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AN IMPROVED CLUSTER HEAD SELECTION TECHNIQUE FOR WIRELESS SENSOR NETWORK USING MODIFIED GENETIC ALGORITHM

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ABSTRACT

Aims: *Wireless Sensor Networks (WSN), a popular medium of low cost infrastructure communication is slowly emerging as an emergent form of wireless technology among the various classes of communication networks such as Cellular Networks, Adhoc Networks and Mesh Networks. Clustering, a classification process in which nodes are divided intocategories via a set of partitioned subset of data, which are commonly known as clusters. A set of predefined categories become a part of the clusterhead and through wireless clustering algorithms, Low-Energy Adaptive Hierarchy (hereafter abbreviated as LEACH) is a popular It involves a set of cluster heads, which are selected as predefined criteria. In the clustering routing algorithms for wireless networks, Low-Energy Adaptive Clustering Hierarchy (LEACH) a well-known hierarchical routing protocol applied in clustered WSN. The above protocol segregates wireless sensory networks into numerous clusters, and sensory nodes within the same cluster where nodes are capable of direct communication. Cluster head selection based on QoS is NP hard. In this work a novel clustering technique using a modified genetic algorithm is proposed. Extensive simulation show the performance improvement of the proposed technique*

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KEY WORDS

Wireless Sensor Networks (WSN), Clustering, Low-Energy Adaptive Clustering Hierarchy (LEACH) and genetic algorithm.

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INTRODUCTION

A network containing numerous sensory nodes and every sensory node involve the potential to process, transmit and sense information gathered from the environment, and such networks are otherwise known as Wireless Sensor Networks or WSNs [1]. Sensory nodes which are employed into the environment have limited capacity in energy, memory and other resources as they are often assisted with batteries. Sensory nodes transfer knowledge collected from base stations or gateways and pass them on to other nodes. Clustering is an efficient and scalable energy management technique which is commonly used for large amounts of wireless sensor nodes and it involves sensory organizations which are divided into groups or clusters. Usually among such clusters, work is divided among all the present nodes and each cluster has a central node which is also known as the Cluster head. The main duty of Cluster hears is to ensure the maintenance of information affiliated to each cluster and node. Also, these heads filter and compress data proposed to be transmitted, apart from the mere collection of data. The freshly compressed data is transferred to other nodes and cluster base stations through gateways or any associated Cluster Head.

Election of cluster heads occurs at the nodal level wherein all nodes of a cluster are involved in this overhead process and during which more energy is consumed by sensory nodes. After Election processes, it is difficult to revitalize sensory nodes and researchers have proposed a variety of schemes to evaluate the limitations of such nodes in terms of battery life, energy levels and memory. But researchers also have to consider multiple parameters to select a sensor node as a cluster head [2]. Parameters like residual energy, location, battery and localized distance are considered to be important.

Hierarchial Routing Protocols are the focus of research among wireless sensor networks. For wireless sensor network protocols, the focus of the research is the hierarchical routing protocol. One of the common hierarchal routing protocols theorized by researchers, namely the LEACH, can prolong network lifetime by 15% compared with the ability of flat routing. Routing Protocol Researches have mainly focused on improving LEACH protocols either at home or the workspace. This consists of improving selecting cluster heads, creating clusters and transmitting data. Computational difficulties in the CH marks a stark problem in the routing process, however these can be handled through efficient heuristic algorithms which are popularly employed and quickly cover local optimum area. Recent studies have seen an increase in genetic computations and algorithms with LEACH protocols. Crossover mutations are commonly performed where the chromosomes are mutated and used for election purposes.

RELATED WORKS

Numerous techniques to improve WSN lifetimes were introduced by Desai & Rana [3]. They found clustering to be a strong enough approach to be used for linking hierarchies in a network. The efficiency in gathering aggregate data to enhance lifelines of networks is the main goal of clustering algorithms and in the proposed CH algorithm choices are made is using node and nodal energy distances. The process is carried out in a way to ensure using approximate distancing between nodes and nodal energy points. Data is then transferred from the CH of every nodal point and all the data is sent to the CH located closest to the NS andthe aggregated data is transmitted to the Base Station (BS).

