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AN EXHAUSTIVE SURVEY ON NATURE INSPIRED METAHEURISTIC ALGORITHMS FOR ENERGY OPTIMIZATION IN WIRELESS SENSOR NETWORK

Soumitra Das[1], S. Barani[2], Sanjeev Wagh[3] and S.S. Sonavane[4]

[1]*Department of Computer Science and Engineering, Sathyabama University, India*
E-mail: soumitra_das@yahoo.com
[2]*Department of Electronics and Control Engineering, Sathyabama University, India*
E-mail: baraniselvaraj77@gmail.com
[3]*Department of Computer Engineering, KJ College of Engineering and Management Research, India*
E-mail: sjwagh1@yahoo.co.in
[4]*Dr. D.Y. Patil School of Engineering, India*
E-mail: sssonavane@gmail.com

Abstract

Todays engineering research is highly motivated towards the nature inspired metaheuristic computational algorithm as they have the capability to give better results as compared to the conventional methods. Wireless Sensor Networks(WSNs) have become increasingly popular due to their extensive array of applications. Desing of energy efficient routing algorithms is an important issue in the designing of WSNs applications as the lifetime of the sensor node is based on the limited battery powered devices. Therefore to maximize the lifetime of sensor node a comprehensive survey of energy efficient routing algorithms based on natural science have been addressed in this paper. The paper will take the readers into the detailed survey of existing energy optimized routing algorithms considering the natural science (metaheuristic) as the base and considering parameters related to energy efficiency as the core objective. The final part of the paper discusses the limitations of various algorithms that has been addressed in this paper and suggestions to overcome them.

Keywords:

Nature Inspired Computing, WSN, Energy Optimization, Optimized Routing, Metaheuristics

1. INTRODUCTION

WSNs is defined as a network of small embedded devices, called sensors, which communicate wirelessly among themselves. WSNs are located strategically in a physical medium and are able to interact with it in order to measure physical parameters from the environment and provide sensed information [1]. The nodes mainly use a broadcast communication methodology and the network topology, which can change constantly due to the fact that nodes are prone to fail. The nodes have limited power, low computational capabilities and limited memory. One of the main issues that should be studied in WSNs is their scalability feature [2], connection strategy for communication [3] and the limited energy available to supply the device. The desire to advance in research and development of WSN was initially motivated by military applications such as surveillance of threats on the battlefield, mainly because WSN can replace single high-cost sensor assets with large arrays of distributed sensors. There are other interesting fields like home control, building automation and medical applications. WSNs can also be found in environmental monitoring applications such as marine fish farms [4] and fire detection units in forest and rural areas [5]. Ant and honey bee's communities have multifaceted communal behaviour along with decentralized organization structure as stated by the authors [6] [7]. This synchronization of activities among social insects helps them solve genuine world problems in the simplest ways. This uniqueness shown in the social insects can be mapped in the context of WSNs where nodes work together to achieve a regular objective in the deployed environment.

The most important purpose of this survey is to present a comprehensive review of different power saving and energy optimization techniques available for WSNs taking into consideration the nature inspired metaheuristic techniques. This invites the interdisciplinary research which is an important driver for innovation.

We will discuss all major modern metaheustrics algorithm as genetic algorithm, ant colony optimization, and cuckoo search.

The below table shows the nature inspired metaheustrics species in terms of behaviour and how it is applied in WSN.

2. METAHEUSTRIC OPTIMIZATION

Metaheuristic optimization deals with optimization problems using metaheuristic algorithms. An optimization can be considered as a minimization or maximization problem. Mathematically optimization problem can be written as,

$$\text{minimize } f_1(\mathbf{x}),...,f_i(\mathbf{x}),...,f_i(\mathbf{x}),\ \mathbf{x} = (x_1,...,x_d),\ \text{subject to}$$
$$h_j(\mathbf{x}) = 0,(j = 1,2,...,J)$$
$$g_k(\mathbf{x}) \leq 0,\ (k = 1,2,...,K),$$

where, $f_1,...,f_i$ are the objectives, while h_j and g_k are the equality and inequality constraints, respectively.

In the case when $i = 1$, it is called single-objective optimization. When $i \geq 2$, it becomes a multiobjective optimization. In general, the functions f_i, h_j and g_k are nonlinear.

