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Design and Construction of Reliable Energy Efficient Routing Protocol for Wireless Sensor Networks using Elephant Herding Optimization Algorithm

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Abstract— **Design of energy efficient routing protocol for Wireless Sensor Networks (WSN) has been one of the most challenging issues with the escalation of lifetime of sensor nodes in scalable network environments. Implementation of low energy adaptive clustering hierarchical routing algorithm is adopted in WSN for sustainable network environments with more residual energy in each node. Elephant Herding Optimization (EHO) is a type of swarm-based metaheuristic search algorithm deducted from the behavior of elephant clans where in each elephant clan with one adult female matriarch considered as leader of the clan with all the male elephant calves till male elephants separated from the clan after reaching their adulthood. In this paper, energy aware routing algorithm for cluster based WSN with IPv6 addressing is proposed using EHO algorithm for solving optimization problems. There are two major parts in EHO, first the clan updating and next the separation mechanism. The node localization problems reported with the query of sensor nodes, issues with routing and network coverage. The algorithm is based on Cluster Head (CH) selection and cluster formation using EHO. The proposed algorithm is focused on residual energy of the cluster heads during data routing process. The experimental results demonstrate the performance of EHO algorithm in terms of network life-time, energy consumption and scalability of the networks.**

Keywords— **Elephant Herding Optimization (EHO), Swarm Intelligence, Wireless Sensor Networks (WSN), Node localization problem, Metaheuristics, Energy Optimization.**

I. INTRODUCTION

Wireless Sensor Networks (WSN) are known to be susceptible from different energy consumption issues and enormous algorithms are devised so far for the escalation of lifetime in the sensor nodes and overall network environment [1]. Low-energy adaptive clustering hierarchy (LEACH) routing is one of the classical approaches that are adopted in many wireless implementations along with the variants of LEACH so that the network environment can be run for long time with more energy in the nodes [2]. Use of IPv6 for WSN has advantages with addressing scheme, high security with QoS services [3]. Montenegro et al. (2007), Hui and Thubert (2011), Shelby et al. (2012) as per specifications of IETF showed the use IPv6 in WSN [4-6]. Wang et al. (2012) proposed Elephant Herding Optimization algorithm (EHO) that is based on herding behavior of elephant clan using clan updating and separating operators [7-8]. Elephant Herding Optimization algorithm (EHO) uses the herding behavior of elephant clans [9]. Elephants from different clans can live together under the leadership of the most senior female elephant called matriarch, and at the same time, the male elephants need to leave their clan on reaching their adulthood. Clan updating and separating operator are the two main behaviors of EHO used for creating routing model. The elephants update their current position with reference to the behavior of matriarch using clan updating and separating operator [10]. EHO algorithm can be used for solving node optimization problems [10–13]. Ismaeel (2019) updated EHO to converge the origin of the basic EHO architecture to find the best routing among nodes and cluster heads [9]. This paper has been organized with following sections. Section 2 talks about different relevant literatures to generate the ideas for the formation of EHO model. Section 3 explains proposed EHO algorithm. Section 4 shows the performance of EHO on simulation results, and Section 5 offers possible directions for future work and conclusions of the study.