Reviews on WSN protocols were conducted by Khan et al [4] especially in the fields of "Low Energy Adaptive Clustering Hierarchy" (LEACH), "Power-Efficient Gathering in Sensor Information System" (PEGASIS) and "Threshold Sensitive Energy Efficient Sensor Network" (TEEN). By accessing “Hop Counts” and otherperformance metrics protocols like the Expected Transmission cost and time and "Energy Consumption" levels were consecutivelyanalyzed toprotocols of general analysis methods. After the above processes, Khan et al gives us a comparative study among three Wireless Sensor Network's Protocols, namely, LEACH, PEGASIS and TEEN.

WSN has been a common focus among actual users and researchers alike and it is an important task The energy utilization in these wireless sensor networks is very important task that increases the lifetime of the sensor network. In WSNs the researchers had explored numerous new protocols by considering the energy utilization as crucial task. There is a prime importance to give preference to hierarchal routing protocols based on scalability, even though there might be multiple WSN protocols available. Battery-powered sensory nodes have to assist in reducing energy consumptions in order to increase lifelines of networks. LEACH is the most commonly used sensory network protocol and is also used as a reference for other protocols. Various LEACH based protocols was accessed by Singh [5].

GP-Leach and HS-Leach algorithms proposed by Karimi et al [6] helped improve energy consumption levels and optimized cluster head selection systems with WSN nodes positioning and residual energy of partitioned systems. The results gained from simulations show how the proposed algorithm has an efficient and increased lifetime network. .

A modern combination method proposed by Barekatain et al [7] with K-means and improved GA based energy consumption patterns helped to improve Gas and extend the lifetime of networks. Under the above method energy consumption is reduced by finding optimum number of CH nodes via Genetic Algorithms (GA). K-means-based algorithms dynamically cluster networks to balance energy distributions. Simulations in NS-2 portray how the proposed algorithm has a longer lifetime network than popular formulas like GAEEP, GABEEC AND LEACH protocols.

A combinatory EA clustering process was suggested by Martínez-Estudillo et al [8] which assisted in evolutionary design basedlocal-search procedures especially inproduct-units neural networks. Only a few individuals are subjected to local optimization methods in the methodology presented. It should also be noted that local optimization algorithm can only be applied to specific evolutionary stage processes. Theproposed results witnessed a favorable performance under the regression method as compared to other standardized methods.

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An efficient clustering method was postulated by Gupta et al [9] which helped in the formation of CHs and assists in sending data to BS and the role of CH modified in every rotation. The final CH is then chosen on the basis of energy distribution and optimum selection procedure via GA. This approach ensures stable operating periods through stable results when it is compared with the probabilistic EC algorithm.

Traditional protocols were reviewed by Dongare & Mangrulkar [10] where energy efficient methods fostered the improvement of appropriate cluster head approaches. Selected formulas chose residual sensory energy clusters via the understanding of optimized cluster heads for proceeding rounds of cluster head operations. Following this equation ensures the survival of the whole network and improves the holistic performance of wireless sensory networks, especially in reducing latent WSN abd bandwidth consumption and lifelines of sensory nodes. The distribution of energy balance among all the nodes increases the round number by which point the first node becomes extinct after the reduction of energy holes within WSNs.

A modern scheme is provided by Maraiya et al [11] which relates to data aggregation clustering and is also known as “Efficient cluster head selection scheme for data aggregation in wireless sensor network” (ECHSSDA). It is comparable tothe proposedLEACH clustering formula and differences can be seen in terms of energy consumption especially in cluster formations and heads. This suggests that the above scheme is predicted to be better than LEACH especially in the case of consuming less energy among cluster node and head sending data to the base station which consume less energy than LEACH programming.

METHODS

Low-Energy Adaptive Clustering hierarchy (LEACH)

LEACH (Low-Energy Adaptive Clustering hierarchy) [12], a self-organized and adaptive clustering protocol adopts randomization which is chosen on the basis of the probability to distributeloads of energy equally among network sensor nodes. The nodes have ability to organize themselves into clusters in LEACH systems especially with one of the nodes acting as a router or data aggregator for other node. This initiates a process of randomized rotation of the high energy nodes as cluster heads to ordinary node and vice versa, and helps in preventing the faster draining of battery life among sensor nodes and enhances the lifelines of network. LEACH also performs the data aggregation and data fusion (data compression) [13] at cluster head level before transmitting data to base station, further reducing the energy consumption and enhancing the network lifetime.

