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Improving the LEACH protocol for minimizing the energy consumption of Wireless Sensor Network using a modified Genetic Algorithm

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Abstract: *Wireless sensor networks (WSNs) face many computational contests in determining energy-optimized routing insidehuge spatial networks. WSN trials can be talkedabout employingcomputationallysignificant metaheuristic optimization approaches. In WSNs, the algorithm known as Low Energy Adaptive Clustering Hierarchy (LEACH) is the regularlyutilized hierarchical routing algorithm, despite some restrictions. The proposed work is captivatedbyrefining LEACH glitches using a modified genetic algorithm (M-GA-LEACH). The software MATLAB is cast-off to simulate the anticipated algorithm and further,the work is associated with numerous state-of-the-art procedures. The considered LEACH is anordered protocol that alters sensor nodes interested in cluster heads (CH), and further, the CH gathers and bandages the facts and directs it to the goal node. The outcomesdesignate that the M-GA algorithm aids to treasure the optimal route utilizing its fitness function. Later simulating the code within MATLAB, the power consumption gets compacted up to 18.97%, furtherfounded on the trialoutcomes, improvement is observed with the proposed method related to the preceding techniques. Further, the parameters like energy consumption, throughput, and network lifetime are mainly taken into account toexamine the effectiveness of the proposed energy-efficient strategies.*

Keywords: *LEACH, WSN, GA*

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I. Introduction

The usage of wireless sensor networks (WSNs) has grown at an exponential rate in recent years and this trend is expected to continue as well. Further, due to rapid development, wireless sensor networks focus on increasing their performance in terms of energy efficiency, communication efficiency, and system throughput. Many unique processes have been developed by adapting the socialbehavior of natural organisms such as bats, birds, ants, fish, and bees known as nature-inspired systems or swarm intelligence, these systems are capable of developing optimization techniques, managing large networks, and circumventing resource limits[1].Wireless sensor networks (WSNs) are a type of ad-hoc network technology that emerged more than 20 years ago for monitoring purposes in military applications. WSNs typically include a large number of sensor nodes that are fundamentally resource-constrained but can connect to other network nodes to transmit scanned data. The main task of each node is to monitor the environment using onboard sensors, in addition to its possible capabilities to act as a transmission or data fusion node[2]. Each node can be used as a router to transmit data from neighbours to a sink or base station (BS). The BS can process data locally or act as a network gateway to transmit data to remote servers, as shown in Fig. 1 below.

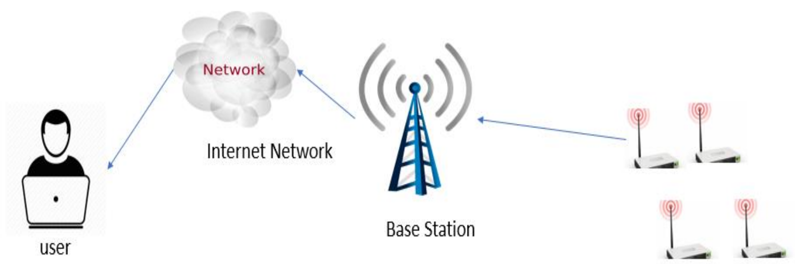

Fig. 1 A WSN architecture[2]

In the earlier two decades, numeroustenders have been anticipated for WSNs, like environmental monitoring, healthcare, smart homes, as well asdisaster management. Although WSNs are considered highly dynamic ad-hoc networks, network topology management has been a major challenge in these types of networks in special resource management, scalability, reliability, as well as efficiency. However, topology management is measuredas a viable practice for fortifying a stable, reliable, trustworthy, and efficient network infrastructure in ad-hoc networks such as WSNs. Clustering is one of the most popular techniques for WSN topology management[3]. A clustering technique organizes nodes into a set of groups called clusters based on a set of predefined standards such as supporting Quality of Service (QoS), optimizing resource consumption, network load balancing, etc[4]. The cluster has one or more Cluster Heads (CH) that amass data sinceadded nodes in the cluster, members call and send (fused) data directly to the BS, or circuitously using additional nodes named intermediary nodes. Employing clustering methods, resource-inhibited nodes are incapable to direct their data straight to gateways (sinks), which can cause energy sourcereduction, as well as interference[5].The purpose of this paper is to explore the mechanism of metaheuristic algorithms in the set of WSNs and also to recover the energy competence and network eminence of LEACH (Low Energy Adaptive Clustering Hierarchy) protocols.