Glover 1986, Glover and Kochenberger 2003 came up with a convention and called all nature inspired algorithms Metaheuristics. Here “heuristic” means to find or discover by trial and error. “Meta” means beyond or higher level and “Metaheuristics” generally perform better than simple heuristics.

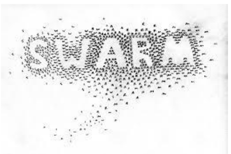
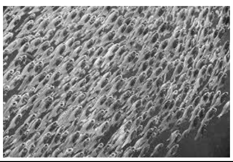
Optimization algorithms are classified into trajectory-based and population-based. A trajectory-based algorithm uses a single agent (one solution) at a time, where as population-based algorithms use multiple agents (many solutions) which will interact and trace out multiple paths. For example, Particle Swarm Optimization (PSO) (Kennedy and Eberhardt, 1995). Further Optimization algorithms can also be classified as deterministic or stochastic. The deterministic algorithms works without any random nature, whereas if there is some randomness in the algorithm, then the algorithm will usually reach a different point every time the algorithm is executed, even though the same initial point is used. Stochastic algorithms are genetic algorithm and PSO.

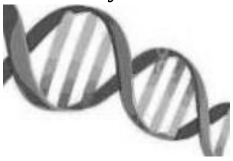
3. INTELLIGENT SOLUTIONS USING NATURE INSPIRED SYSTEMS

There are various energy optimization techniques based on nature inspired systems. Numerous problems exist in our day to day life, which are difficult to solve by the traditional ways because of their limitations. Therefore, many researchers have shifted their focus from traditional ways of nature inspired ways to solve these problems. Nature inspired algorithms have their own methods and principles to resolve the problems. For this one should understand the nature's principles, rules and mechanisms of working. The process of designing intelligent systems through nature inspiration has the following phase: understanding the nature process, design patterns of nature process, identification of analogies and technological modeling for the problem [8].

One of the key features of nature inspired systems is searching the best solutions in optimization space. Most of the time, optimization process needs iterations of working sessions. Foraging behaviour in ants and bee's systems, bird flocking, herds, wasps, fish schools, genetic systems, Cuckoo's, Chameleon and termite's functions, are some of the typical examples of iterations of working sessions for the optimal respective solutions for WSNs shown in Table.1.

Table.1. Natured inspired species

Nature Species	Behaviour	Applied Applications in WSN
Swarms 	Swarm behaviour is a collective behaviour exhibited by animals of similar size, which aggregate together or migrate in some direction. Swarms represent an individual animal that follows three rules: 1) They move in the same direction as their neighbors move. 2) Always remain close to their neighbors. 3) Keep away from collisions with their neighbors	Distributed system of interacting, autonomous agents, performance enhancement, process optimization, distributed task allocation
Honey Bees 	Proficiently combine replication and evasion to allow network to continue to deliver data for a long time during a congestion attack.	An energy-aware defense framework against base-station congestion attack in WSNs
Ants 	Control is fully distributed among a number of individual communications among the individuals happening in a localized way. The overall response of the system is quite robust and adaptive with respect to changes in the environment.	Allocation of the computing; resources to number of cluster units; control can be fully distributed among a number of clusters; cluster interacts in simple and localized ways
Wasps 	A colony of individuals working together for the survival of the colony. Coordinate their behavior in order to build such complex nest structure.	Applications of self-assembling robots; cluster formation in sensors and evolutionary design to architecture in WSN
Termites 	Termites move from a non-coordinated to a coordinated phase only if their density is higher than the threshold value.	To balance the network traffic load and prolong the network lifetime without performance degradation
Fish Schools 	Any group of fish that have collectively come together in some locality is termed as aggregation of fish. These can be structured or unstructured. An unstructured aggregation is a group of mixed species and sizes that gathers at random near some neighboring resource, such as food or nesting sites.	Used for node deployment algorithms, nodes clustering with many applications, for example Traffic Monitoring System.