The selection method of cluster head in LEACH protocol [14] is that the sensor node generates a random number between [0,1], if the random number is less than or equal to the node's threshold T (n), the node is elected as the head node of the cluster.

$$T(n)=\begin{cases}\dfrac{p}{1-p*[r \bmod (1/p)}, & n\in G\\ 0 & ,n\notin G\end{cases} \tag{1}$$

In which the letter p stands for the probability of cluster head nodes each round that is the ratio of the total number of cluster head nodes and sensor nodes, the current number of rounds is represented through r and the letter g is the set of the nodes never become cluster head in recently 1/p round.

A few drawbacks of LEACH systems are:
The non-deterministic nature of the setup phase due to randomness, can elongate the entire setup period. Instability during setup phase depends on the density of sensor nodes and this is not applicable on larger networks due to its usage of single hop communication methods. The consumption of energy depends on the location of the CH from the BS. It does not guarantee the good cluster head distribution and it involves assumption of uniform energy consumption of cluster heads during setup phase.

Other problems of LEACH cluster mechanism are the complete dependence on randomized nodally generated numbers for other attributes of the nodes, such as the current residual energy, location are not considered, which has the following problems:

1) The selection of low energy nodes as cluster heads without considering any residual energy of nodes when select cluster head and this causes the quick exhaustion of energy in nodes.

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2) Nodal location is not considered during the distribution of cluster heads and this cannot guarantee uniform distribution of cluster head. This may also cause some cluster heads to be distributed densely, or cluster heads are too sparse, even no cluster head in certain areas.

Improvement of Cluster Mechanism

Taking note of the position of energy and nodal positions into account, especially in view of problem in LEACH protocol, in order to optimize the selection mechanism the improved algorithm introduces three parameters include the number id neighbor nodes, energy, and the distance between node and base station to correct threshold.

1. Considering the current residual energy of the node when select the cluster head, and the energy adjustment parameter is introduced.

$$T_1(n)=\begin{cases} S(i).E/E_{ave}, & \mathrm{S(i).E}>E_{ave} \\ 0, & \mathrm{S(i).E}<E_{ave} \end{cases} \quad (2)$$

Where is the current residual energy of the node i, is the average energy of all nodes.

2. The distance between the node and the base station is considered when select the cluster head, and the distance adjustment parameter is introduced.

$$T_2(n)=\begin{cases} S(i).\mathrm{dis}/\mathrm{Dis}_{ave}, & \mathrm{S(i).Dis}>\mathrm{Dis}_{ave} \\ 0, & \mathrm{S(i).Dis}<\mathrm{Dis}_{ave} \end{cases} \quad (3)$$

Where is the distance between node i and base station, is the average distance of all nodes.

3. The density of nodes is considered when select the cluster head, and the number of neighbor nodes adjustment parameter is introduced.

$$T_3(n)=\begin{cases} S(i).\mathrm{Node}/\mathrm{Node}_{ave}, & \mathrm{S(i).Node}>\mathrm{Node}_{ave} \\ 0, & \mathrm{S(i).Node}<\mathrm{Node}_{ave} \end{cases} \quad (4)$$

Where the number of neighbor nodes is, is the average number of neighbor nodes of all nodes. The improvement of threshold for LEACH-H is expressed as follows:

$$T(n)=[w_1T_1(n)+w_2T_2(n)+w_3T_3(n)]*p \quad (5)$$

Where w is the weight of the factors, its range is [0,1], w1 is the weight value of the residual energy of the node,w2 is the weight value of the distance between node and the base station, w3 is the weight value of the number of neighbor nodes, and $\sum_{i=1}^{3} w_i = 1$

Genetic Algorithm (GA)