II. Related Work

Energy consumption is a chiefapprehension in the development of wireless sensor network applications as a result, many strategies have been discussed for specific applications. Daanoune et al.,[6]presented a study by categorizing LEACH-based routing protocols for CH choice and data communicationmethods. This study confers the assets and restrictions of each variant of the LEACH protocol. Kumar et al.[7], proposed I-LEACH (Improved LEACH) with two chiefvariations, the primary was the remaining energy utilized to choose the CH (Cluster Head) as a substitute of the probability as considered in LEACH, to custom sensor nodes within different initial energy and coordinates. The results illustrate that I-LEACH advances network lifetime over LEACH. Sivakumar et al.[8], proposed a better LEACH (LEACH-C) algorithm named Partition-based LEACH (pLEACH), which primarilydivides the network into an ideal number of segments, then picks the node thru the maximum energy as the head for each sector using centralized computation. Pitchaimanickam et al. [9], presented the Firefly processby Particle Swarm Optimization (HFAPSO) within the LEACH-C tactic for the best cluster head choice. The hybrid wayimprovesfirefly's global search behavior and attainsthe best cluster head assignmentutilizing PSO. Further, Su et al.[10]offered a gradedfusion genetic algorithm (GA) with the particle swarm optimization (PSO) intended for the dispersedgroup in significant WSNs, and the proposed tacticeffectuallylessens energy consumption, as well as aids,cover network lifetime. Visu et al. [11]demonstrated the influence of residual energy and distance to the base station on LEACH. Further, to minimize the energy consumption of cluster heads, the author considers the node with high energy and minimum distance from the BS as the cluster head (CH).The author founds that RED_LEACH cuts power consumption 3 times concerning thenovel LEACH moreover the network lifetime is stretched twice. Mahmuddin et al.[12],presented a cluster routing protocol in which LEACH is stretched to classify the cluster head by the cordial degrees of distance as of the base station to contract energy consumption in the cluster nodes and the whole network. Demri et al. [13], proposed a biologically inspired routing protocol based on hybrid clustering using cuckoo search and simulated annealing algorithms (HRP-CSSA). The protocol customs the rewards of SA in that it avoids being ensnared in local minima and the efficacy of the CS algorithm in answering global optimization. The concert of the proposed procedure is allied with LEACH-C as well as ECBSCP, and the results show that HRP-CSSA has the best performance in terms of energy consumption, stability time, network lifetime, and amount of data received by base stations. Chen et al.[14]presented aninnovative routing protocol, LEACH-EPM, which optimizes CH node selection and considers Dijkstra's algorithm to make a routing process amid cluster head nodes.Rajpoot et al.[15]proposed a model using the LEACH protocol for progressing the network measures and efficiency to resolve the data redundancy. The model used an independent data fusion algorithm based on IRNN (recurrent neural network), namely DFAIRNN. The simulation and comparison results show that the mean value method and the minimum distance method used in the LEACH-DFAIRNN protocol reduce the data redundancy caused by neighboring sensor nodes by simultaneously flooding data to one node. Xiao et al. [16], presented the LEACH protocol based on PSO (Particle Swarm Optimization) and ACO (Ant Colony Optimization). The proposed tactic is usuallyconsidered in WSN routing protocols to reduce WSN data transmission energy consumption and optimize data transmission routing. The clustering procedure of the LEACH protocol does not select the best CH because it randomly selects a CH regardless of power consumption due to variables such as location and data processing. LEACH uses PSO to achieve a globally optimal one-hop representative cluster head, which allows the cluster head to use all resources early in the LEACH data transfer process, thus shortening the network cycle.Ajmi et al.[17]presented a model considering chicken flock optimization as well as the genetic algorithm, CCSO-GA cluster head selection. The comparison displayed that the technique performed fineconcerning energy efficiency, packet loss, packet delivery rate, and throughput. However, no algorithms areintricate in creating a cluster. Though, numerous studies have been proposed to choose the Cluster Head CH. This work differs from existing works in the following:

1. Energy consumption reduction with LEACH optimization comparing GA and M-GA to improve network lifetime, reduce overall network energy losses, and equalize energy distribution in space.
2. Increase in throughput, which is a measure of the competence of the entire network regardinglatency reduction.

Overview of LEACH

In 2000, the Low Energy Adaptive Clustering Hierarchical (LEACH) protocol was projected to address the limitations of WSNs to improve energy efficiency and enhance the network lifetime. LEACH is the TDMA-based MAC protocol that is measuredas the prominent and the first ordered routing practice that utilizes the clustering[18].

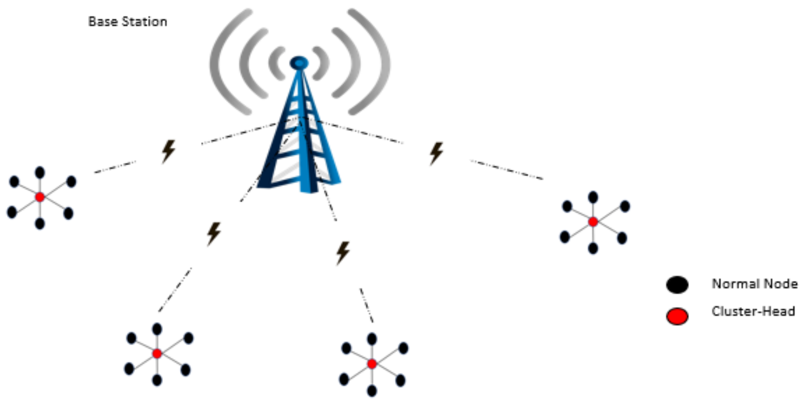

Fig 2. The LEACH Architecture[4]

LEACH is known as the routing protocol that is based on a clustering technique in which nodes are assembled to form discrete clusters soapiece cluster becomes the master node known as CH that totals the cluster participant data, and furtherdirects it to sink[19]. LEACH errands are branded by revenues and each round contains two key phases that are the setup as well as data transfer phases. The formation phase includes choosing CH, creating clusters, and creating the schedule of TDMA.LEACH is intended to curtailenergy consumption by randomly dividing nodes into 2 phases: a setup phase as well as a steady state phase[20].

Setup phase: Primary phase is envisioned to hand-picked CHs and make clusters. Each sensor node polls to turn out to be a leader despite its group. This decision hinge on a random number chosen through the sensor node at the startof every epoch. The choice of value is within 0 and 1. The sensor node converts a CH within the existing epoch uncertainty lower than that of the threshold function defined eq.1and it converts to a normal node. CH selection consequently the waythat leads to the circulation of energy amongstthe total nodes of the network.

$$T(n) = \left\{ \frac{P_L}{1 - P_L * \left(r \bmod \left(\frac{1}{P_L} \right) \right)} \quad , n \in C \right\}$$

Wherever$P_L$signifies the proportions of CH in individual epoch, r isthe current epoch as well as C is the set of sensor nodes not within the CHperiod of $1/P_L$epoch.After CHs are selected, the network makes nodes to know about their status through messages. After that, the sensor nodes will seam its consistent CH liable on the forte of the node acknowledged signal as of CH. The acknowledged signal has a topasset if the CH is near the node. When a node indicates to join the CH it is alerted with anappeal to enhance this node to its cluster members. When clusters are formed, each CH sends its members a TDMA schedule. Further, the TDMA schedule lets nodes know their time spaces to direct their accumulated data to the CH[13]

Steady phase

The steady phase consists of numerous frames as well as it is much lengthier than the primary phase. At this period, everynode directs its accumulated data to its possible CH employing a time-space TDMA schedule. Later merging CHs data, it will be promoted to the sink utilizing the CDMA code to evadeanimpact.

