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Effective Energy Optimization in Marine Networks Using Genetic Algorithm

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Abstract

In this paper, a low energy efficient hierarchical clustering and routing protocol based on the Genetic Algorithm (LECR-GA) for marine networks is proposed, which uses clustering and routing algorithms to efficiently intensify the lifespan and to enhance the quality of service (QoS) parameters. The proposed algorithm's operation divided into two rounds which extend the lifetime of marine networks by selecting the optimum cluster head (CH) and the shortest route for sending the aggregate data at a base station (BS) to save the energy. The efficient energy optimization is successfully achieved by using LECR-GA as the performance of LECR with GA protocol has remarkable abatement in terms of energy consumption rather than simple without GA. Network simulator2.35 is used to examine the performance of the LECR-GA protocol for marine networks in-terms of parameters such as delay, packets received at BS and throughput.

Keywords: *Energy optimization, Marine Network, NS2.35, , Routing and Clustering protocol.*

I. INTRODUCTION

The expeditious evolution in microelectromechanical systems (MEMS) led to an astounding rise in the utilization of wireless sensor networks (WSNs). These miniature sensor nodes are used in numerous applications like marine monitoring, agriculture monitoring, industrial monitoring, forest monitoring, smart house, disaster monitoring, weather monitoring and animal behavior monitoring [2]. Researchers discover the systematic way to overcome the considerable issues which WSNs are facing today like instant energy consumption and routing information in the network [3]. This paper proposed a LECR-GA protocol for marine networks to effectively optimize the energy, which intensifies the lifespan and enhance the QoS parameters of WSN [1]. Previously, oceanographic research vessels were hiring to sense the marine networks, which fetches more time that has an inexpensive resolution for both in time and space and a very expensive network. Recently, wireless sensor network (WSN) based technique can be used to sense the marine networks which can enhance the access to real-time information for a long duration as well as prodigious geographical areas, for monitoring the marine networks [23]. Even, there are enormous tiny sensors that are used to sense identical physical and chemical parameters, for instance, water's temperature, water's pressure, turbidity and PH in a WSN-based marine environment system [24] [25] [26]. The below Figure 1 depicts an architecture of marine networks which composes of five parts such as tiny sensor nodes, sink nodes or CH, a BS, a server and user terminals. Further, these tiny member nodes of the cluster can sense the environmental parameters such as salinity, water's temperature, water's pressure, and broadcast gathered information via wirelessly using wireless communication protocol to the sink node. There are usually point to point communications between member nodes of the cluster and a sink node or CH in the network. After that, the CH of each cluster in the network accumulates information from a group of member nodes and transfers the gathered information to the BS wirelessly. Moving on, the primary function of the server is to store and process the acquired information from the BS and user terminals connect internally with server and internet to share the information [15]. This paper is systematically organized in various sections as follows. Firstly, the literature review is presented in section 2. The recapitulation of GA is discussed in section 3.

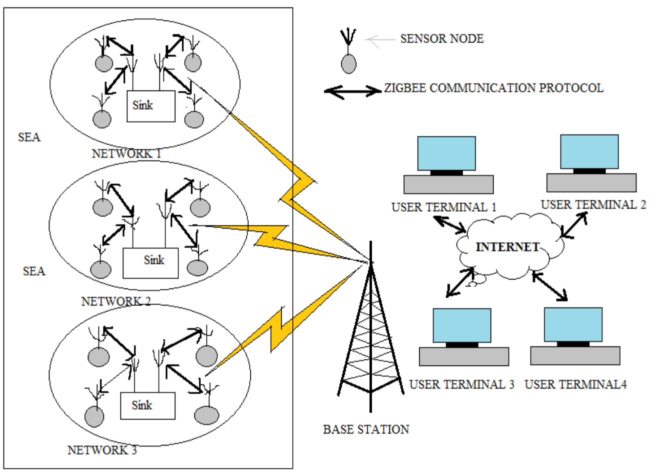

Figure 1: Architecture of Marine Networks [15]

LECR-GA based protocol is presented in section 4. Experimental results and analysis are presented in section 5. Lastly, the conclusion is given in section 6.

II. LITERATURE REVIEW

This section provides a comprehensive survey of contemporary success in this domain and identifies future research directions are as follows.

Awan proposed the communication technique of underwater challenges to enhance the network lifetime, QoS and to give future directions to researchers which are still not yet explored in the research area [19]. Iyer proposed GA based optimization technique for the positioning and deployment of underwater wireless sensor network (UWSN) nodes to maximize the lifetime of the entire network for effective communication [16]. Lloret demonstrated a group based UWSN to monitoring the accurate total quantity of fecal waste as well as uneaten feed which deposited on the seabed that can base the vandalization of the fauna and flora. This evolution took several factors such as several sensor nodes, network topology, communication technologies and distribution of sensor nodes. Jin proposed a water environment monitoring system based on WSN which can sense video information and monitor various water quality parameters such as water's temperature, water's turbidity using two wireless communication protocols like ZigBee and GPRS [27]. Xu analyzed an enhanced WSNMAC protocol for marine networks to reduce energy consumption and prolong the network lifetime using QoS parameters. Regan et al. introduced a real-time heterogeneous water quality monitoring and sensor maintenance using Zig Bee communication protocol with energy harvesting technique solar panel used to sense the parameters such as temperature, pH, turbidity and conductivity to monitor the water quality of marine environment [15]. Yang presented a multi-hop communication protocol to monitor the marine environment in terms of water temperature, salinity to reduce energy consumption and increase the lifetime of the entire network [28]. Hamidouche designed two algorithms, one for clustering and second for routing in WSNs. The clustering algorithm