An adaptive Genetic algorithm (GA) was introduced by J.Hollandfor usage as search algorithm [15, 16]. GAs successfully handled many areas of applications and was able to solve a wide variety of difficult numerical optimization problems. GAs requires no gradient information and is much less likely to get trapped in local minima on multi-modal search spaces. GAs found to be quite insensitive to the presence of noise. The pseudo code of the GAs method is shown in figure

```
begin GAs
    g = 0 generation counter
    Initialize population
    Compute fitness for population P (g)
    While (Terminating condition is not reached) do
        g = g + 1
        Select P (g) from P (g − 1)
        Crossover P (g)
        Mutate P (g)
        Evaluate P (g)
    end while
end GA
```

Fig. 1: Pseudo code for Genetic Algorithm

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The above problem is encoded via Gas within chromosomes which represent every possible solution. Fitness Functions investigate individual quality of each population members and these members undergo mutations and crossovers to recreate the next generation. Crossover functions create concatenated new solutions which are a part of two chosen chromosomes. Whereas a mutation is beneficial in overcoming local-minima entrapments and this continuous and repetitive process leads to an eventual solution.

Local Search

This is the basis of multiple combinatorial optimization methods especially in terms of Local search [17, 18]. This is a simple iterative method for searching good approximate solution and it is based on the trial and error method. For instance combinational optimization problem is described through(S, g) in which S signifies the set of every feasible solutions and g is defined as the objective function which can maps every element sin S to a given real value. The end result is finding a solution sin S which will minimize the objective function g.
The problem is visualized through the following equation:

min g(s), s S (6)

Where N represents the function of the neighborhood or problem format(S, g) where it is representedfrom S to its powerset by the given mapping format:

N: S (7)

N(s) is also symbolic of the value of the neighborhoodsand it contains each possible solution which is reached via a single move from s. The move represents operators who convert multiple solutions with minute changes. x then represents the solutions which is otherwise known as thelocal minimum of g with respect to the neighborhood N iff:

g(x)   g(y), y   N(x) (8)

The process of minimizing cost functions g or the Local search function is the successive steps in each of which the current solution x is being replaced by a solution y such that:

g(y) <g(x), y   N(x) (9)

Most local search begins with arbitrary solution and end with the selection of local minimums. There are multiple ways to conduct local searches and the complexities in local search computations are dependent on neighborhood set sizes and its approximate time required to evaluate moves. It is thus noted that neighborhood size grows in size and this effects the time required to search for it, in order to determine a better local minima.
Local Search uses notion of state space, neighborhood and objective function.

i.State space S: the set of possible states that can be reached during the search.
ii.Neighborhood N(s): the set of states, neighbors that during which can be reached from the state, s in one step.
iii.Objective function f(s): A value that represents the quality of the state, s. The optimal value of the function is achieved when s is a solution.

Pseudo code for Local Search is as follows:

```
Select an initial state s0€S
While s0 is not a solution D0
        Select by some heuristic, s€N(s0) such that f(s)>f(s0)
Replace s0 by s
```

Modified GA using Local Search

In genetic algorithm [19, 20], four parameters are presented. The size of the population, cross probability , mutation probability   and weight accuracy of influence factors . The figure 2 shows the flowchart for proposed method.

- Coding the chromosome according to the required accuracy.
- Initial population of weight values: By the size of the population and the length of the individual obtained and the initial population of weights can be obtained.
- Calculating the fitness value of chromosome combined by weight values.

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- Perform selection, crossover and mutation operators
- Perform local search operation
- If the new solution value generated by GA operators still can't satisfy the optimization condition, then go to 3). Else draw the optimal solution value