An Outline of Genetic Algorithm

Genetic Algorithm (GA) is the heuristic search algorithm aimed at generating solutions for optimization problems. GA was anticipated by John Holland in the year 1970 utilizing the theory of genetics as well as Darwinism, known as the father of the GA. The genetic algorithm solves optimization complicationsby utilising theoretical applications to reinforcenumerous problems in actual applications. The operation of the GAcomprises 3 steps after random choice of the preparatory population[21] the selection, Crossover,as well as Mutation. The selection favors the healthier individual to contest the existence of the rightest to permit the genes scheduled to the following generation. The Crossover signifies a discrete pairing, i.e.producing a noveloffspring for the succeeding generation built on randomly nominated bit strings. The former step in the operation of the GA is mutation. Mutation contains random amendments on new individuals having a low probability and allows a cohort to upholdvariety and early convergence[22].

III. Methodology:

I. CH selection Procedure: In the base station, the GA is utilized to treasure the sensor node's optimal probability to develop the cluster head within thelowest energy consumption to finish the primary round. Further, the preparation phase entailed only after the launch of the setup phase as well as the steady state phase. Moreover, the setup phase, as well as the steady state phase, are similar to the LEACH protocol. The procedure of the GA algorithm is as trails:

Step 1: Initialize the GA with the fitness function for the optimization waythat is builtupon the fitness function. Further, the nodes that takeextra energy are thrown downon or after the route, and further, the route is in step to hand over the data to the actual node. Hence, the node taking low energy considers in the further step.

Step 2: Take animproved cluster head to adjust the route on basis of the residual energy for individual sensornodes. Subsequently selecting the top CH within the network, a reliable route is achieved to get the route within its transitional nodes. The notion of a trusted path is considered to reduce the search time when the data transference is frequent within the fixed source as well as the destination nodes.

Step 3: Accumulate the optimized route within the reliable table of the cluster position and measure the significant parameters like throughputplus power consumption rate.

Step 4: Now change the mutation and repeat step 2 and the results are saved as M-GA-LEACH (Modified Genetic Algorithm LEACH) and the fitness functions are shown in Figure 3 below.

Step 5: Compare the performance of WSN with GA-LEACH and M-GA LEACH.

