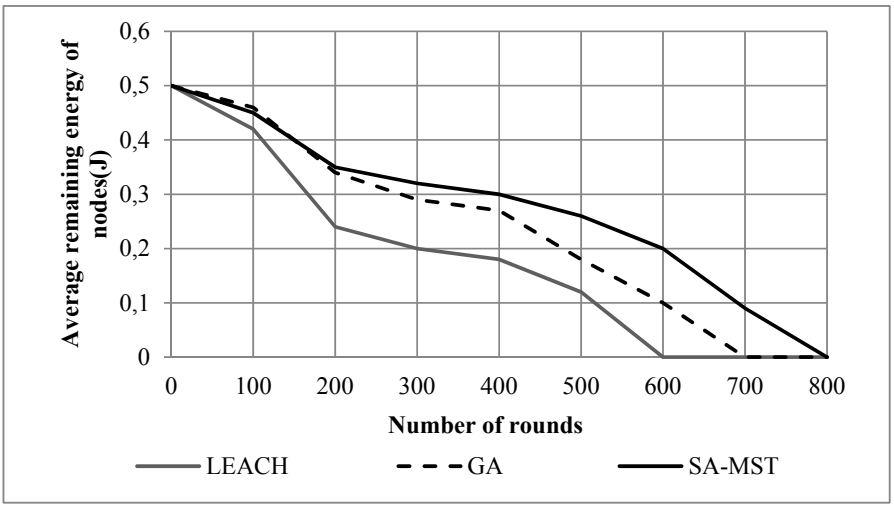

Fig. 6 Remaining energy computation for LEACH, GA and SA-MST

TABLE VI
REMAINING ENERGY COMPUTATION FOR LEACH, GA AND SA-MST

Number of nodes	LEACH	GA	SA-MST
0	0.5	0.5	0.5
100	0.42	0.46	0.45
200	0.24	0.34	0.35
300	0.2	0.29	0.32
400	0.18	0.27	0.3
500	0.12	0.18	0.26
600	0	0.1	0.2
700	0	0	0.09
800	0	0	0

Table VI and Fig. 6 compares the remaining energy consumption for LEACH, GA, and SA-MST. Results prove that the SA-MST performs better than LEACH in the range of 50 to 200% and better than GA in the range of 2.2 to 66.67%.

V. CONCLUSION

Global optimization finds absolutely best set of admissible conditions to achieve an objective under constraints, assuming that they are formulated in mathematical terms. It is more difficult than convex programming or finding nonlinear programs local minimizers, as the gap between necessary conditions for optimality, and known sufficient conditions for global optimality are tremendous. The features of cluster formation and CH selection using MST was proposed for intra-cluster communication where the clusters were formed by optimizing network parameters such as energy spent, life, Packet Delivery Ratio, and end to end delay. SA-MST was applied since both are commonly used technique. SA-MST performs better by improving Packet Delivery Ratio than LEACH in the range of 0.19% to 11.61% and by lowering End to End Delay than LEACH in the range of 2.14% to 4.0%.

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