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optimizes the energy which balances the lifetime of the CHs as well as member nodes of the cluster and reduces the energy depletion of the entire network. Further, the routing algorithm chooses the optimum route for transmission and the number of hop-count. Both the algorithms have been described with chromosome representation, and fitness function followed by the GA operations to prolong the lifespan of an entire WSN and enhance the QoS parameters in terms of first node dead (FND), last node dead (LND) and throughput [1]. Jha proposed twenty varieties of GA approach that have been applied to three energy models of WSNs to determine the smallest energy value during data communication from CH to BS. Moreover, the communication distance between the CH and a BS should be *(d)* $\geq 87m$ for the entire simulation [9]. Panhwar presented the two manners namely a deterministic manner where a multi-hop technique is used to send the aggregated data from member nodes to BS in the network and random manner where a single-hop technique is used to transfer the collected data at BS. Randomly, any individual node can send its data directly to BS which consumes more time as well as depletes more energy of tiny nodes as compared to the previous manner which is more effective in terms of time and energy [4]. Rodriguez analyzed MOR4WSN an algorithm based on GA for choosing the optimum number of sensor distribution. Here, GA operator is used in terms of three phases such as crossing, mutation, and initial population to increase the network longevity [7]. Song demonstrated an energy-efficient based multipath routing in WSNs for GA where multipath scheduling is used, which can significantly escalate the lifespan of a relay node network. Proposed work enhanced the network's longevity, reduction of energy consumption and packet delivery ratio [12]. Miao presented an improved LEACH that is LEACH-H protocol based on GA where the weight values of the three influencing factors effects the overall performance of the network. These factors are the current residual energy of member nodes, the total number of the neighbor nodes and the distance between nodes and BS [13]. Hussain analyzed the intelligent hierarchical clustering approach based on GA. This approach is more energy-efficient than traditional cluster-based routing approaches. Moving ahead GA is used to effectively produce energy-efficient clusters for routing in WSNs [8]. Zahhad demonstrated a new Genetic Algorithm-based Energy-Efficient adaptive clustering hierarchy Protocol (GAEEP) to efficiently maximize the longevity and stability period of miniature sensors by selecting the best CHs and their locations. The prime factor of this method is to minimize the consumption of energy which is used by sensor nodes and simulation is done with Matlab tool [11]. Bayrakli proposed a GA based energy-efficient clustering technique (GABEEC). The cluster-based approach GABEEC is compared with the existing protocol LEACH. GA uses its five-phase to escalate the lifespan of the entire network. Afterward, the whole process of the network is accomplished with two rounds. In the first round, the entire network is divided into clusters and each cluster has its own CH and member nodes are known as set up round. After set up round, the network is ready to transmit their aggregated data at BS is known as a steady-state round [5]. Bhondekar presented a node placement methodology based on GA in WSN. Subsequently, GA controls the entire system of tiny nodes to behave like active, operate, medium transmission range, low transmission range which is important as it consumes little energy for communication purposes. Proposed work having less active sensors is an advantage over larger energy consumption for communication purposes [6].

After a thorough investigation of the literature, it has been observed that the battery life of nodes exhausted more quickly with time in traditional algorithms. Moreover, researchers have not considered the situation of node failure during communication. Also, traditional algorithms can communicate within-cluster rather than intra-cluster communication. Based on research gaps, the following problems have been formulated:-

- LECR-GA protocol can be used to escalate the lifespan of member nodes of marine networks.
- We can consider the case of node failure during communication.
- The intra cluster communication can be used to reduce energy consumption in an efficient way which prolongs the lifetime of the entire network.

Whereas, all communication process in marine networks depends on the efforts of miniature sensor nodes and their battery powers. Therefore, the overall lifetime of the entire network depends upon the battery of sensor nodes. In marine networks, energy optimization is an effective way to use the energy of sensor nodes to reduce energy consumption while communication to inclined the lifetime of the entire network. Here, GA is used as an optimization algorithm in marine networks due to forthcoming reasons:-

- Multiple parameters are considered such as energy, distance to reduced energy consumption [7].
- Moving on, GA consists of five primary parts to increase the lifespan of marine networks and enhance the performance of quality of services (QoS) parameters such as throughput, packets received at BS, and propagation delay [19].
- Lastly, GA intensified the efficiency of marine networks comparatively existing algorithms [24].
- Moreover, the battery lifespan of GA is long-lasting as it survives the last round of the network [14].