Genetic system 	Based on the behavior of genes. Systems genetics are an approach to understand the flow of biological information that underlies complex traits. It uses a range of experimental and statistical methods to quantitatively integrating intermediate phenotypes, such as transcript, protein or metabolite levels, in populations that vary for traits of interest.	Optimum time for topology transitions; intelligent routings in WSN; intelligent clustering in WSN
Cuckoo's 	It was motivated by the behavior of cuckoo species and their method of laying eggs in the nests of other host birds. This is the basic motivation for development of this new evolutionary optimization algorithm.	Solving optimization problems in WSN and for searching improvement in performance; efficiency plotting of nodes in graph and trees.
Chameleon 	It was inspired by the behavior of chameleon species where the chameleon changes its colour dynamically according to the environment.	Dynamic modeling to determine the similarity between pairs of clusters
Bird Flocks 	Flocking behaviour is the behaviour exhibited when a group of birds, called a flock, are foraging or in flight. There are parallels with the shoaling behaviour of fish, the swarming behaviour of insects and herd behaviour of land animals.	Support a robust and self-adaptive congestion control protocol in the context of WSNs, controlling congestion

4. REVIEWS OF NATURE INSPIRED METAHEURISTICS ALGORITHMS

The focus of our review is to provide broad coverage of the existing literatures. We have discussed the revolutionary efforts, most influential work and the recent trends in the area for each of the topics. We have referred to the following species during the whole review work: the ant, the cuckoo and the genetic based clustering and routing protocols inspired by nature.

4.1 THE ANT COLONY OPTIMIZATION (ACO) APPROACH

ACO was pioneered by Marco Dorigo in 1992 [9, 10] and is based on the foraging behaviour of social ants. Many insects such as ants use pheromone as a chemical messenger. Ants are social insects and live together in organized colonies consisting of approximately 2 to 25 million individuals. Each ant lays scent chemicals or pheromone to communicate with others. Each ant is also able to follow the route marked with pheromone laid by other ants. When an ant finds a food source, it will mark it with pheromone and also mark the trail to and from it.

However, the pheromone concentration ϕ decays or evaporates at a constant rate γ . That is,

$$\phi(t)=\phi_0 \exp[-\gamma t]$$

where, ϕ_0 is the initial concentration at $t = 0$. Here the evaporation is important, as it ensures the possibility of convergence and self-organization.

From the initial random foraging route, the pheromone concentration varies and the ants follow the route with higher pheromone concentration. In turn, the pheromone is enhanced by the increasing number of ants. As more and more ants follow the same route, it becomes the favored path. Thus, some favorite routes emerge, often the shortest or more efficient ones. This is actually a positive feedback mechanism. As the system evolves, it converges to a self-organized state, which is the essence of any ant algorithm.

4.1.1 Energy balanced ant based routing protocol (EBABRP), 2009:

In this paper [11], the author has proposed an adaptive dynamic routing algorithm which is based on energy balanced ant based routing protocol i.e. ant colony optimization. The proposed algorithm is based on inter-cluster routing method where ant colony algorithm (ACA) was applied to determine the most excellent path from cluster heads to the base station. The algorithm first chooses a cluster head, which is based residual energy and distance between the available cluster heads. Once the cluster heads are chosen,then the cluster formation takes place, where cluster head broadcasting a message to all the nodes which are within the range of the cluster head and in response the nodes based on most best distance and energy from the cluster head send an acknowledgement message for their willingness to associate with that cluster head. The collection and transmission of the sensed data from the member nodes to the cluster head follows a TDMA time slot mechanism. The proposed algorithms simulation result shows that more than 30% enhance in extension of network life when compared with LEACH.

4.1.2 Adaptive clustering for energy efficient WSN based on ACO, 2009:

In this paper [12], the author has proposed an adaptive clustering for energy efficient wireless sensor network based on ant colony optimization where the cost function is taken care at the base station. The transmission and data aggregation, cost is minimized by distributing evenly among all the sensor nodes. The author's algorithm objective is to pick the *K* number of cluster heads from the given *N* number of nodes with the help of software ants. The Author has simulated the algorithm in Matlab and tested the results obtained with leech and found that leach-c and particle swarm optimization performs better in terms of delivery of data and lifetime of the network.

4.1.3 Ant colony clustering algorithm, 2009:

In this paper [13], the author has proposed an improved version of leach termed as ant colony clustering algorithm based on ant colony. The author has considered parameters such as residual energy of the node and the distance between the member node and the cluster heads while selecting the cluster head. The algorithm works on inter cluster routing, which uses the Ant Colony Algorithm to reduce the energy consumption of cluster heads, which ultimately extend the lifetime of the sensor network. The author has simulated the algorithm in Matlab and the results were compared with the results of leach and found that the energy consumption and alive nodes outperforms. The author failed to consider throughput, delay in routing protocol and due to overheads the energy efficiency is weak.

