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Cluster Based Data Aggregation in WSN Using Swarm Optimization Technique

Bharathi M.A, B.P. Vijayakumar, D.H. Manjaiah

Abstract*— The area of wireless sensor network has been researched for more than a decade ,but no better solution is yet found for retention of cumulative lifetime of the network. Hence, after digging down the possibility of performing energy optimization, this paper is based on potentials of biologically optimized algorithm targeting the lifetime of network. The paper introduces a newly designed algorithm (Elephant Swarm Optimization-ESO) that is based on unique cognitive and social behavior of elephant, where it was strongly felt that adoption of their patterns in social behavior can highly be formulated in the area of energy optimization in wireless sensor network. The proposed algorithm is empirically designed in Matlab and simulation results were compared with frequently used LEACH protocol, to observe that the proposed ESO protocol outperforms LEACH on the basis of network lifetime, packet delivery ratio and residual power.

***Index Terms*—Bio-inspired algorithm, Energy Optimization, First Node Death, Wireless Sensor network.**

I. INTRODUCTION

Many artifacts have been built throughout history, and many of which have obtained their inspiration from phenomena in the natural world. It is noted that "progress often occurs at the boundaries between disciplines." [1] In the field of computer science, especially in artificial intelligence, there is growing interest in parallel-distributed intelligent theories and approaches that are inspired by the principles of nature and that can solve difficult problems. Bio(logy)-inspired approaches are probably the best known examples of such nature-inspired approaches. Successful bio-inspired approaches include Genetic Algorithm [2], Ant Colony Optimization [3, 4], and Particle Swarm Optimization (1995) [5]. There are also physics-inspired approaches such as Simulated Annealing Algorithm. Evolutionary computation (EC) [6] is a paradigm in the artificial intelligence realm that aims at benefiting from collective phenomena in adaptive populations of problem solvers utilizing the iterative progress comprising growth, development, reproduction, selection, and survival as seen in a population. EAs are the most well known, classical and established algorithms among nature inspired algorithms, which is based on the biological evolution in nature that is being responsible for the design of all living beings on earth, and for the strategies they use to interact with each other. EAs employ this powerful design philosophy to find solutions to hard problems. EAs are non-deterministic algorithms or cost based optimization algorithms. A family of successful EAs comprises Genetic Algorithm (GA), Genetic Programming (GP), Differential Evolution [7], Evolutionary Strategy (ES) and most recent Paddy Field Algorithm [8]. The members of the EA family share a great number of features in common. They are all population-based stochastic search algorithms performing with best-to-survive criteria. Each algorithm commences by creating an initial population of feasible solutions, and evolves iteratively from generation to generation towards a best solution. In successive iterations of the algorithm, fitness-based selection takes place within the population of solutions. Better solutions are preferentially selected for survival into the next generation of solutions. In viewpoint of application, the proposed system has considered wireless sensor networks (WSNs) that offers a wealth of capabilities in interacting with the physical world by collecting, transmitting, and processing data from the environment and responding accordingly [10]. Typical applications of WSNs include environmental monitoring (such as fire, flood, earthquakes, etc.), infrastructure protection, intelligent homes, military battlefield surveillance, rescue operations, observation of chemical and biological processes, and so on. As sensors are battery-powered, consideration of energy efficiency is of paramount importance in WSNs. Due to the energy constraints of sensors, communication protocols and hardware architectures for WSNs necessitate an energy-aware design to ensure the longevity of the network. Algorithms are expected to address the power constraint of WSNs without compromising the standard of the solution provided by them. As each transmission of data over a link in WSNs consumes a certain amount of energy (energy consumption is directly proportional to at least the square of the Euclidean distance of the link), special care must be taken so that protocols minimize the amount of communication. Local collaboration among sensors, redundant data suppression, data compression, and avoidance of direct transmission to long-distant sensors are some of the important factors that influence algorithm designers to devise novel distributed, scalable and energy-efficient solutions for WSNs. Moreover, the dynamic nature of WSNs, e.g., sensor and link failures (due to physical damage or power failure of sensors) requires algorithms to be robust and resilient in such situations. The proposed system highlights a possibility of considering a design of a new WSN that has optimized lifetime using biologically inspired algorithm drawing the motivation from the cognitive behavior of an elephant. In section 2 we give an overview of related work which identifies all the major research work being done in this area. Section 3 highlights about the logic of mechanism for understanding cognitive behavior of elephant that makes the formulation of proposed

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system. Proposed system is discussed in Section 4 followed by Implementation and results in Section 5. Section 6 discusses about some concluding remarks.