II. Literature Review

The most significant challenges in the design of Routing protocols using IPv6 depends on the survival of nodes in the networks and limiting the use of the batteries of each node [1]. Using IPv6 without compressing of header may lead to the consumption of more energy and shorten the lifetime of nodes in WSN [14]. The use of compression algorithm for the applications of WSN using IPv6 can help to minimize the energy consumption and maximize the lifetime with the use of inter-cluster routing. The algorithm with separate inter-cluster and intra-cluster routing can be useful for increasing energy efficiency in case of the use of IPv6 addressing [15]. EHO algorithm, type of group of swarm intelligence metaheuristics, can be used for design of routing protocols for WSN using IPv6. For improvement in the span of energy in nodes of WSN, a novel and energy efficient approach of population-based optimization is introduced using EHO [8]. In this approach, the behavior of the elephants in selecting their heads is adopted to form the dynamic cluster head in WSN. Wang et al. (2015) studied metaheuristic elephant herd optimization (EHO) algorithm for WSN. EHO exhibits better performance in comparison with other metaheuristic methods and provide suitable solutions for searching nodes for various routing operations [7-10]. The performance of the EHO algorithm has been significantly improved without fitness evaluations and additional operations [8]. Meena et al. (2018) identified a multi-objective improved EHO algorithm to handle distributed energy resources (DER) which can tackle problems of distribution systems by joining the method for the arrangement of nodes [16]. Correia et al. (2018) proposed modified metaheuristic algorithm of EHO to address localization problem in WSN for the energy-based sources. The model provides solution about the energy issues between sensor nodes for the optimization of EHO algorithm [17]. Jayanth et al. (2019) used EHO to handle the optimization issues [18]. Jafari et al. (2018) explained the new hybrid algorithm in the name of the elephant herding optimization cultural (EHOC) algorithm with the modification of EHO with cultural algorithm (CA). CA is required to modify the standard EHO Model using separating operator to create new local search optimum space. EHO, EHOC and CA algorithms can be used to assess the performance of routing and it is observed that EHOC can be used to increase the rate of convergence viably and can provide suitable result compared with CA and EHO [19]. Rashwan et al. (2019) carried out experiments with standard testing measures of WSN for analyzing the impact of the control parameters to enhance and optimize the performance of EHO [20]. Different scholarly articles proposed many variants of EHO and explained the use of routing protocol based on IPv6 for WSN [21]. In our study, WSN routing method is proposed for IPv6 using EHO for hierarchical clustering and selection of cluster heads using EHO. The clustering for WSN and cluster head selection involves many indicators including power consumption of nodes, number of hops, cluster head selection and types of nodes in cluster.

III. Energy Aware Routing using EHO

Inspired by the herding behavior of different types of elephant members in elephant clans for the solution of node and path optimization problems in WSN, Wang et. al. (2015) proposed Elephant Herding Optimization Algorithm (EHO) [7-9]. The energy optimization is quite a big domain that is under research and still huge energy loss scenarios occur in the wireless sensor networks. The property of leadership of a matriarch and nature of the behavior of female elephants and calves belonging to different clans living together without male elephants has been used in EHO. Male elephants need to leave their clan after reaching their adulthood. The elephants update their present position as per direction of matriarch through clan updating operator and removal of male adult elephants from the clan using the separating operator. The methodology to implement Elephant Herd Optimization algorithm (EHO) with the behavioral analysis of the elephants is proposed for the selection of matriarch in their herd. The EHO algorithm can solve the issues of optimization problems and the herding behavior of the elephants can be modeled as, (1) each population is composed of clans with the elephants of fixed numbers in each clan, (2) for the new generation, adult males need to leave their clans and live far away, (3) the elephants can stay together under the leader called a matriarch in each clan. Different operations in EHO are performed by the clan updating operator and the separating operator. The herding behaviors of EHO model depends on (I) Clan updates, (II) Separation of adult male elephants, (III) Clan modification and formation. In each clan, other female elephants live under supervision of matriarch which has been compared with the cluster head in WSN. The position of clan elephants is influenced by the positions of the matriarch, Similarly, cluster formation follow same procedure of clan formation and update of clusters depends on cluster head which is studied by the behavior of matriarch. There are three possibilities for routing messages in EHO where RSS is the signal quality received by head of the cluster from its node, (1) all single hop packets propagate routing information to help member nodes for choosing their cluster head as per RSS, (2) all multi-hops packets can limit the number of heads and help the member nodes for the selection of the cluster heads to reduce the total number of hops of the network, and (3) mixed packets to decide the utilization of single hop or multi-hops for the communications from the lower bound of RSS [22]. Routing depends on swarm intelligence of EHO where elephant swarms involves several sub-warms called clans, consisting of claves and female elephants which is used for cluster formation. Every clan is under the supervision of matriarch and under supervision of matriarch the clan is managed which is adopted from the behavior of cluster for the formation of cluster head. In any clan, whenever any male calf reaches to adulthood it leaves the clan, similarly if any node is not capable of routing it is not involved in cluster and cluster organization changes accordingly [23]. The role of elephant herding is based on the behaviour of matriarch and male elephants in each clan. The use of clan updating and separating operators can help in Routing in EHO. In EHO, each elephant needs to change or update the position based on its current position and position of matriarch. EHO is characterized by a strategy of decomposition of population to sub-populations (clan). First, an initial population of P elephants has been randomly generated. Elephants are arranged by their fitness value and the entire clan population is divided into sub-populations (nClan) with the goal of each clan C_i containing N_i elephants. Second, inside every clan C_i, to improve all elephant in C_i with clan updating operator an evolution process is applied by the use of separating operator to replace only the worst elephant in each clan C_i. All the elephants in all clan are combined (mixed) and reordered looking at the properties of the clan.