4.1.4 An energy efficient clustering solution for WSNs:

In this publication [14], the author Wei D et al. proposed a distributed clustering algorithm termed as EC, which is responsible to find out the cluster sizes based on hop distance to the sink while achieving equal life time of the sensor nodes and reduces the energy consumption of the network. Each sensor node senses a single packet then sends the packet to its cluster head. Then each node collects those packets from its associated member nodes and combines to produce a cluster. Trade–offs, hop distances to the sink and approximate equalization of energy levels are three step processes which are referred to as a single data collection round of the WSN operation. This protocol enhances lifetime of the network and provides equalization of energy level of nodes at different hop distances to the sink.

4.1.5 An ant colony optimization based load balancing,routing algorithm, 2010:

In this paper [15], the author has proposed an Ant colony optimization based load balancing, routing algorithm for wireless multimedia sensor networks. In the initial phase of the protocol, it build's intra-cluster routing by using a minimum spanning tree algorithm and the root of the tree as a cluster head. Ant colony optimization algorithm is applied in inter-cluster routing to get the best possible route from the cluster head to the sink. The author proposed results were compared with M-IAR and AGR with respect to end-to-end delay and energy efficiency and concluded that the proposed algorithm performs better.

4.1.6 A Novel routing algorithm based on Ant colony optimization for hierarchical wireless sensor networks, 2011:

In this paper [16], the author has tried to utilize the energy of nodes efficiently and also tried to reduce the overhead, efficiently by using inter cluster routing algorithm based on Ant Colony optimization. In the first phase heterogeneous types of nodes were deployed in a cluster so that the demand of large scale WSN is met. In the second phase the author has defined some weighted parameters, related to the node and then tried to map these predefined parameters with the variables of Ant Colony algorithm. The new algorithm was developed by considering the Ant Colony algorithm to get best possible routes among cluster heads. The author has also used the concept of multiple routing so that the validity of data transmission is enhanced. The simulation results obtained shows improvements in optimization probability and able to balance the network load in very superior manner.

4.1.7 Ant colony optimization based routing in WSNs, 2013:

In this publication [17] the author K. Syed Ali Fathima et al. has presented a new protocol for WSN routing operations. The protocol is achieved by using ACO algorithm to optimize routing paths, providing an effective multi path data transmission to obtain reliable communications in the case of node faults. The authors aimed to maintain network life time in maximum, while data transmission is achieved efficiently. Authors study was concluded to evaluate the performance of ant based algorithm and AODV routing protocol in terms of Packet Delivery Ratio, Average end-to end delay and Normalized Routing Load. From the comparison it is concluded that overall performance of ant based algorithm is better than AODV in terms of throughput. The proposed algorithm can control the overhead generated by ants, while achieving faster end-to-end delay and improved packet delivery ratio.

4.1.8 Prolonging the lifetime of WSN based on blending of genetic algorithm and ACO, 2015:

In this paper [18] the author Soumitra Das et al. has proposed an algorithm, which is a combination of two techniques i.e. Genetic Algorithm (GA) and ACO to prolong the network lifetime and save the energy of sensor nodes, which is the need of the sensor network. Here, the GA is used for the formation of the clusters and selection of the Cluster Head (CH). Once the cluster is formed and CH is chosen, the ACO algorithm is applied to find the shortest path from source CH to the destination sink using multipath routing algorithm. The multipath routing helps in reliable communication when the node fails in between the route. The proposed algorithm was simulated in MATLAB R2009b and was compared with Genetic Algorithm Based Energy Efficient Clusters [GABEEC] and EEABR. The evaluation of the algorithm was done by comparing the following parameters as energy consumption with respect to time, energy comparison in each round, network lifetime and throughput of the network, which clearly indicates that the proposed algorithm conserves more energy.

4.2 THE GENETIC ALGORITHM (GA) APPROACH

GAs are probably the most popular evolutionary algorithms with a diverse range of applications. A vast majority of well-known optimization problems have been solved by genetic algorithms.