III. RECAPITULATION OF GA

GA is a Metaheuristic optimization technique, which assembles fruitful outcomes in identical domains. Charles Darwin was a British naturalist who was proposed the theory of biological evolution by natural selection of small variations that increase the individual's ability to compete, survive and reproduce. Five phases in GA are:-

- Initial Population
- Fitness Function
- Selection
- Crossover
- Mutation [1]

These five phases of GA are discussed in the Figure 2:-

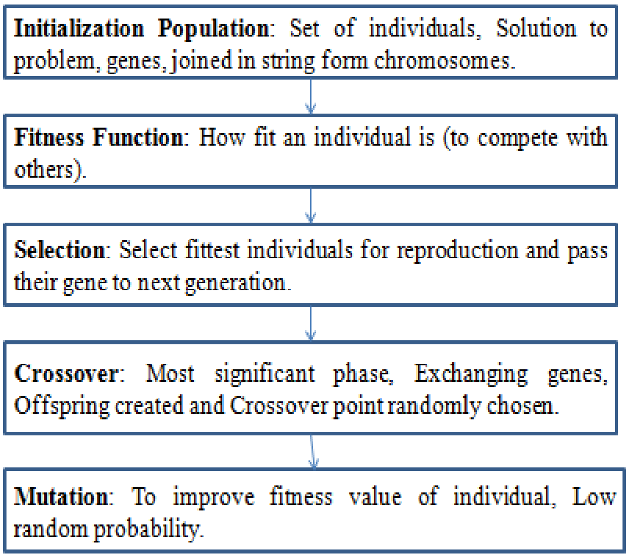

Figure 2: Flow chart of GA [1]

A. LECR Protocol Based on GA

This section presents the working of the LECR-GA protocol in marine networks. LECR-GA divides into two rounds shown in Figure 3 where the first round starts to divide the entire network into clusters and BS determines the location of CHs and assign member nodes of the cluster to each CH. Followed by the second round, where sensed information is transmitted to CHs and that information is gathered in frames then finally frames are transmitted to BS [19].

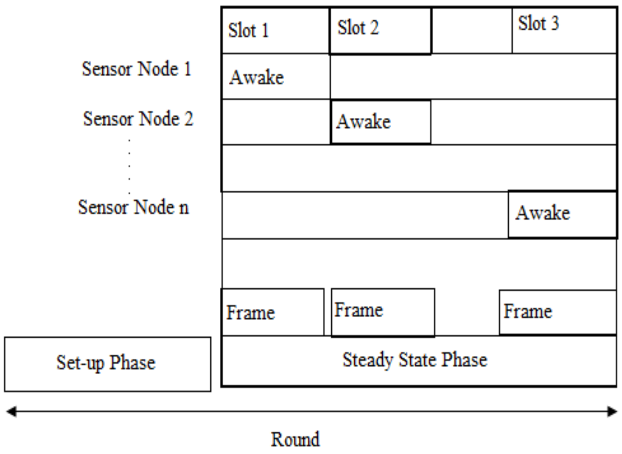

Figure 3: One round operation of LECR-GA [1]

The following assumptions are fixed about the network.

- The BS is a resource-rich device and excellent in terms of computing power and memory.
- The BS for the marine environment is located outside the network [20].
- After deployment, all tiny sensors and BS are moveable and tiny sensors have GPS location determination devices.
- Initially, all sensor nodes have the same amount of energy as a network includes homogeneous sensor nodes [21].

Mainly, LECR-GA protocol follows two algorithms such as clustering and routing algorithm which are discussed in forthcoming paragraphs [1].

B. Clustering Algorithm Based on GA

The clustering of nodes plays an essential role in preserving the energy of marine networks as well as its focus to transmit effective data at BS [3]. Also, clustering reduces the number of transmission to the base station (BS) so that the technique is more energyefficient for marine networks [4]. This algorithm provides a detailed discussion about Cluster head (CH) selection by using parameters such as chromosome representation, population initialization, performance evaluation; crossover and mutation operations are discussed below.

- **Chromosome Representation**

Each gene of the chromosome is the concatenation of two values that are residual energy and distance between the node and its neighbors [6].

- **Population Initialization**

The initial population is generated by a set of chromosome and the size of the string or chromosome depends on the number of live nodes in the network. It means the initial population can be indicated by live nodes in the network [1]. The calculation of the average energy E(average) after iteration is completed by equation 1 and table 1 depicts the average energy of the network.

$$E\ (avg) = E_{S1}+E_{S2}+E_{S3}+\ldots..+E_{SN}/N$$

$$E\ (avg) = \sum_{i=1}^{N} ESi/N \qquad \ldots\ldots.. (1)$$

Where Esi = the residual energy of the node, N = number of living nodes [7].

Table- I: Average Energy of the network [1]

Nodes	S1	S2	S3	S4	S5	S6	S7
Residual Energy (J)	0.014	0.01	0.012	0.011	0.011	0.015	0.018
Average Energy(J)	0.01322222						

- **Performance Evaluation**

After performing the previous step of the initial population, performance is evaluated according to energy criteria. According to Table I, if the residual energy of any node is more than the average energy of any cluster then that node can be a CH such as S1, S6, and S7 [11].