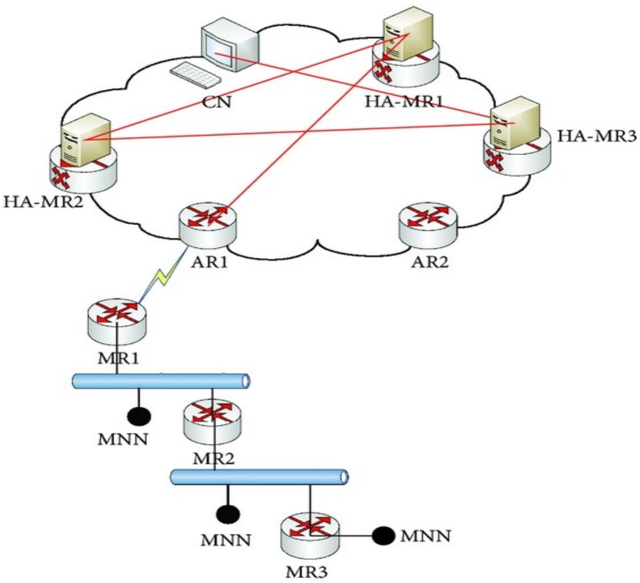

Fig. 1. Formation cluster

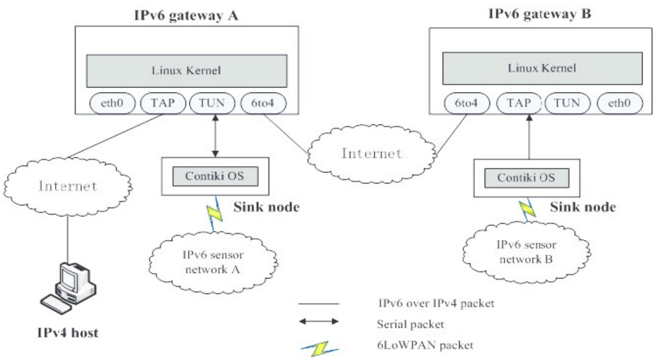

Fig. 2. Formation of IPv6 Gateway

According to EHO, the sending of data packets needs to be routed through MR's home agents with encapsulated packets send to MR (shown in Fig. 1). After upper MRs routed as per the structure of the nested tree, encapsulate packets reach the management of AR where IPv6 gateway helps to find the routing for IPv6 packets (shown in Fig. 2).
EHO can be used for designing topology of WSN with clan updating operator for updating the node positions based from its current position and that of

the cluster head (shown in Fig. 3) as per the properties of matriarch in the respective clan. Subsequently, the worst elephant can be removed from the clan which can accelerate the speed of convergence and significantly improve the population diversity. Moreover, elitism strategy is incorporated into the EHO method, intended towards choosing the best elephant from the position and properties of updating operators.