II. RELATED WORK

Saleem et al [10] have proposed biological inspired self-optimized routing mechanism for Wireless Sensor Networks. This mechanism is based on delay, energy and velocity model. This model introduces a great energy efficient solution while keeping velocity also under consideration. This velocity parameter will maintain performance for the real time applications as well. The optimal decision also depends on an addition factor which is reinforcement learning (RL) technique. Finally, this autonomic routing mechanism will come up with better throughput rate. In this paper the author also designed and work on ant based autonomous routing method for wireless sensor network are presented. Certain parameters like energy level, link quality and velocity are considered while making the decision. These decisions will come up with the optimal route to forward data towards destination. The given bio-inspired self optimized mechanism will maximize traffic throughput while reducing the end to end delay over the network. Breza et al [11] have presented one example algorithm that exploited this knowledge to efficiently manage more than one managerial parameter. This algorithm was then tested using simulations (a standard practice for the field). However, when implementing the algorithm on actual devices they soon found some unexpected results. They discuss this phenomenon and suggest some causes aiming to illustrate that current WSN bio-inspired research simulations have limited usefulness in the real world. Aksa et al [12] have tried to make a comparison between geometric field and bio-inspired system through a case study of two algorithms: one, which has already existed, known as DIR or compass routing protocol and the other one, which is a new proposal, known as BeeRP-(*BeeRoutingProtocol*) inspired from bees' communication. The outcome of this work shows that both algorithms are similar having the same intrinsic principle based on direction towards the destination in routing, whereas their tools differ. Therefore; the choice of nature, with its boundless source of ideas, proves that it can give the same solutions as geometric field. Raghavendra et al [13] have discussed PSO and BFA, bio-inspired algorithms for determining coordinates of the nodes in a WSN in a distributed and iterative fashion. The localization problem is treated as a multidimensional optimization problem and addressed through the aforementioned population-based optimization algorithms. Distributed localization proposed here has the advantage of reduced number of transmissions to the base station, which helps the nodes conserve their energy, which is a serious concern in most WSN applications. The paper has briefly outlined the algorithms and presented a statistical summary of their results for comparison. The results show that the proposed algorithms have a trade off issue. While the PSO determines the node coordinates more quickly, the BFA does so more accurately. Cheng et al [14] has proposes a bio-inspired de-centralized clustering algorithm for wireless sensor networks. The clustering algorithm is evaluated assuming a first-order radio model. Simulation results show that the proposed algorithm brings a 16 % to 161 % improvement over other de-centralized clustering algorithms in terms of network lifetime. Simulation results also show that the proposed de-centralized clustering algorithm has a similar performance as the centralized clustering algorithm. Ozdemir et al [15] have presented three bio-inspired optimization approaches for minimizing simultaneously dissipated energy and coverage loss in WSNs. Results reflect that MOEA/D can serve as a tool to lengthen the networks lifetime with simultaneously better coverage rate. The flexibility of MOEA/D is, thus, promising for more complex scenarios in the future work such as involving realistic and uneven terrain models or exploring the protocol's robustness due to node failure. Selvakennedy et al [16] has proposed, a novel atypical application that allows their protocol to converge fast with very limited overhead. An analysis is performed to determine the optimal number of clusters necessary to achieve the highest energy efficiency. In order to allow for a realistic evaluation, a comprehensive simulator involving critical components of the communication stack is used. Their protocol is found to ensure a good distribution of cluster heads through a totally distributed approach. To quantify certain clustering properties, they also introduced two fitness metrics that could be used to benchmark different clustering algorithms. Saleem et al [17] has proposed a novel architecture by implementing the most well known and successful approaches. ACO method is utilized for the optimum route discovery in multihop WSN. This technique will be accomplished by assigning each procedure to the group of agents. The agents will work in a decentralized way to collect data on individual nodes and carry to the required destination through multihop communication. A vast literature exists on bio inspired approaches for solving an impressive array of problems and, more recently, a number of studies have reported on the success of such techniques for solving difficult problems in all key areas of computer science. The two most predominant and successful classes or directions in BIAs involves Evolutionary Algorithms and Swarm based Algorithms which are inspired by the natural evolution and collective behavior in animals respectively. But still, this has been further refined so as to classify the algorithms based on the area of inspiration from nature so as to enhance a broader view over the domain. This paper presents a survey and review on the BIAs along with taxonomy and the relevant application areas.