- **Mutation and Crossover**

As the clustering algorithm reaches the optimum for the first time, therefore, this step will not need either crossover or mutation. The probability of crossover (Pc) and the

Probability of mutation (Pm) are very small and neglect them in this case [17].

B. Routing Algorithm Based on GA

After cluster formation, the entire cluster space divides into four layers shows in Figure 4 that helps to choose the next hop to transmit their data according to the distance criterion which saves energy [11]. Then after, divide layers into regions such as North-East, North-West, South-East, and South-West that able to be choosing the next hop by energy criterion. Both divisions are done to reduce the energy consumption of the marine network. Once a grouping is completed, GA can apply on it and path construction with GA are operated in flow chart illustrates in Figure 5 [8].

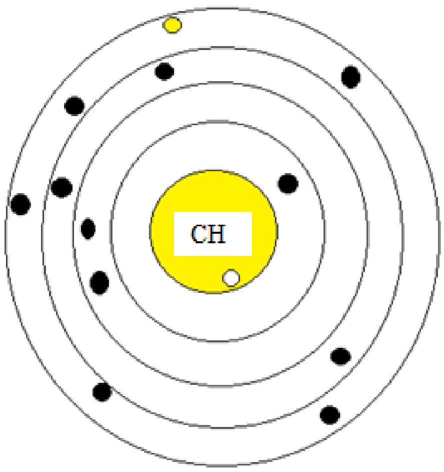

Figure 4: Cluster division in layers [11]

- **Cluster Division in Layers**

After finding the best CHs and their locations, "Tree Trunk Approach" is used. Divide the entire space of cluster into layers and the middle of the tree trunk is indicated by the CH. Here, the node closest to the CH is the nearest node and the node farthest to CH is the farthest node. This division is done to select the next hop according to the distance criterion [19].

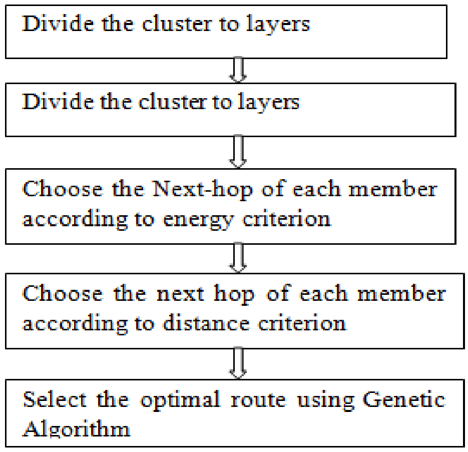

Figure 5: Path construction with GA [8]

- **Cluster Division in Regions**

After the first division, divide cluster space into regions indicates in Figure 6 to make a more appropriate way to find the next-hop by energy criterion which prolongs the lifetime of the entire network. The second division is used to choose the node having maximum energy [23].

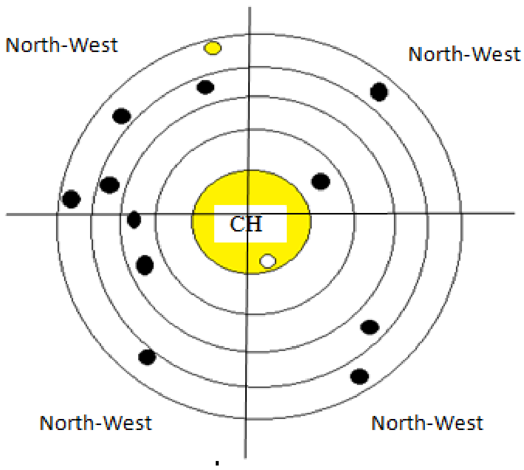

Figure 6: Cluster divisions in regions [23]

- **Determination of the next-hop by energy criterion**

In this step, next hop is present in the adjacent upper layer or in the same layer. If a node not

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verifying these conditions in the upper layers then CH will be the next hop.

Table II: Residual energy of nodes [7]

Nodes	S1	S2	S3	S4	S5	S6	S7	S8
Energy (J)	0.011	0.012	0.011	0.011	0.018	0.016	0.016	0.016

Table II, III and Figure 7 illustrates the next hop of nodes S1, S3 and S8 colored in blue according to energy criterion [7].

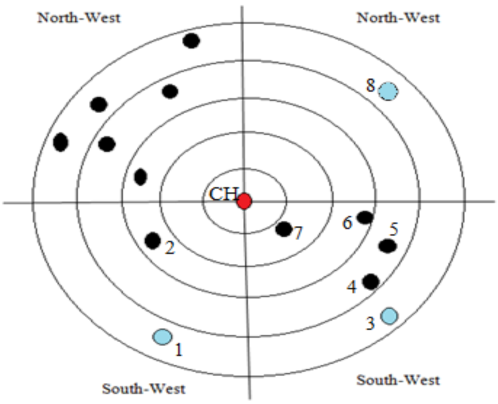

Figure 7: Next hop by energy criterion [7]

Table III: Next hope of nodes 1, 3 and 8 [7]

Nodes	S1	S3	S8
Next Hop	S2	S5	CH
Justification	There is no node in the adjacent layer and belonging to the same region	S5 has more energy than S4	There are no nodes in the same region

- **Calculation of the next-hop by a distance criterion**

Here, next hop in the upper layer is calculated by distance criterion means that the nearest node in the upper layer is chosen as the next hop [9]. The next hop is always the CH for layer L0.