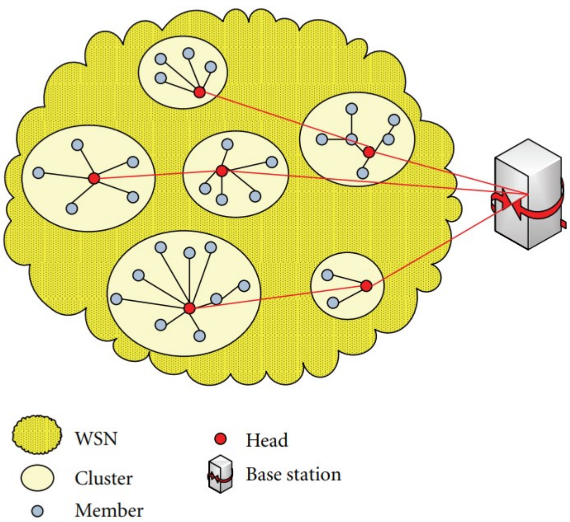

Fig. 3. Formation of cluster Head

A clan (family group) comprising females and calves (as shown in Fig. 4), where all the females prefer to stay in clan and subsequently male elephants need to leave the group on reaching the adult hood. All the individuals in the clan pay full attention to the calves that are generally the Centre of a family group. The entire population of elephants is made of some groups called clans with same and fixed number of elephants in each clan. In the simplest form, each clan has exactly equal and fixed number of elephant individuals. The basic EHO can be explained by following rules (Fig. 4-6):

1) Elephants from various clans can remain together where each group led by matriarch with fixed number of female elephants and calves. There are same sorts of groups of families consisting equivalent number of elephants.

2) The conduct of EHO models are based on the updating operator. The positions of each elephants in each group are based on relationship with the matriarch.

3) On reaching adulthood, male elephants must leave the clan using a separating operator. In the process of updating EHO models for each generation, a fixed number of male elephants on reaching adulthood need to be removed from clans.

4) Matriarch, the eldest female elephant, considered to be the fittest in the clan considered for the selection of cluster-heads for optimization problems.

In general, the matriarch can be visualized as the fittest elephant individual in this clan for optimisation problem. The highest level of element in the elephants in terms of higher age factor is the matriarch elephant that becomes the head or leader or cluster or group in the clan. High Energy Cluster Head is analogous to Matriarch Elephant that follows the process like the formation of head in the clan of elephants. Based on the highest energy and more lifetime, the cluster head (shown in Fig. 3) is selected so that the overall scenario or network can be preserved for highest time span.

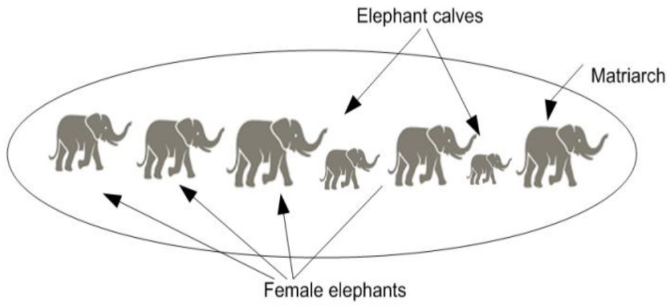

Fig. 4. Structure of clan

The Approach of Elephant Herd Optimization algorithm (EHO) is used for the optimization of result.

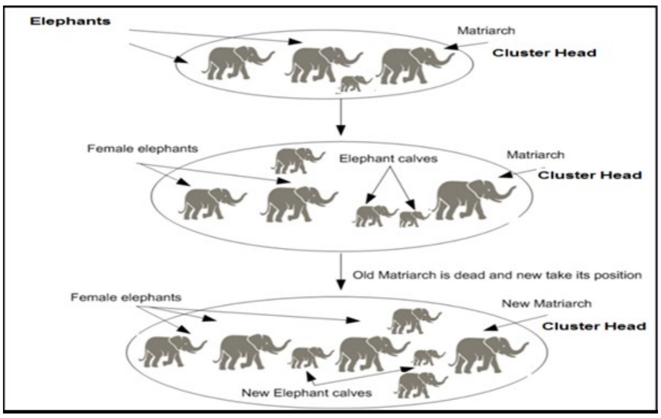

Fig. 5. Behaviour of Elephants in the Clan for Selection of Cluster Head

EHO is one of the prominent metaheuristic approaches which can be used for global optimization of results and selection of Cluster Head. Elephants swarm groups consists of several sub-groups, called clans, comprised of female elephants and calves. Every clan behavior changes as per the supervision (leadership) of a matriarch (female adult elephant). The group is initially divided into k clans. The role of matriarch with other elephants needs to be defined in clan c_i, for the finding of its next position as per the direction and influence of matriarch c_i. After sorting elephants, the clan updating operator is applied according to their fitness. In each i^{th} clan, the member j can find the next move with the best fitness value according to the elephant matriarch, c_i,

$$x_{new,ci,j} = x_{ci,j} + \alpha\,(x_{best,ci} - x_{ci,j})\, r \tag{1}$$

The movement of adult male explained by role of the worst element in each communication and the position of the worst elephant in ith position is

$$x_{worst,ci} = x_{min} + (x_{max} - x_{min} + 1)\, y \tag{2}$$

where x_{max} and x_{min} is the upper and lower bound value for each node respectively.