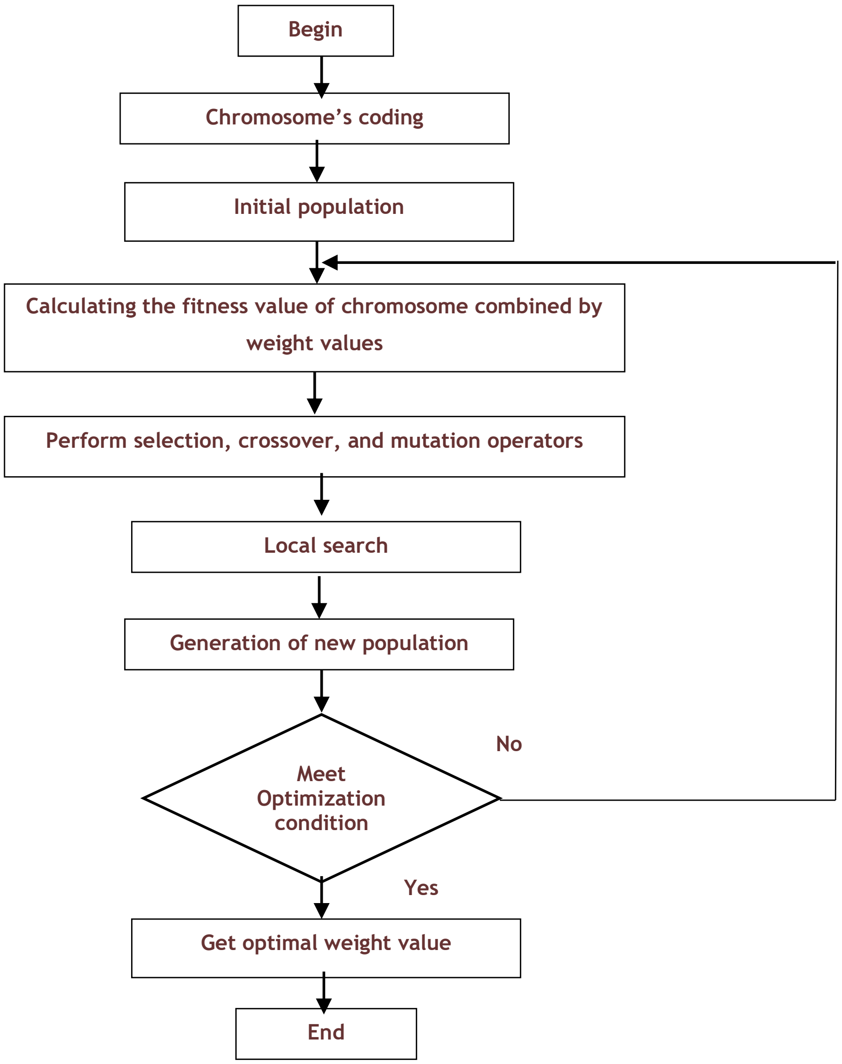

Fig. 2: Flowchart for Proposed Method

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RESULTS AND DISCUSSION

Table 1 to 4 and Figure 3 to 6 shows the results of number of clusters formed, average end to end delay (sec), average packet loss rate (%) and lifetime computation respectively. For experiments number of nodes considered is 100 to 600.

Observations from Table 1 and Figure 3 suggest that the number of clusters formed for GA and modified GA performs better than LEACH. When the number of nodes increases, the number of cluster formation also increases.The average of modified GA performs better by 3.15% than LEACH but reduces by 1.23% than GA.

Table 1: Number of Clusters Formed

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Number of nodes	LEACH	GA	Modified GA
100	10	11	11
200	15	16	17
300	26	29	26
400	34	33	34
500	32	35	34
600	39	39	39

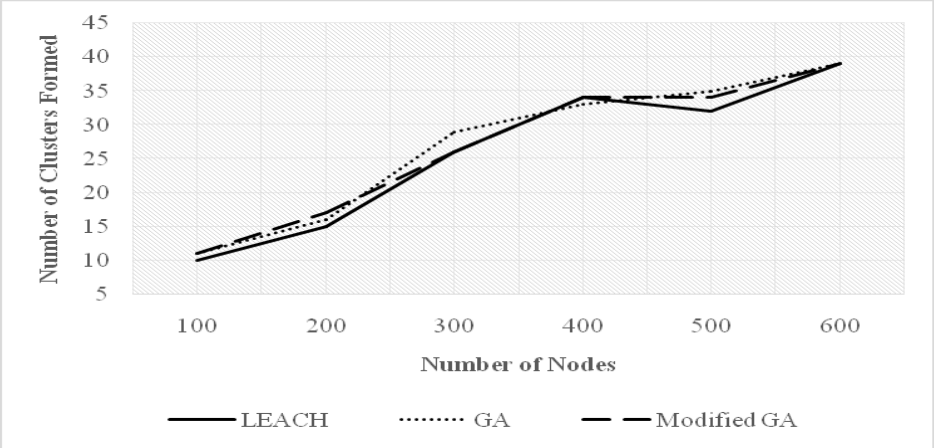

Fig. 3: Number of Clusters Formed

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Table 2: Average End to End Delay (sec)