GA is a search heuristic that mimics the process of natural selection. GA was introduced by Holland.

This heuristic (also sometimes called a metaheuristic) is routinely used to generate useful solutions for optimization and searching problems. which works with the theory of Darwin's assumption of natural evolution [19]. Darwin's suggested that the individual who is the fittest will continue to exist in the context of survival. Performance of GA is based on four operators: crossover, mutation, selection and fitness function. These genetic operators are the essential components of genetic algorithms as a problem-solving strategy.

Crossover: In this process, two parents are selected based upon the fitness function as they are responsible to reproduce a new offspring. It is assumed that the offsprings produced will inherit all the good characteristics of both the parents or may have better characteristics than its both parents. Commonly used crossover are one point crossover where a a random crossover point is selected and bits of parent chromosomes are swapped to produce a new offspring [20, 21, 22].

Mutation: In mutation a bit which is 0 becomes 1 and the bit which is 1 becomes 0. Mutation is applied at mutation probability. After mutation, regular node may become a cluster head and a cluster head may become a regular node. When a CH becomes a regular node, members of that cluster join nearest cluster head and if a regular node becomes clusterhead, the nodes which are close to it will join this cluster [23, 24].

Selection: Selection is used to select chromosomes for mating process i.e. crossover. Mating process will reproduce new chromosomes which will join current population. This will be called as a new generation.

Fitness function: However, there are many different ways of defining a fitness function. For example, we can assign an individual fitness relative to the whole population

$$F(x_i) = f(\xi_i) \Big/ \sum_{i=1}^{N} f(\xi_i)$$

where, ξ_i is the phenotypic value of individual *i*, and *N* is the population size. The form of the fitness function should make sure that chromosomes with higher fitness are selected more often than those with lower fitness. Poor fitness functions may result in incorrect or meaningless solutions.

The pseudo code for standard GA is illustrated in the algorithm 1.

Algorithm 1: Genetic Algorithm - Pseudo code

Begin

1. Randomly initialise the population of chromosomes;
2. Evaluate the chromosomes;
3. If maximum generation not reached then select superior chromosomes;
4. Perform single point crossover on selected chromosomes and Evaluate the offspring;
5. Append offspring with current population;
6. Select superior chromosomes and Perform mutation on the selected chromosomes;
7. Evaluate the offspring and append the offsprings with current population;
8. Return best chromosome;

End

4.2.1 Genetic algorithm based energy efficient clusters (GABEEC) in wireless sensor networks, 2007:

In this paper [23], the authors have proposed a cluster based method which is similar to LEACH and consists of two phases namely set up phase and steady state phase. As there is only one cluster head associated with each cluster therefore the number of cluster head and clusters are equal in number. In the first phase the member's nodes choose themselves to join the *CH* based on the nearness from member node to the *CH*. In the second phase the data is actually transmitted to the *CH* using the TDMA technique. The responsibility of the member nodes is to sense atmospheric data and transmit the sensed data to the *CH* and in turn *CH* sends this data *BS*. The execution of phase I and II is considered as one round. The clusters are not changed in every round but the *CH* may be changed depending on residual energy left within it, if energy of *CH* is less than the average energy of the entire member node. If a need arises to change the *CH* then the node which has highest residual energy within the cluster becomes the new *CH* and the old *CH* becomes the member node. The above network can be genetically represented by Chromosome as the *CH* will be designated as '1' and member nodes will be designated as '0'. The initial population is randomly generated and every node is evaluated for its fitness. Based upon the fitness, fittest chromosome is selected for applying crossover and mutation. The author has used the following Parameters for fitness function as a Cluster distance *C* (It is sum of distance from member nodes to *CH* and *CH* to *BS*), round which first node dies (R_{fnd}), round which last node dies (R_{lnd}).

Limitations

1. Residual energy is not only the fitness parameter.
2. Only rotation of the cluster heads takes place. Clusters are not changed throughout the lifetime of the network.