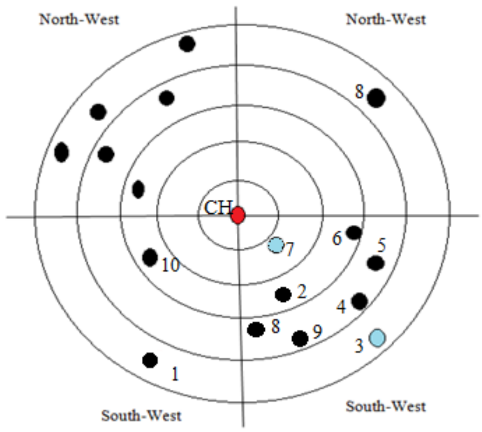

Figure 8: Next Hop by distance criterion [16]

Table IV: Distance of Five Nodes from Source Node 3 [16]

Nodes	S4	S5	S8	S9	S2
Distance	2	4	5	3	6

Figure 8 and Table IV illustrates the next hops of nodes 3 and 7 colored in blue are S4 and CH respectively [16].

C. Application of the GA in network

After finding the next hop by both criteria, GA can apply to determine the optimal path to reduce energy consumption while communication. Moreover, all basic steps of GA namely chromosome representation, initial population, crossover, mutation are as follows [3].

- **Chromosome Representation**

In chromosome representation, each tiny node transfers its collected information to CH directly if CH in the nearest node's range else information is transferred by the rest of the sensor nodes. The routing schedule of a South-East of the marine network is illustrated in Figure 9. Further, it shows the string in terms of path1 includes member nodes as well as CH used for chromosome representation. Every gene of chromosome indicates the identity of tiny nodes and the hops represent the size of the string. The South-East region of Figure 9 indicates the value of the gene in position 17 is 16 or 15 which shows that the node 17 choose

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the nodes 16 or 15 as the next hop of the cluster is dependent on two criteria [2].

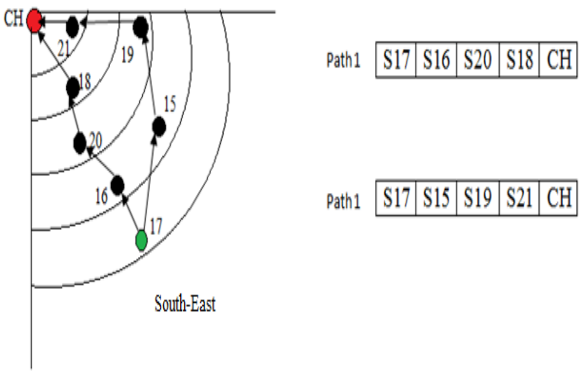

Figure 9: The two paths of node 17 [2] and Initial population of South-East pole of cluster 1 [2]

- **Initial Population**

In this step, each tiny node has two ways to send its aggregated information to the CH dependent on both energy and distance criterion. These two paths shown in Figure 9 are our initial population of the South-East region of the cluster [14].

- **Calculation of Distance, Hop, and Energy**

Distance is defined as the distance traveled along this path. Hop is the total number of hops that uses for transmission of data and energy is the total energy of nodes to form a route. Table V illustrates the calculated value of distance, hop, and energy [15].

Table V: The calculated value of distance, hop, and energy [15]

Routes	Route 1	Route2
Distance (m)	20	20
Energy (J)	0.038	0.047
Hop	4	4

- **Performance Evaluation**
- The below equation 2 is used to determine the performance of the above said two routes by fitness function [7].

Fitness Function = (0.04*Distance) + (0.02*Hop) + (0.94*Energy) …..(2)

Here 0.04, 0.02 and 0.94are constant used for the whole simulation process. Given equation 2 is used to minimize the fitness function as minimum fitness reveals that information proceeds through this route having minimum distance, very high energy and a reducing number of hops show in Table VI [8].

Table VI: Fitness of two routes [8]

Routes	Route 1	Route 2
Fitness	0.91572	0.92418

- **Crossover**

Crossover is the most significant phase in GA. A crossover point is selected randomly within the tiny nodes. New paths are established by interchange the nodes of clusters among themselves until the crossover point is reached. An example of a crossover at 1 point is shown in Figure 10 [12].

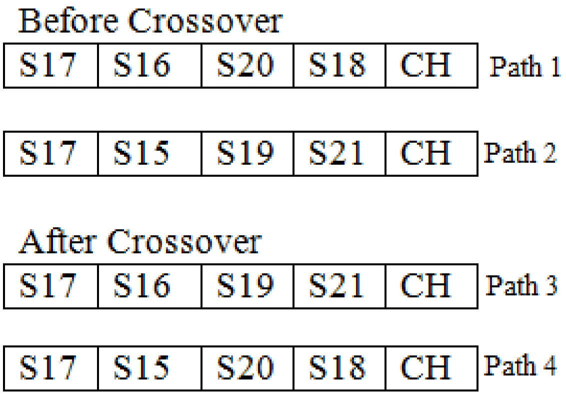

Figure10. Crossover at point 1[12]

- **Mutation**

The mutation is applied after the process of crossover to improve the fitness value of the individual node illustrates in Figure 11.