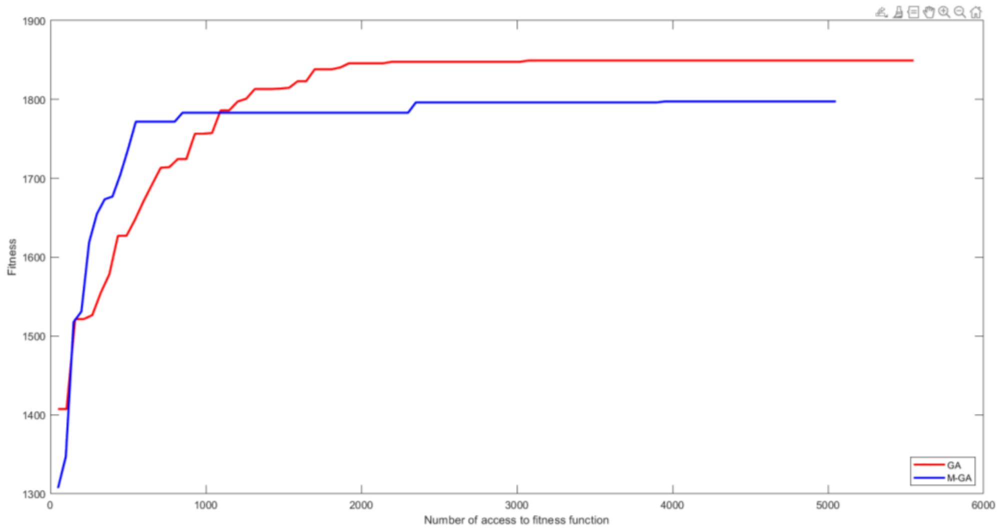

Fig. 3 Fitness functions of GA and M-GA

I. Energy Model

In the proposed model, WSN for sensor nodes is builtupon the first-order radio model. In this, the transmitter devours power through the radio technologyas well as the power amplifiers are sending the data to a distance d[23].

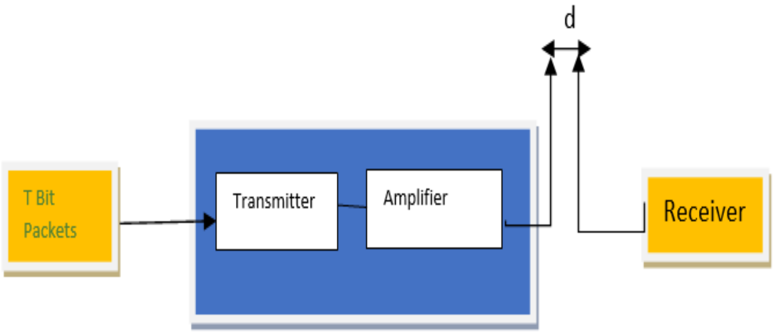

Fig. 4 the Energy Model

$$E_{TX(k,d)} = \begin{cases} k.El + \epsilon_{fs}.d^2 \\ k.El + \epsilon_{amp}.d^4 \end{cases}$$

On the other hand, the energy disbursedthrough a sensor node to receive kbit data at distance d is specified by

$$E_{RX}(k,d) = k.\ El,$$

wherever Elrepresents the energy spent to function the circuitry getting or conveyingthe data bits. $\epsilon_{fs}$and ε_{amp}signifies the power spent by the amplifier aimed atcommunication over short as well as long distances, correspondingly, $d_0$means the transmission distance threshold given by next formula:

$$d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{amp}}}$$

II. Experimental Setup:

An assessment of GA-LEACH, as well as MGA-LEACH was executed by means of the MATLAB simulation. The nodes are arbitrarilydispersed over arange of 100 x 100 m^2 and the base station(BS) is placed in the center of (50, 50) as shown in figure 4 and Table 1 below:

Table I Parameters of the Simulation Model

Parameters considered	Values
Number of nodes	100
Location	Randomly distributed
Network Area	100x100 m^2
Packet size	3000 bits
Protocols	LEACH, GA- LEACH-C, and MGA-LEACH
Maximum Rounds	10000
Initial energy	1.5 Joules
Transmitter energy	5 x 10^{-8} J /bit
Receiver energy	5 x 10^{-8} J /bit
Cluster head probability	0.125,0.5
Maximum iterations	30