4.2.2 Performance Evaluation of Genetic Based Dynamic Clustering Algorithm over LEACH Algorithm for Wireless Sensor Networks, 2011:

In this paper [24], the author's basic aim was to determine clustering, position of cluster heads and to optimize energy consumption of nodes and network. The wireless network is represented as bits of chromosome i.e. '0' represents a member node and '1' represents a cluster head. The genetic operators used in proposed method are selection, mutation, fitness function and crossover.

$$\text{Fitness} = RE + ((X*SE) + (1-X)*(N-CH))$$

where, "*N*" represents the total number of nodes, "*RE*" represents sum of residual energy in cluster heads, "*CH*" represents total number of cluster heads, "*X*" represents a weight factor whose value lies between 0 and 1 and *SE* is represents as [24],

$$SE = \sum_{i=1}^{M} \left(RS_i - \left(RH_i + HS\right)\right)$$

where, "RS_i" represents sum of energy which is required to transmit one message from all regular nodes to sink, "RH_i" represents sum of the energy which is required to transmit one message from regular nodes to *CH* and "*HS*" represents the sum of the energy which is required to transmit one message from all *CH* to sink.

The author has simulated the work in Matlab and the results of the proposed system was compared with conventional LEACH and the author has found that the proposed system is better in respect to the following parameters Uniform distribution of cluster heads in a network, total residual energy and number of alive nodes.

Limitations

1. A single parameter i.e. energy is considered in a fitness function.
2. Distance of the node from sink is not a fitness calculation parameter.
3. Also centrality of the node and mobility of the node are not considered.

4.2.3 Heuristic Clustering for WSNs using GA, 2013:

In this research paper [25] the author Sanjeev Wagh et al. has proposed a GA based method to optimize the sensor nodes' energy consumption with clustering techniques. Multi-objective algorithms were used by them to generate an optimal number of sensor clusters with cluster heads. The main objectives were to reduce the energy consumption and the network traffic by using the multi-objective GA. They have used linear ranking selection scheme for fitness assignment with selective pressure of 1.5 to 2 with generation gap 0.95 as the fitness assignment scheme. The stochastic universal sampling is used for selection procedure to deal with global optimization problems with continuous variables. For energy optimization problem and coverage in WSN, the technique of fitness sharing was proposed. The clustering algorithm was simulated in Matlab and compared with Low Energy Adaptive Clustering Hierarchy (LEACH) protocol. The evaluation was done by considering the successful packet delivery rate with respect to numbers of packets, number of alive nodes against a number of rounds for both single objective and multi-objective against LEACH and found that the proposed algorithm was better in terms of energy consumption and prolongation of the network lifetime.

4.2.4 Hierarchical Clustering using GA in WSNs, 2013:

In this publication, [26] the author Mohammad M. Shurman et al. has addressed the issue of long distance communication between sensors and sink nodes. The author has integrated the GA with hierarchical clustering to reduce long distance communication between sensors and sink nodes. This ultimately reduces the energy consumption in the network. Initially a certain number of nodes were deployed and then the location of the base station, population size (i.e. Chromosomes), the number of runs (i.e. Generation) are determined. At last, GA is applied on the network. A group is formed among the CHs and the CH, which is close to the sink acts as a super CH that is responsible for gathering data from all the CHs within that group and transfers it to the sink. The simulation results show that the proposed algorithm decreases the long distance communication and is also scalable and shows significant improvements related to energy efficiency.

4.2.5 Trust based Energy Efficient Clustering using GA in WSN, 2015:

In this paper [27] the author Nivedita B Nimbalkar et. al has discussed about saving energy in the network by the clustering of sensor nodes method to prolong the battery life. They have proposed a GA based technique called Trust based Energy Efficient Clustering using GA (TEECGA) in WSN wherein security is added and termed as trust. Initially the fitness of all the nodes is calculated and then genetic operators are applied to the nodes and the node with the highest energy is selected as *CH*. This system aimed at ensuring successful delivery of the data and reliability by calculating trust of all the nodes. A node with low trust value is not selected as a *CH*. In TEECGA, multihop communication between *CH* is used to send the sensed data to the sink node, which eventually increases the network lifetime. The simulation was carried out in Java, considering an area of 200 × 200 meter square with dynamic number of sensor nodes. The algorithm was evaluated considering the parameters as residual energy, distance between sensor nodes, number of sensor nodes, number of *CH*s and trust with the classical method of clustering and it was claimed that the proposed system show significant improvements and trust.