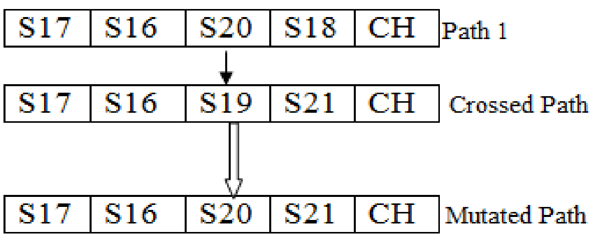

Figure11. Mutation at point 1[12]

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IV. Experimental Results and Analysis

In the results section, simulation is performed using Network Simulator 2.35 to analyze the performance of the LECR-GA protocol. For marine networks, where 117 nodes are randomly scattered within the 100*100m^2 area represents in Figure 12. Also, the packet sending rate is one packet per second. In this scenario, the entire network is divided into four clusters and one BS [9]. Each cluster consists of one CH that operates for transmission as well as the reception. The simulation parameters are summarized in Table VII.

TableVII: Simulation parameters

Parameters	Value
Tool used	NetworkSimulator 2.35
Network size	100m*100m
Number of nodes	117
The initial energy of nodes	2J
Protocol used	LECR-GA
Sink	1 (Node116)
Number of cluster heads	4

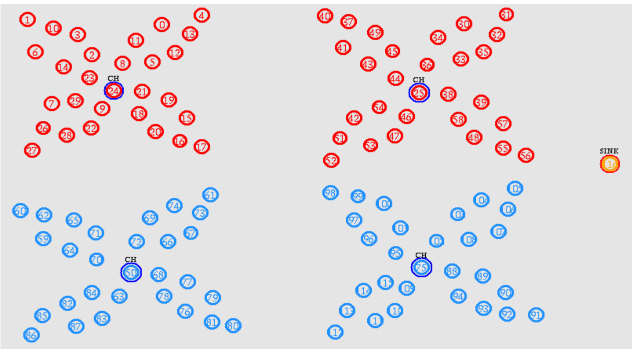

Figure12: Network of 117 nodes

Above mentioned Figure 12 represents nodes in two colors which are red and blue and BS (sink) in orange color. After deployed the network, we take two experiments shown below.

A. Experiment 1

In this experiment, firstly we design and simulate LECR-GA for Marine Network shown in Figure 12. After data transmission at BS, simulation results conducted in three QoS parameters such as average end-to-end packet delivery delay, packets received at BS and throughput. Simulation scenario runs 10 times and results are illustrated below in Figures 13, 14 and 15 respectively.

1) Propagation delay

Delay is the average time difference between the packets produce at the source side and packet received at the sink side. As it is evident from Figure 13, there is more than 75% no delay in total time. However, a delay occurs only for 5.5 seconds of total time. Therefore, a lower value of delay indicates improved performance as maximum packets are reached on time at BS.

2) Packets Received at BS

The performance of the LECR-GA protocol is examined in terms of the total numbers of packets collected by BS means that how much generated packets by source nodes are received at BS successfully. It can be seen from Figure 14 the curve depicts that, in the beginning, no packet is reached at BS with a certain time. Afterward, the curve abruptly inclined to reach its peak point and constantly high for 18 seconds means BS received maximal packets for entire simulation and the maximum value represents better performance.