Number of nodes	LEACH	GA	Modified GA
100	0.00157	0.00159	0.00141
200	0.00161	0.00157	0.00153
300	0.01604	0.0165	0.01455
400	0.02632	0.02551	0.0244
500	0.05805	0.05988	0.05246
600	0.06473	0.06066	0.05305

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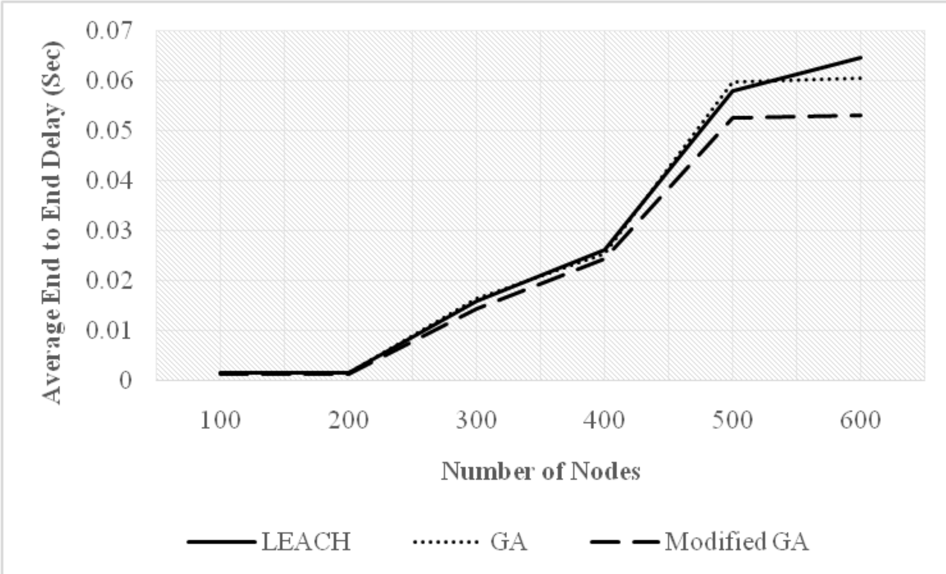

Fig. 4: Average End to End Delay (sec)

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Observations from Table 2 and Figure 4suggest that the average end to end delay for modified GA performs better by reducing the delay than LEACH and GA. When the number of nodes increases, the delay also increases. The average of modified GA performs better by 13.25% than LEACH and reduces by 11.69% than GA.

Table 3 Average Packet Loss Rate (%)

Number of nodes	LEACH	GA	Modified GA
100	11.07	8.77	8.35
200	17.64	13.75	13.47
300	18.19	13.26	12.63
400	23.01	20.88	18.25
500	31.99	26.9	24.57
600	43.89	30.73	28.89

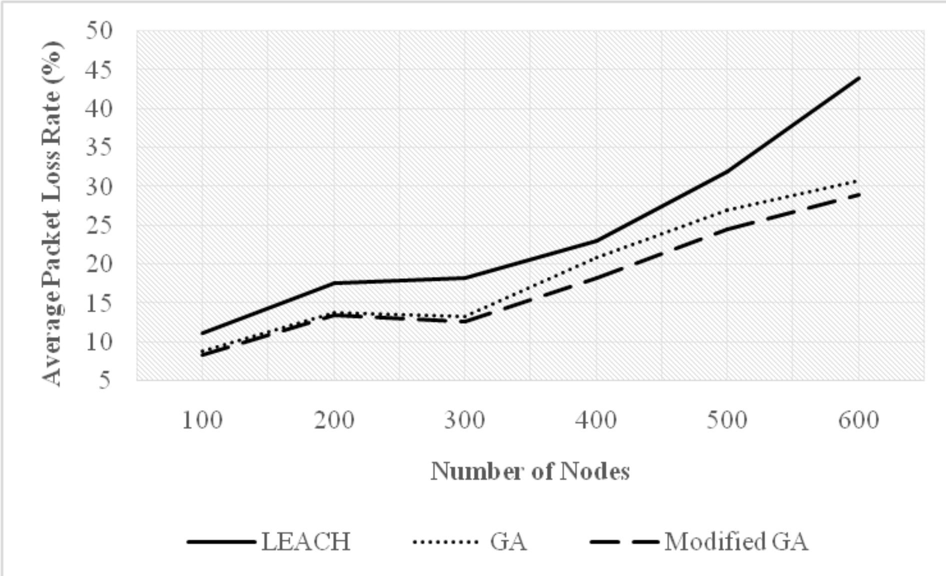

Figure 5 Average Packet Loss Rate (%)