III. LOGIC

Biologically Inspired Algorithms [18] are such heuristics that mimics /imitate the strategy of nature since many biological processes can be thought of as processes of constrained optimization. They make use of many random

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decisions which classifies them as a special class of randomized algorithms. Formulating a design for bio-inspired algorithms involves choosing a proper representation of problem, evaluating the quality of solution using a fitness function and defining operators so as to produce a new set of solutions. The current paper will consider a unique pattern of elephant for formulating the new biologically inspired algorithm that will be applied for optimization of energy in the area of wireless sensor network.

Fig 1 Depiction of Elephants for Designing BIA [19].

According to National Geographic [19], elephants are the most quite, gentle, and social animals who always like to stay in a group (herd) (Fig.1). Elephants are the largest of land mammals living in very advanced social organizations that require good levels of communication between the groups of individuals. This is because they live in a "fluid fission-fusion" [20] society which simply means that their family units are constantly being divided and reunited whilst, at the same time, they are meeting different individuals on a daily basis. This requires an advanced level of communication and recognition to allow individuals to mediate between the complex relationships that they develop with other individuals. A family can range from 2-50 individuals and they interact together in an organized and coordinated manner. Such interactions include teamwork, offspring care, group defence and resource acquisition which all involve decision making, normally made by a powerful "matriarch". The matriarch is a dominant female leader within the group who is the oldest and thus the wisest and most experienced. She makes the decisions regarding movement, safety and resource acquisition. "Bond groups", otherwise known as a "kinship groups", are groups of individuals that are closely related genetically. These groups form when bonds in a family are weakened and thus divided by fission. There is a large degree of philanthropy and cooperation that is associated to the relative selection within the family group. This phenomenon will eventually mean that one elephant will assist to maximize another elephant's lifetime and number of offsprings and thereby assist in maximizing that elephant's gene contribution to future generation without any cost of their own survival and reproduction. Another prominent charecteristics of elephants is that when they feel that they are about to die and have completed their life cycle than they chose to disassociate from the herd in which they were residing for the purpose of not to affect the lifecycle of others, which itself is a eye-catching feature when it comes to optimization in the area of WSN. Also an altruistic behavior observed in elephants is the courageous behavior of the matriarch, who protects his herd by exposing herself to danger. Communication is an essential aspect of social behavior in elephants and this is achieved by the efficient use of all their senses. This is important as it enables a herd to keep track of their relatives, defending territories and alerting the group of danger, as well as conveying their reproductive state and associating females with their young prior to weaning. Thus, they require a long distance network of communication due to this fluid social system which can convey information about their physical and emotional state as well as transmitting their intentions.

IV. PROPOSED SYSTEM

The proposed system will chose to use the phenomenon studied from the social behavior of Elephant for the purpose of optimizing the lifetime of the wireless sensor network and hence termed as Elephant Swarm Optimization (ESO). The proposed ESO algorithm will be applied on wireless sensor network considering data aggregation technique. The consideration of the proposed system is as follows:

- Considering each node as elephant, cluster of nodes as herds of elephants and "matriarch" as cluster leader.
- Simulating the behavior of elephant swam optimization on considered wireless sensor network.
- Consider each cluster have unique numbers of nodes where the nodes will be classified again based on residual power in current pass.
- Consider a data aggregation scheme where the sink is located in far distance with respect to the other clusters in order to check the efficiency of data communication.
- Consider before initiating simulation, each nodes have maximum battery-lifetime in order to check the enhancement in first node death.
- Finally consider the availability of neighbor nodes.