4.3 THE CUCKOO SEARCH APPROACH

Cuckoo searching (CS) is an optimatization algorithm developed by Xin-she Yang and Suash Deb at 2009 [28, 29]. It was inspired by the obligate brood parasitism of some cuckoo species by laying eggs in the nests of other host birds of other species. Some host birds can engage direct conflict with the intruding cuckoos. For example, if a host bird discovers the eggs are not their own, it will either throw these alien eggs away or simply abandon its nest and build a new nest elsewhere. Some cuckoo species such as the new worlds brood-parasitic Tapera have evolved in such a way that the female parasitic cuckoos are often very specialized in the mimicry in colours and pattern of the eggs of a few chosen host species [30]. CS search idealized such breeding behaviour, and thus can be applied to various optimization problems. It seems that it can outperform other metaheuristic algorithms in applications.

Representations of CS:

- Each egg in a nest represents a solution, and a cuckoo egg represents a new solution
- The aim is to use the new and potentially better solutions (cuckoos) to replace a not-so-good solution in the nests. In the simplest form, each nest has one egg
- The algorithm can be extended to more complicated cases in which each nest has multiple eggs representing a set of solutions

Three idealized rules of CS:

i. Each cuckoo lays one egg at a time, and dumps its egg in a randomly chosen nest;
ii. The best nests with high quality of eggs will carry over to the next generation;
iii. The number of available host's nests is fixed, and the egg laid by a cuckoo is discovered by the host bird with a probability $Pa \in (0,1)$. Discovering operates on some set of worst nests, and discovered solutions dumped from further calculations.

4.3.1 Energy Efficient Computation of Data Fusion in WSNs using Cuckoo based Particle Approac, 2011:

In this paper [31] the author Manian Dhivya et al. has researched on optimization of the network by the Cuckoo Based Particle Approach (CBPA) to achieve energy efficient WSN and multimodal objective functions. CS is applied to the *CH* selection and formation of clusters among the sensor nodes. After the *CH* is selected, the information is collected, aggregated and forwarded to the base station using a generalized particle approach algorithm. Minimization and conservation of energy of WSN and maximization of the lifetime are the performances that were measured. The proposed CBPA was compared with the standard LEACH protocol and Hybrid Energy-Efficient Distributed clustering HEED protocol. The simulation was carried out in Matlab. The simulation results exhibited that CBPA produced comparable results mainly due to optimal search process in cluster formation and allocation of appropriate paths in the transmission of sensed data.

4.3.2 *Energy Efficient Cluster Formation in WSNs using Cuckoo Search, 2011:*

In this paper [32] the author Manian Dhivya et. al. has focused on the issues related to reduction of the energy consumption and prolongation of lifetime of the network. The authors have proposed a meta-heuristic optimization technique called CS to aggregate the data in the network. The authors have divided the nodes into two categories as least energy nodes, responsible for sensing the data and high energy nodes, for acting as CHs for communication with the base stations. The *CH* is selected from the best fit of the CS process. The objective was to fairly balance the energy consumption among the sensor nodes, according to their residual energy and to extend the longevity of the network. The proposed algorithm was simulated in MATLAB (7.11.0.584) and compared with HEED and LEACH considering the network lifetime and energy consumption as the parameters. From the results it is clear that the proposed method prolongs the network lifetime by 15% more as compared to HEED and LEACH.

4.3.3 *Sensor Communication Networks using CS Algorithm, 2014:*

In this paper [33] the author D. Antony Arul Raj et. al. has addressed the issues of energy efficient routing to save the energy in WSN. The authors have used CS algorithm for finding the energy efficient path and then routing is performed. In the problem statement, the author has shown the concern over the layers which use energy and demonstarted that the network layer is responsible for consuming the most amount of energy and also emphasised on bio-inspired computing techniques for getting better results in terms of energy efficient routing. Considering the bio-inspired techniques, the author has proposed a novel algorithm called Enhanced Energy Efficient Multipath Routing Protocol (EEEMRP) using CS. The author has compared EEEMRP with Ad-hoc On-Demand Multipath Distance Vector (AOMDV) routing protocol with respect to the following parameters such as throughput, packet delivery ratio, delay and energy consumption. The algorithms were evaluated in Network Simulator 2 (NS2) and showed that the energy consumption and throughput of the EEEMRP is much better than AOMDV.