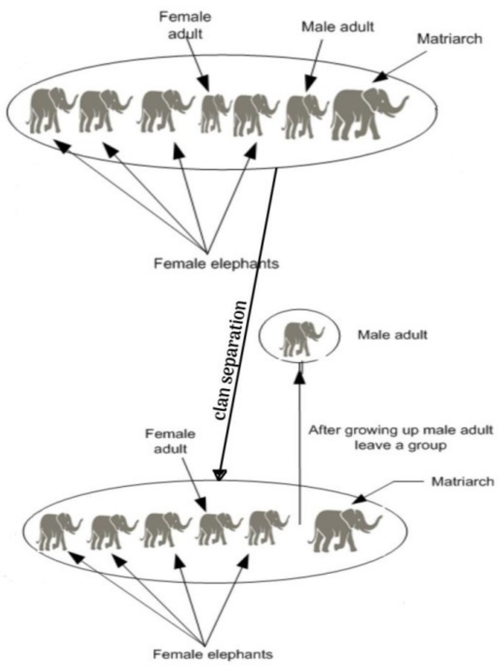

Fig. 6. Formation of clan after separation

Elephant herding optimization algorithm (EHO) is considered as a novel metaheuristic nature-inspired swarm intelligence optimization algorithm have following two operators:

1) CLAN OPERATOR

Under the leadership of a matriarch, each female elephants and calves can live together in each clan. In this manner, each elephant of group finds the next position based on the role and influence of matriarch.

2) SEPARATING OPERATOR

The elephant herding optimization algorithm (EHO) could able to identify the investigation affected by the unjustified convergence due to the update operator and towards the origin the exploration/exploitation trade-off. Based on the behavior of EHO, the following steps are proposed:

Step 1: Identification of sensor nodes with the segmentation of the type of nodes. This is analogous to the evaluation of elephants in EHO. Each sensor nodes act as the elephant and the EHO optimization initiates.

Step 2: Based on the types of the sensor nodes and its current energy level, the best fit sensor is fetched to form the cluster head on its current energy and historical records. This is like the extraction of Matriarch Female Candidate in the Elephants Clan.

Step 3: The iterations process initiates with the lifetime of network and regularly checking the life of each node and current energy level. The specific nodes are used to keep track on the information of each node with the cluster association. The optimization parameters for Female and Male Objects are set.

Step 4: The cluster head is used to maintain the group of nodes in its cluster or clan. Female Candidate from Elephant Herd leading the group deemed as Cluster Head.

Step 5: The use of common identifier to each node is done so that the demarcation between normal node and cluster head or clan head can be done. The matriarch is used to identify the group head.

Step 6: The destination node is identified by the cluster head or elephant head in the EHO. This is done so that the authenticated nodes can be having access to the private signals. In case of any sniffing, the packet or signals are rejected by the elephant

head or cluster head so that higher security and minimum energy loss takes place.
Step 7: The integration and maintenance of routes is decided by the cluster head so that only authenticated path can be set and decided by the cluster head.
Step 8: The shortest path with higher degree of security is selected by the cluster head to achieve the performance and minimum energy decay. The refining of results using EHO and Threshold Analysis initiates with the process of error removal using fitness score.
For the sensor node localization problems in WSN, EHO is combined with TGA (tree growth algorithm). Successful utilization of the tree growth algorithm (TGA) approach in the swarm intelligence metaheuristics of elephant herding optimization (EHO), the multi-stage node localization problem has been addressed indicating the energy status of the mobile sensor nodes for analysis of the behavior of node.

IV. PERFORMANCE ANALYSIS

The performance measures of the new proposed EHO routing algorithm has been compared with generic and modified LEACH Routing protocols for the calculation of throughput, packet delivery ratio, energy consumption, delay and lifetime. The parameters for simulation are stated in Table 1.