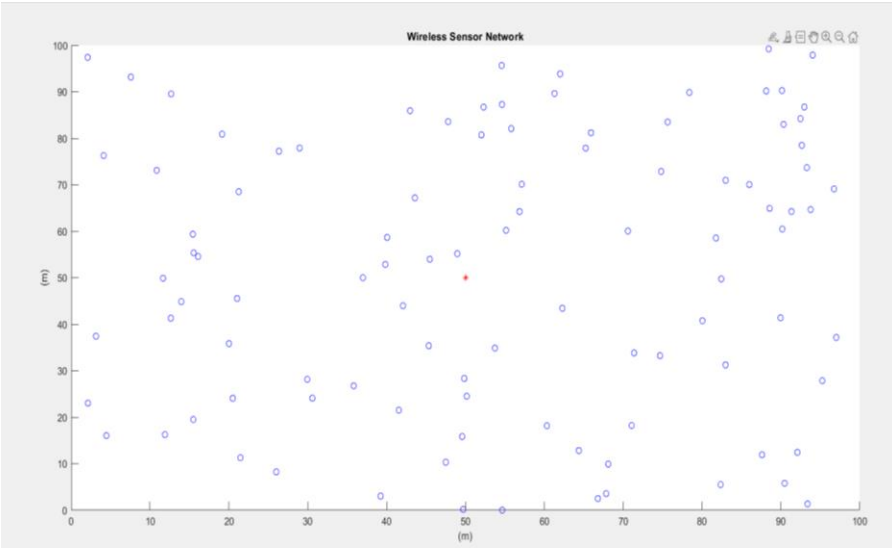

Fig.5 the WSN Network

Result Analysis:

This section describes the results obtained after the executionof the performance metrics. The 100×100-meter square area with 100 nodes in the WSN is taken in the proposedelementary network system. The code is deployed in the MATLAB simulator and given the primary node parameters. To simulate the network, the initial energy is delivered to each node in joules, and analyze the total energy consumption after the simulation. First, the LEACH routing protocol is well-known, and then valid network traffic is produced. Performance measures such as throughput and power consumption rates are then calculated. The throughput of the proposed network is shown in Fig. 6. The X-axis outlines the numeral of rounds and the Y-axis outlines the throughput quantity for the GA-LEACH and M-GA LEACH protocols. The average throughput value with GA-LEACH as well as M-GA-LEACH is 379.33526 kbps & 459.49116 kbps, respectively. Thus, there is an upgrading of approximately 17.44% in the proposed work by means of the M-GA-LEACH routing way. The exact performance of the proposed work is defined in Figure 6 and Table 2 below