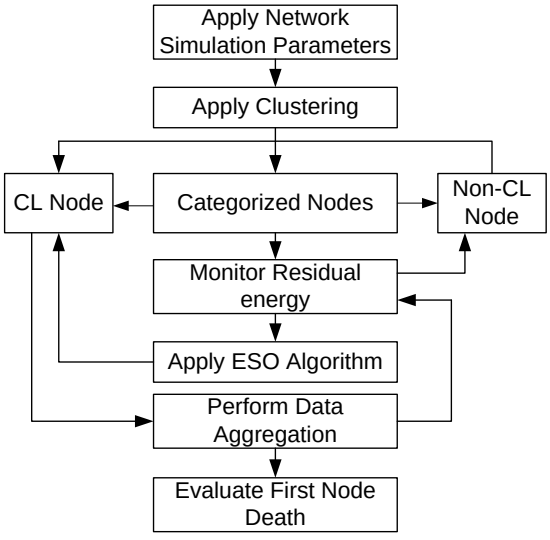

Fig 2 Proposed Flow of System

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Once the simulation is initiated it will draw the logic of operation from the social behavior pattern of elephant that is equivalent to one node in WSN. The flow of the proposed ESO system in WSN is exhibited in Figure 2.

V. IMPLEMENTATION & RESULTS

The proposed system is experimented on 32 bit OS with core i3 processor using Matlab as programming tool and the accomplished results are compared with LEACH protocol [21]. A simulation environment is created considering 60 nodes with. Once the simulation starts the ESO system starts classifying the nodes to Cluster leader (matriarch) as well as non-cluster leader node on the basis of residual power. The cluster leader (matriarch) than gathers the data from all the candidate nodes (Candidate nodes are those nodes who has comparatively less power than the existing cluster leader, but while in every pass of iteration, candidate nodes have higher chances of becoming cluster nodes as the previous cluster nodes will have drainage of power in every transmission to sink). The proposed scheme also uses node-to-node interaction scheme which maps the concepts of common social behavior of elephant moving in herds (availability of neighbour nodes). The ESO scheme makes sure the candidate nodes should always have minimum number of neighbour nodes to gather the data effectively and thereby minimizing the loads on every other nodes present in same cluster. The same phenomenon is repeated for other clusters too. The simulation is continued until the stage comes when the network witness its first node death (FND). In order to optimize the first node death instance, the ESO system will segregate the dead nodes so that routing of the data packets transmitted to the cluster leader is not affected. This phenomenon will be equivalent to when an elephant is about to die they disassociate themselves from the entire herd in order not to affect their growth cycle. This phenomenon of ESO will also be highly helpful for selection of "matriarch" node who has highest battery life and the entire operation carried out will also maintain a better equilibrium of data segregation process as only the node with highest battery life will be able to participant in data segregation process retaining the average energy of all other nodes inside the cluster. The results are exhibited as below:

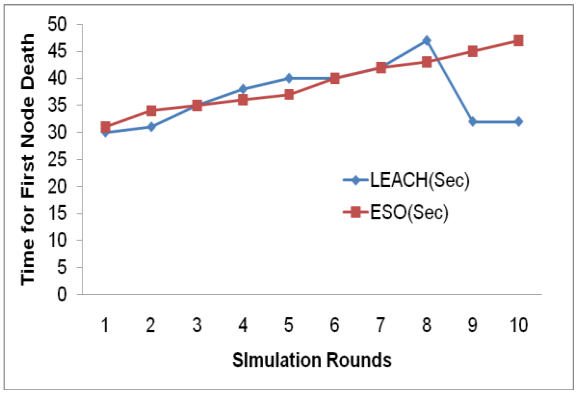

Fig 3 Times for First Node Death

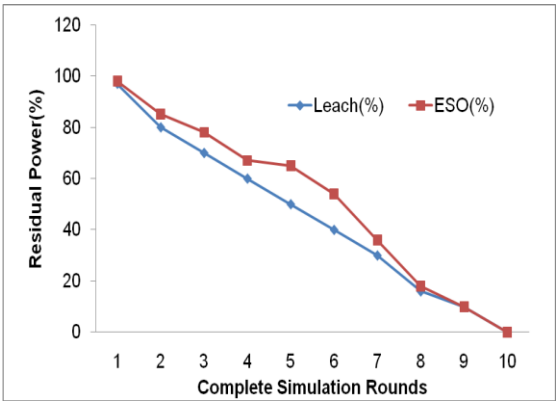

Fig 4 Residual Power

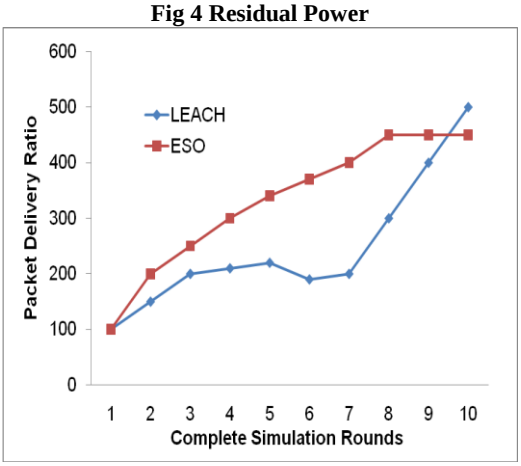

Fig 5 Packet Delivery Ratios

Figure 3 highlights the results accomplished for Time for first node death. The prime intention is to relate the instant of time representing FND (First Node Death). The evaluation is performed for data aggregation scheme using the proposed concept of ESO as well as in LEACH protocol. Figure 3 shows the number of the active nodes with respect to the operation performed on network in 10 complete simulation rounds for various scenarios. The simulation results shows that the proposed ESO technique highly enhanced the life time of the sensor node during the process of data aggregation. Figure 4 highlights the residual power estimation considering LEACH and ESO system. It can be observed that curve of LEACH has a gradient descent, while proposed ESO system is found to be have better retention of power as compared to LEACH. It is because the proposed system allows each nodes to share the load equally and forward it to the matriarch node for which reason, there is enough preservation of power in each node in the network resulting. Figure 5 highlights the results for packet delivery ratio. It can be observed that LEACH protocol performs better in initial simulation rounds, which is found to decline on 5th simulation round which is because of higher set-up phase (when cluster leader are chosen), however with the resuming of simulation round it has uniform flow in packet delivery ratio. The same phenomenon is not observed in ESO System, due to extensive group interaction (node-to-node), ESO system maintain faster selection of Cluster leader or matriarch node, who are more focused in transmitting the data as compared to LEACH.

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Hence an optimized flow in maintained by ESO that can ensure better Quality of Service even when the base station is far from each clusters (herd).

VI. CONCLUSION

The phenomenon of data aggregation in wireless sensor network is guided by the consideration of the routing schemes used or deployed while performing communication. By visualizing various issues in routing that has strong impact on data aggregation technique, the proposed paper discusses about usage of bio-inspired swarm optimization technique based on cognitive behaviour of elephant termed as Elephant Swarm Optimization (ESO) in the area of Wireless Sensor Network. The results accomplished were compared with the frequently used LEACH algorithm. The proposed ESO system is evaluated based on time for first node death, residual power, and packet delivery ratio, to find the ESO performs better than LEACH protocol. The next phase of work is to scale the system to include the correlation of n nodes at any one node. This will enable the testing of the algorithm in full network simulations that are likely to be encountered in real life, such as forest fires and landslides. The future work will be to enhance the bio-inspired algorithm considering the possibility of other living beings that has some cognitive behavior that can be preferably used for energy optimization in wireless sensor network.

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