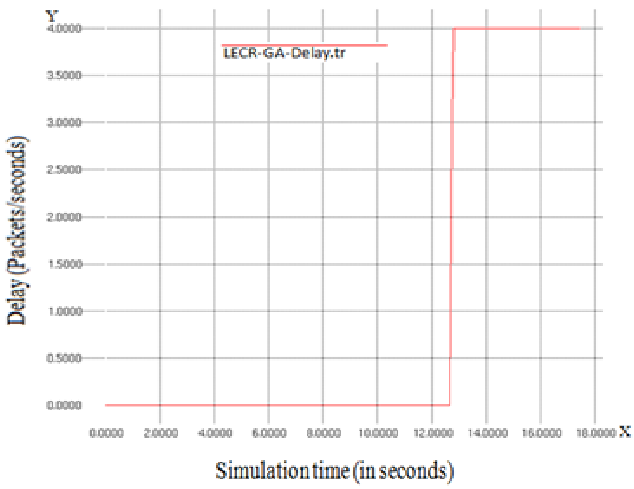

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Figure13: Delay of LECR-GA

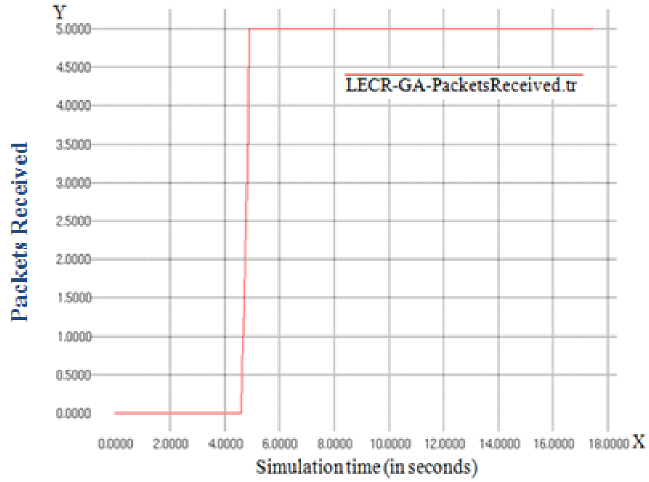
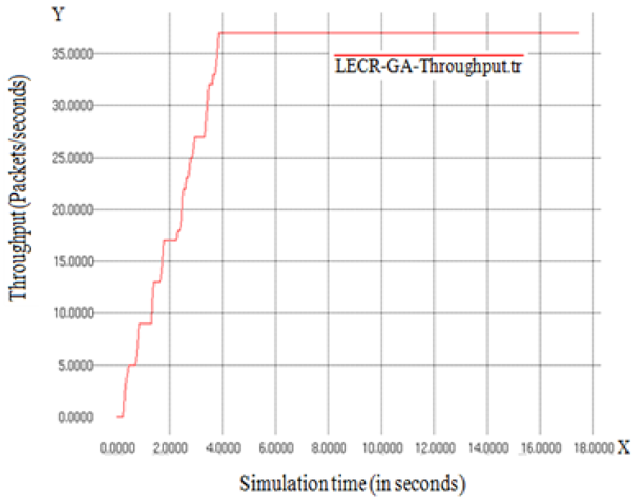


Figure14: Packets received at BS of LECR-GA

3) Throughput of LECR-GA

The throughput can be measured as the numbers of packets are successfully collected by the BS per unit time.



The graphical representation of throughput depicts that average throughput steadily inclined as time increases illustrates in Figure 15. The curve increases little by little as time increases and then maintaining the same level. Therefore, the constantly high value of throughput means maximum packets are received at BS that prolong the lifetime of the entire network.

B. Experiment 2

To analysis the performance of the designed network in case of CH failure. In the proposed network, when one CH is dead while communication, then the nearest node of that CH managed the whole responsibility of inter and intra communication of that cluster as nearest nodes have maximum energy to transmit their aggregated data successfully than farthest nodes. The simulation scenario in Figure 16 and result comes out in terms of Packets Received at BS, Average Delay, and Throughput that shown in Figures 17, 18 and 19. Further, the performance is evaluated in terms of energy consumption with GA and without GA illustrate in Figure 20.

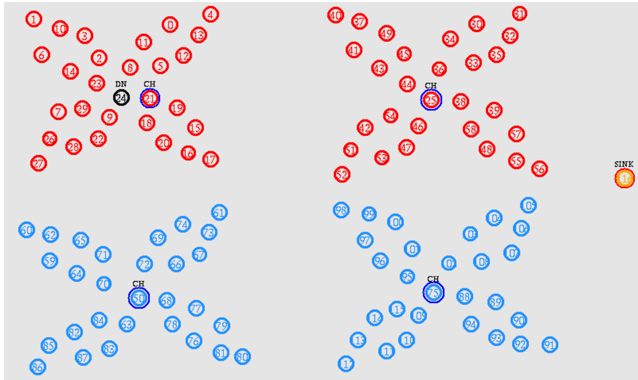


Figure16. Simulation scenario

1) Propagation delay

According to the aforementioned definition of average delay, Figure 17 reveals in the case of node failure that, initially there are zero delays for 25 seconds. After that, as time increases the curve sharply escalated for a few seconds. Then, there is constantly no delay for the entire time of the simulation.

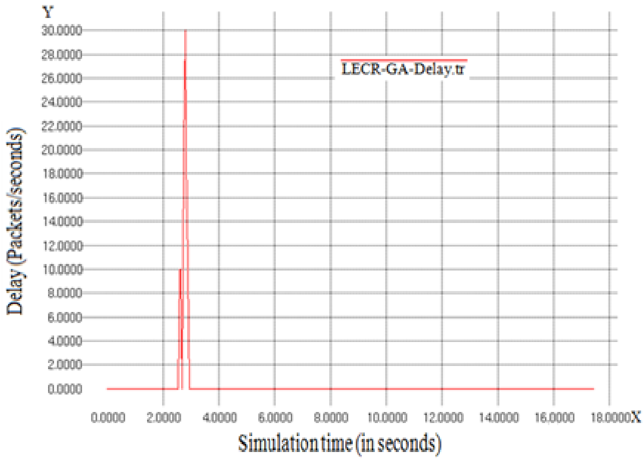


Figure17. Average end-to-end packet delivery delay

2) Packets Received at BS

In Figure 18 the curve depicts, no packets are received by BS for 15seconds of total time. Eventually, the curve fluctuates and quickly reaches its highest point and remains stable. To stay at the same level illustrates that extreme packets are received at BS.