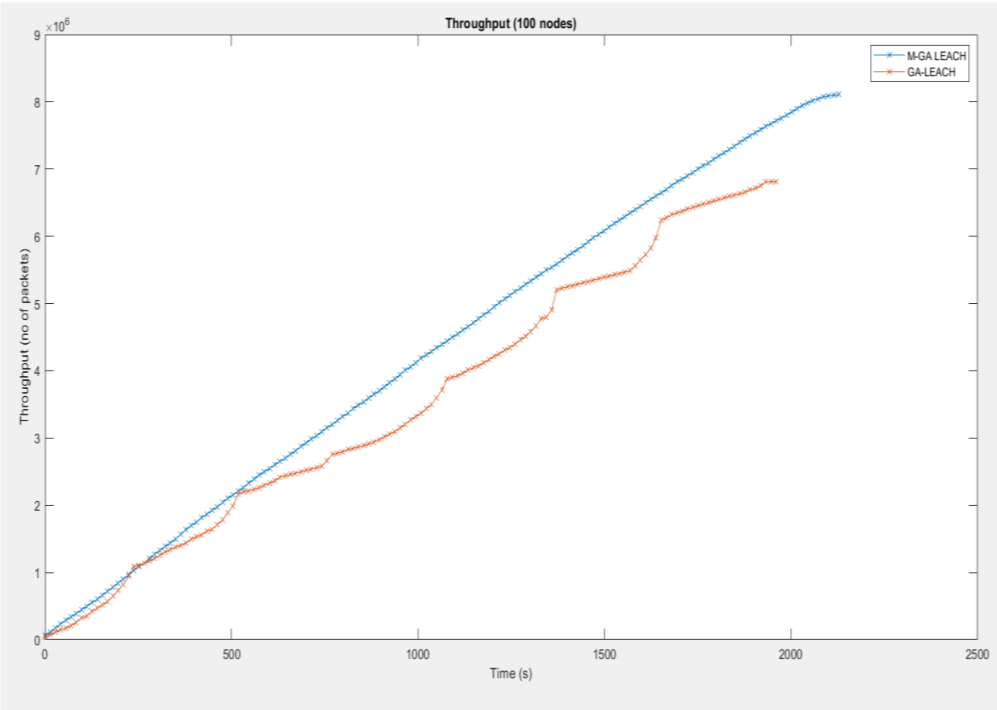

Fig. 6 Comparison of throughput with the GA-LEACH and M-GA-LEACH

Table 2 Comparison of throughputwith the GA-LEACH and M-GA-LEACH

Number of Rounds	GA-LEACH	M-GA-LEACH
1	812.675	867.342
2	1067.345	1189.780
3	1556.365	17.4589
4	2142.898	2378.342

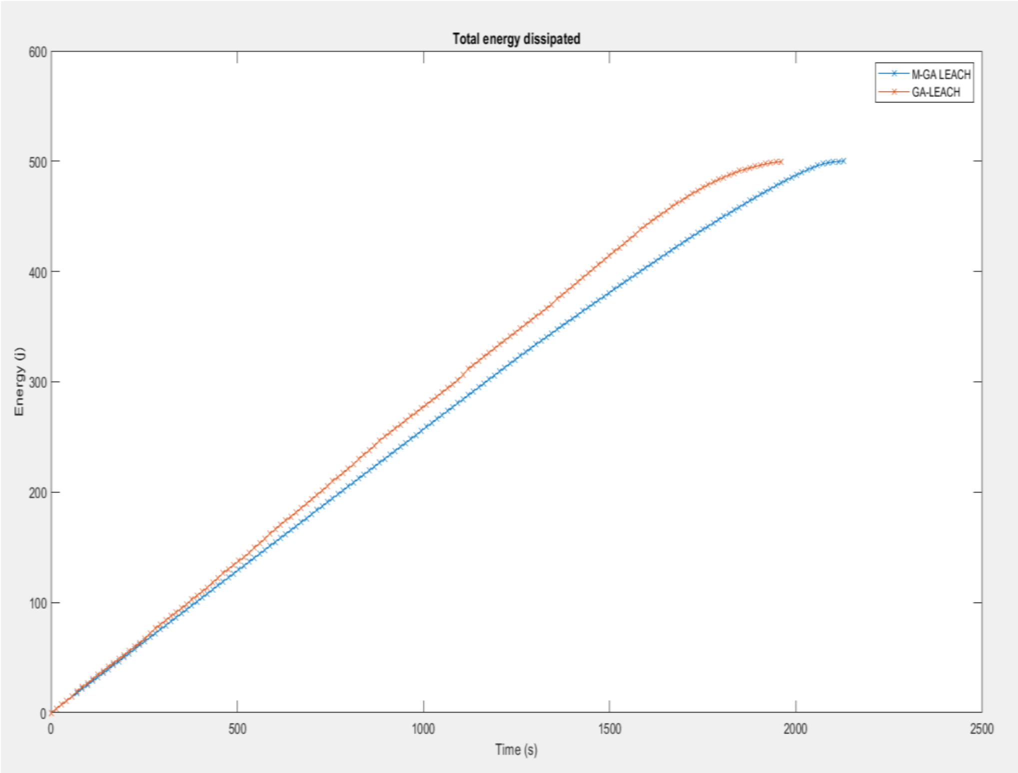

Fig. 7Energy Consumption using GA-LEACH and M-GA-LEACH

Figure. 7 displays the energy consumption within the sensor nodes during sending of the data from the base to the destination. It is clear from the figure that the energy depletion by the M-GA-LEACH routing algorithm is a reduced amount of GA-LEACH. The precise energy consumption with the GA-LEACH and M-GA-LEACH routing protocol is tabulated in Table 3 given below. The mean value of the energy consumption percentage for GA-LEACH and M-GA-LEACH is 69.15 J, respectively. 45.98 J. Thus, when utilizing the M-GA-LEACH protocol the energy consumption rate is reduced by 18.97% compared to GA-LEACH.