Table I: The parameters used in the simulation

Parameters	Value	Parameters	Value
Size of target area	100 x 100 m^2	Data packet size	512 bytes
No. of sink nodes	5	Metadata packet size	25 bytes
No. of sensor nodes	95	Maximum radius, R	20m
Initial Energy	10 J	α_1	1
Transmitting energy	50 nJ/bit/m^2	α_2	1
ξ_{elec}	50 nJ/bit	α_3	1
e_s	100 nJ/s	α_4	1

The network simulator helps to study the behavior of the proposed routing protocol. Using proposed routing protocol, data routing is calculated at constant bit rate (CBR) and residual energy of each mobile nodes help to find packet delivery and lifetime of nodes. The result is analyzed based on the simulator results. The parameters are set as per the values chosen for the experiments. The outcome is determined based on the simulation results.

Fig. 7, 8 shows the average path length increases with the increase of scalability where Fig. 9 demonstrates the average number of packets in scalable networks. Fig. 10 shows the lifetime of the network and Fig. 11, 12 compared the performance in terms of PDR (packet delivery ratio).

The result shows the improvement in terms of scalability, packet delivery ratio and network life-time of nodes in WSN.

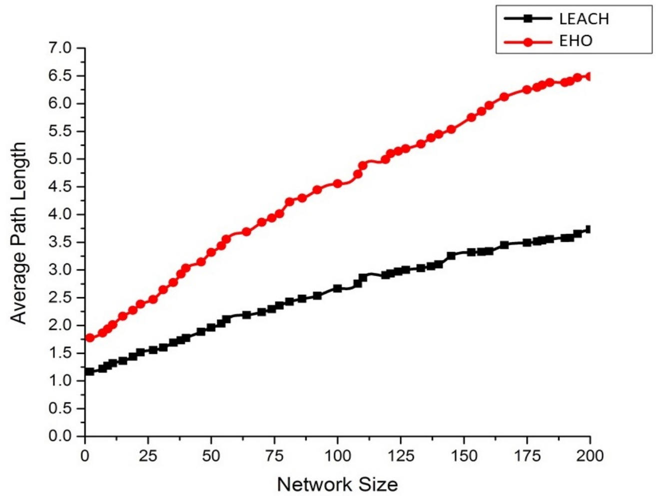

Fig. 7. Average Routing Path in Scalable Network