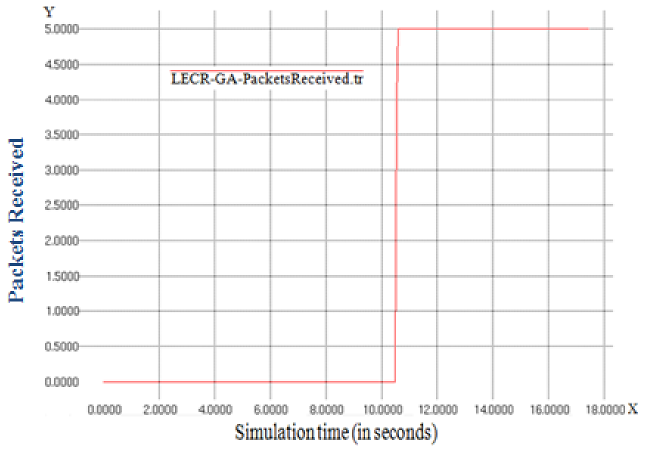


Figure18. Packets Received by BS

3) Throughput of LECR-GA

The curve in Figure 19 shows a steady inclination of throughput. At the early stage of time, throughput is zero and suddenly little change has occurred. The curve is slightly 20% rising and remains constant for 40% of total time. Again, it repeats the same level but the curve is significantly 80% rising and stable for the rest of the period.

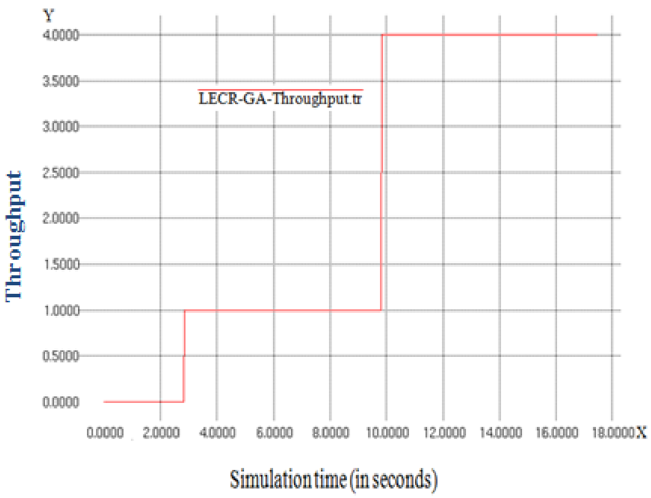


Figure19. Throughput

4) Energy Consumption with GA and without GA

The curve in Figure 20 depicts that the energy consumption of nodes in a marine network with GA and without GA. The curve in red color shows that LECR consumed 234J energy with 20% of total time. However, the curve in green color represents that LECR-GA consumed 234J energy for complete simulation time. It means that efficient energy optimization is successfully achieved by using LECR-GA as this protocol has remarkable abatement in terms of energy consumption rather than LECR. Although, one more reason to reduce the energy consumption is that, tree trunk technique is used by GA which helps to divide the network into four layers and regions

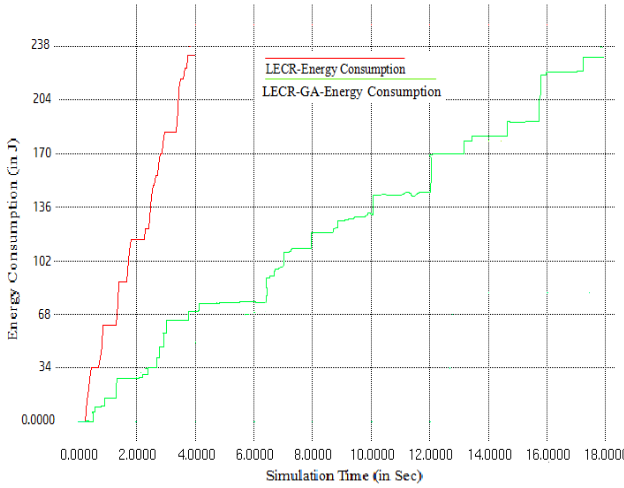


Figure20. Energy consumption with GA and without GA

V. CONCLUSION

In this paper, two algorithms are presented which are clustering and routing in marine networks. The clustering algorithm reduces the energy consumption of sensor nodes as well as balances the lifetime of CHs. The routing algorithm selects the shortest path for transmission to save energy. Further, both algorithms are described with five prime phases of GA operations. The proposed protocol LECR-GA consumes less energy than LECR. The experimental results carried out in NS2 have shown that the performances of proposed algorithms in terms of QoS parameters are better. The less delay, maximal packets received at BS and higher throughput reduces the energy consumption and prolongs the lifetime of marine networks.

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Our future attempt will consider the energy-based optimization for marine networks and combine this algorithm with other bio-inspired techniques and evaluate their performance for marine networks. In marine networks, stationary tiny nodes are unmanageable and its continuous fluctuation would increase the energy consumption of the tiny sensor nodes. Therefore, coming directions needs to be the focus on the network's longevity and gradually diminish the energy of miniature nodes are considerable matters.

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