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Observations from Table 3 and Figure 5 suggest that the average packet loss rate for modified GA performs better by reducing the packet loss than LEACH and GA. When the number of nodes increases, the packet loss also increases. The average of modified GA performs better by 31.46% than LEACH and reduces by 7.37% than GA.

Table 4" Lifetime Computation

Number of rounds	Percentage of nodes alive - LEACH	Percentage of nodes alive - GA	Percentage of nodes alive- Modified GA
0	100	100	100
100	100	100	100
200	87	94	96
300	74	89	91
400	41	75	79
500	24	52	61
600	2	22	35
700	0	7	18
800	0	0	7

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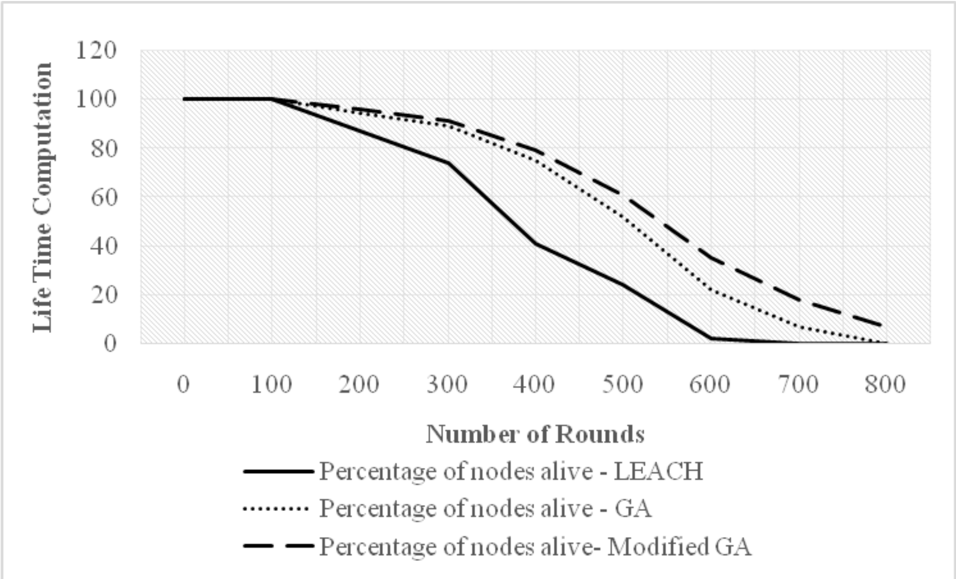

Fig. 6: Lifetime Computation

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Observations from Table 4 and Figure 6suggests that the lifetime computation for percentage of nodes alive - modified GA performs better by increasing lifetime than percentage of nodes alive -LEACH and percentage of nodes alive - GA. When the number of rounds increases, the lifetime computation decreases. The average of modified GA performs better by 31.33% than percentage of nodes alive - LEACH and by 8.53% than percentage of nodes alive - GA.

CONCLUSION

A generic procedure, clustering is most commonly used to reduce distance in communication and help preserve nodes energies. Since genetic algorithms(GA) is superior to traditional optimization methods for its simplicity to operate and high stability in solving combinatorial optimization problems, GA is applied to obtain the optimal solution of weights of every impact factors, enabling the network to use the node energy more efficiently and balance the overall energy loss of the network . Results show that the average end to end delay for modified GA performs better by reducing the delay than LEACH and GA. When the number of nodes increases, the delay also increases. The average of modified GA performs better by 13.25% than LEACH and reduces by 11.69% than GA. Similarly performs better cluster formation, lifetime computation and reduces packet loss rate in a better way.

CONFLICT OF INTEREST

The authors declare no conflict of interests.

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None.

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