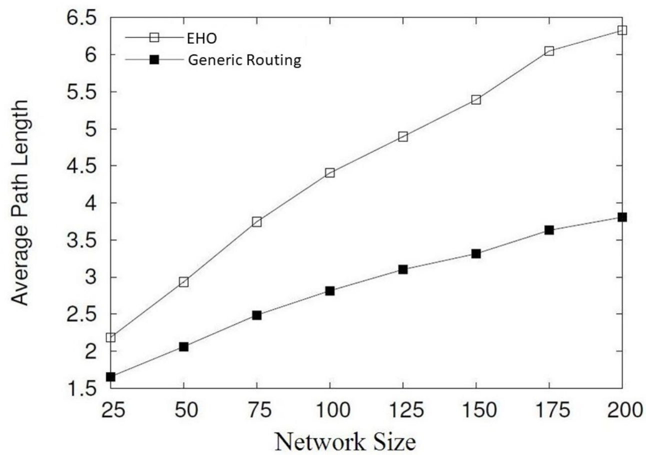

Fig. 8. Average Routing Path in Scalable Network

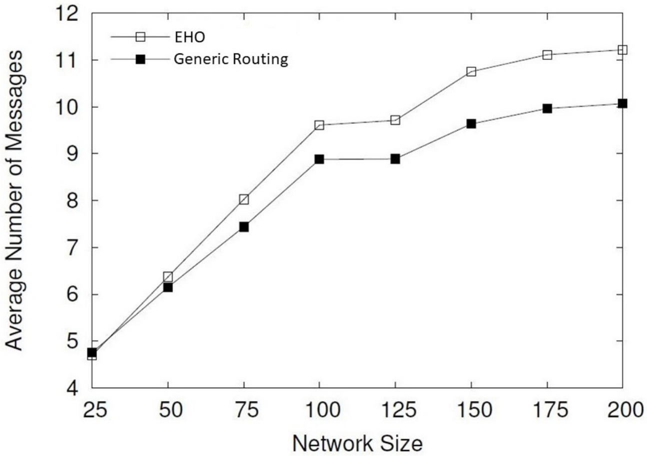

Fig. 9. Average Packets in Scalable Network

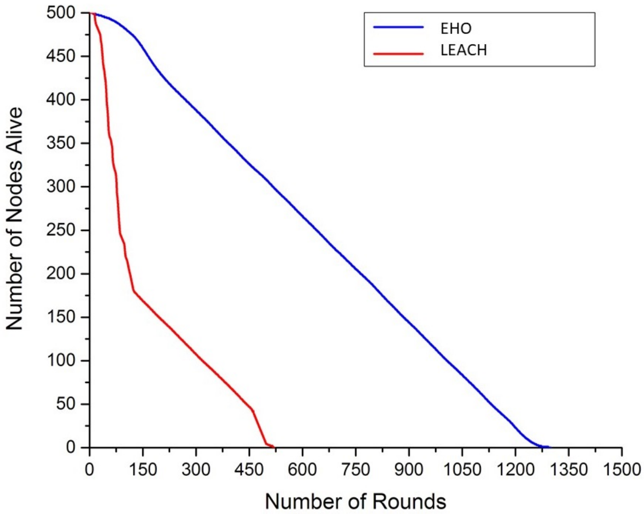

Fig. 10. Network life-time after different stages of Routing

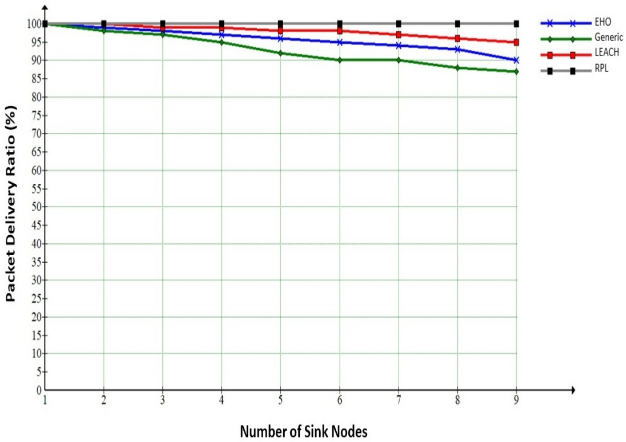

Fig. 11. Performance (PDR) with increasing sink nodes

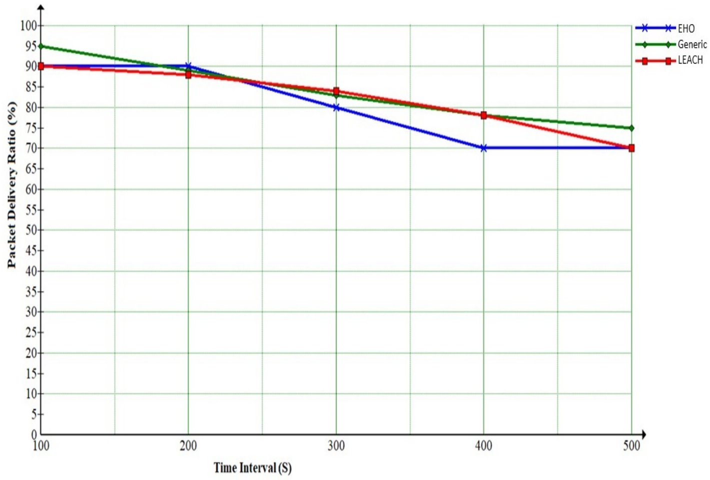

Fig. 12. Performance (PDR) after time interval

V. Conclusion and Future Work

In this work, EHO based routing solution has been discussed with localization in WSN. The approach of using metaheuristics for localization and maximum likelihood has been discussed by approximation method. EHO algorithm has been used first time for Routing in WSN using IPv6. Using simulators, the key parameters of routing in WSN using EHO algorithm have been optimized so that energy issues between sensor nodes can be solved. The performance analysis between EHO and LEACH has been discussed and shows that the proposed algorithm has reduced computational complexity compared to existing non-metaheuristic methods. The performance can be further enhanced with congestion control in routing which can be the future work of this model.

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