4.3.4 *Cuckoo based Energy Effective Routing in WS, 2014:*

In this paper [34] the author Gurpreet Kaur Bhatti et. al. has worked in the direction to improve the energy efficient routing so that better network lifetime and throughput is achieved. The authors have proposed an opportunistic routing where network optimization is on the basis of CS and they have modified the Power-Efficient GAthering in Sensor Information Systems (PEGASIS) algorithm on the basis of fuzzy system so that network lifetime and throughput is improved. The proposed algorithm was simulated in MATLAB by considering 100 nodes, placing them in 100m × 100m square field. The simulation has focused on the prime performance indicators such as number of sensor nodes alive, the average energy of the network and cost slot per iterations. The authors claimed that the proposed algorithm based on the simulation is better and saves more energy, improves the network lifetime, which is 92% as compared to 76%. This showed a significant amount of improvement, 16% as compared to the earlier algorithms.

4.3.5 *Clustering approach for WSNs based on CS Strateg, 2014:*

In this paper [35] the author Sandeep Kumar E et.al has concentrated on the clustering in WSN concept to save the energy of the sensor nodes in the network. They have proposed a brood parasitism of few cuckoo bird species, thereby increasing the lifetime of the network. This was an attempt towards bio-inspired computing in WSNs for achieving the energy efficiency. The simulation was carried out in MATLAB 2013 by considering the following parameters as 100 numbers of nodes plotted in the 100m × 100m area. The authors compared their proposed algorithm with basic LEACH with respect to residual energy against rounds; the number of dead nodes against rounds and comparison of network residual energy for different values of rejection probability threshold and comparison of the number of dead nodes for different values of rejection probability threshold. The results clearly showed that the proposed algorithm is outstanding in terms of energy efficiency and it prolongs the network lifetime as compared to basic LEACH.

5. GENERAL DISCUSSION AND REVIEW COMMENTS

Natural science based research shows a amazing contribution for various problem solving methods. Within the nature, interdisciplinary research of combination based on the natural science is coming up in a big way to further enhance the results as compared by conventional research methods.

Furthermore, the effectiveness of the nature based solutions to solve various artificial problems depends upon the type and scale of the problem. So to present even a summarized view depicting the relationship, various natures based systems wherein the routing issue is solved by the Swarm Intelligence (SI) as it deals with some good properties as being adaptive, robust, scalable and distributive. From this review, it is clearly demonstrated that significant efforts have been made in addressing the techniques to design effective and efficient routing protocols for WSNs taking into consideration the nature based techniques.

The focus is obviously towards the nature inspired metaheuristics energy optimization algorithms which can be applied in designing, planning, and controlling problems for energy optimization in WSN. The methods can be grouped together into two categories, one is based on organ bodies i.e. genetic system, neural system, cellular system and immune system and non-organ bodies discussed through work strategies of various social insects, i.e. honey bees, ants, the wasps and termites for practical energy optimization problems.

From this review work, we found that the following points were not addressed by the authors, as algorithms fail to show the scalability feature, deployment area were small in nature and only small amount of sensor nodes were deployed with all the sensor nodes are of static type. The algorithms that have been designed so far, the researchers have overlooked the Quality of Service (QoS) features, which is very much essential for the WSN. All the proposed algorithms were developed and tested in the simulation environments, as actual implementation and deployment in the live fields will differ the results.

6. CONCLUSION AND FUTURE SCOPE

This review paper evalauated the significance of nature inspired algorithms for energy and clustering efficiency as well as efficient routing protocols with an aim to achieve energy preservation in WSN. An artificial system based on nature inspired species are very efficient in terms of energy preservation.

There lies an immense scope for development and improvement of efficient cluster formation and data routing, though the published literature focuses on enhancements of various protocols. There is also a need to focus on the quality of service, inspired by natural species.

To conclude, there are various methods to explore this field taking into consideration the chameleon algorithm and its applied application in WSN, which is related to clustering, routing and energy efficiency. We also require to focus on the hybrid systems to optimize the problems encountered in WSN to achieve enhanced results. These hybrid systems can offer new dimensions to uncover optimal solutions of WSN. Furthermore, this proposal can also be widened for the multi-objective minimum energy network connectivity setback for wireless sensor networks.

Our extensive review will aid researchers to understand the most recent accomplishments in the field of nature inspired routing and GA based routing for real world problems for energy optimization in WSN.

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