Table 3 Energy consumption with theGA-LEACH and M-GA-LEACH

Time in seconds	GA-LEACH	M-GA-LEACH
500	110.12	95.64
1000	235.34	213.12
1500	395.85	352.26
2000	521.61	463.32

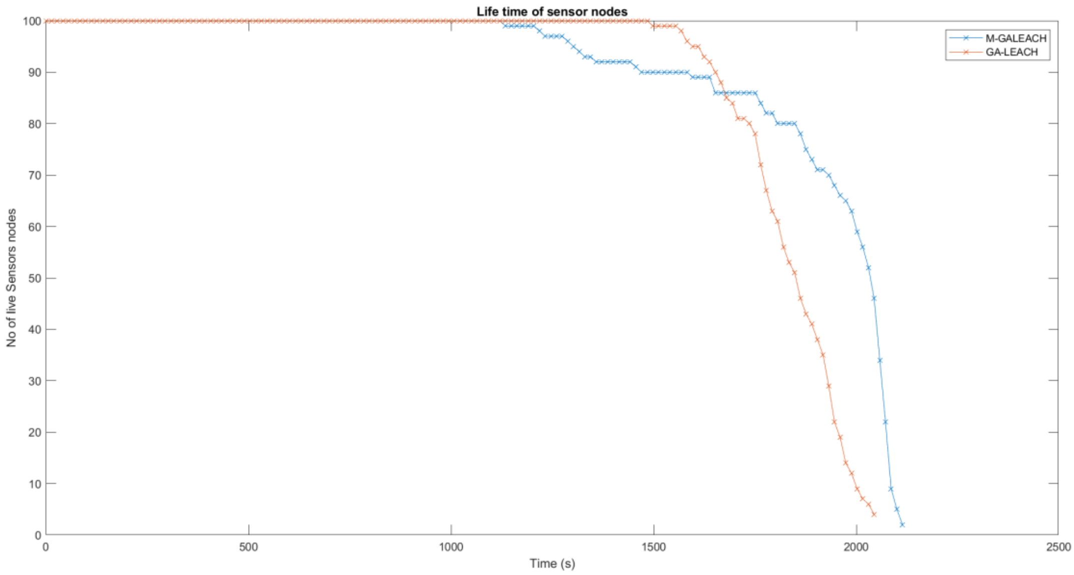

Fig. 8 Network Life Time with GA-LEACH and M-GA-LEACH

Table 4 Network Lifetime with GA-LEACH and M-GA-LEACH

Time in seconds	GA-LEACH	M-GA-LEACH
500	110.12	95.64
1000	235.34	213.12
1500	395.85	352.26
2000	521.61	463.32

Figure. 8 displays the network lifetime whilesending data from the base to the endpoint using M-GA and GA. It is clear from the figure that the network's lifetime with the M-GA-LEACH routing algorithm is longer than that of GA-LEACH. The network lifetime with GA-LEACH and M-GA-LEACH routing protocol is tabulated in Table 4 below. The mean lifetime rate of the network by GA-LEACH as well as M-GA-LEACH is 34.10% and 48.42%. Thus, using the M-GA-LEACH routing protocol within the proposed work, the network lifetime is improved by 12.32% compared to GA-LEACH.

IV. Conclusion

In this paper, the different protocols are linked that are deployed in WSNs with GA-LEACH and M-GA LEACH and observed that M-GA-LEACH executeswell thanGA-LEACHregarding energy consumption, M-GA-LEACH outperforms GA-LEACH by 18.97%. This isdetected that the Cluster head selection founded on M-GA-LEACH minimizes power consumption and provides alonger network lifetime as well as increased throughput. As a result, M-GA-LEACH increases the lifetime by 12.32% on average over the GA-LEACH routing protocol. In the future, the era of the M-GA-LEACH network can be enhanced by modifying the selection of cluster heads to lessen energy consumption throughout the period of the network.

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