The Study On Nature-Inspired Principles For Solving Routing Issues In Wireless Sensor Network

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Abstract: Routing in Wireless Sensor Network (WSN) plays a significant aspect in tracking environment, traffic monitoring, etc. Wireless Sensor Network has become an regressing work in research and development by reason of the populous count of applications it supports. In recent times nature-inspired optimization algorithms achieved limitless recognition in resolving large-scale and complex routing problem. The vital purpose of this type of algorithms is to find the optimal path. These principles afford different aspects that can be practiced in large-scale network. The study annotates diversified existing principles and their dominance in routing related issues. Certainly, an analytical sketch on the practice of principles is presented.

Keywords: Routing, Nature- Inspired Algorithms, Optimization

I. INTRODUCTION

A Wireless Sensor Network comprises of a enormous number of small, low-cost sensors with limited memory, energy and processing capacity are connected together to perform a particular task. It is being used on the large scale to monitor the environmental status like environmental tracking, military application, industrial process monitoring, dynamic routing management etc. The characteristic of WSN includes self-organisation, concurrent processing, low cost, restricted energy resources and small radio range. However, the characteristics of WSN require a more effective method for data forwarding. The structure holds heterogeneous detection stations called sensor nodes each of which is mini, less weight and portable. These nodes in the network are capable of sensing, computation and communication. Sensor nodes are known as Micro Electro Mechanical System (MEMS) that sense a measurable amount of reaction to a general change in physical characteristics like temperature, humidity etc. The power of every sensor node is endowed from the battery. Hence the nodes possess limited energy in a constrained communication. Furthermore, nodes have limited processing speed, storage capacity and communication capabilities. Research work has been carried out to overcome the limitations of the network. Once the nodes are deployed they are important for self-organising the network as a legitimate infrastructure by sending control messages to the neighbours. Routing is vital to forward the data from the source to the sink. It is used for selecting a path that consumes less bandwidth. Each time when the route is calculated it consumes energy. The process of routing leads to decreased network lifetime with increased energy consumption. The other challenges in routing include node deployment, scalability, coverage and security. Here routing presents far-reaching part in communication and sustainability of the network, hence it must be handled carefully. A proper mechanism is needed to overcome complication in routing. Nature gives better solutions than humanly derived results. Elucidation drawn from nature recognises the most crucial problem. It relates to the intrinsic characteristics of plants, animals and other features of the world that develop knowledge on their own. Communication is essential for social foraging behaviour of animals and this can be practiced in sensing group of WSN. Nature motivates the development of nature-inspired Optimization (NIO) principles. These principles can be applied in the engineering problems to find global optimality and to solve a broad range of problems. Optimization is the procedure of achieving the finest possible result under given circumstances. The goal of the optimization is either to minimize effort or maximize the benefit. The basis of the optimization algorithm is to generate a better solution point at $x^{(t+1)}$ from a current solution x^t . Correspondingly the purpose of the routing is to find the best immediate node from the current node. In routing, optimization is used to maximize the performance and to minimize the cost. NIO algorithm works well in communication failures and data aggregation and dissemination mechanism. There is no specific method for fixing all obstacles efficiently. Therefore, a number of methods have been developed to solve different kinds of problems. In this literature, a handful of techniques are described that mimics the behaviour of animals or insects groups. The knowledge gained from nature is used to improve the performance of the traditional routing problems.

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II. REVIEW OF OPTIMIZATION TECHNIQUES

There are two fundamental steps in Nature Inspired principle constitutes exploration and exploitation. Exploration leads to global maxima and exploitation leads to local maxima. An equivalence among these two steps is crucial in Nature Inspired principles. These principles personify one common behaviour that is searching for wild food resources. The efficiency of this principle counts on divers factors such as its closeness to the food source, centralisation of its energy and ease of obtaining that energy.

A. Ant ColonyOptimization (ACO)

ACO [1] is used for finding optimal path based on the behaviour of ants. Ants are tiny individuals that use perceptive behaviour to find the smallest path between nest and food. Initially, ants move randomly and leave pheromones on the path. When other ants hit the pheromones, they are likely to follow the path with some portability. Ants build a network of communication. The path with highest pheromones reproduces the shortest-path. The mechanism is iterated until the condition is met. The shortest pathway is represented by equation (1)

$$T_{ij} \leftarrow (1-\rho).T_{ij} + \rho.\Delta_{T_{ij}^{best}} \quad (1)$$

B.ArtificialBee Colony Optimization (ABC)

ABC [2] was inspired from the foraging nature of honey bees. Bee's aim is to search food with high nectar. Intelligent bees (employed) search food based on their experience (predefined knowledge) and they adjust their position accordingly. Employed bees know the source, destination, distance and time required to reach the destination. Others (scouts) fly randomly without experience. If current position has highest nectar bees forgot the previous position. Scouts get information from employed by means of probability value associated with food source. This probability is represented below in equation (2)

$$p_i = \frac{fit_i}{\sum_{n=1}^{\infty} fit_n} \quad (2)$$

C. Bacterial Foraging Optimization (BFO)

BFO [3] is inspired by the social foraging behaviour of Escherichia coli. It is a global search approach and has fast convergence. Bacteria hunt for nutrients in order to maximize its energy level. Bacteria communicate with other by means of sending signals. There are three phases in BFO: chemotactic, reproductive, elimination and dispersal. At each iteration, bacteria move to new position and at each point cost function is calculated. When bacteria move to the favourable condition, it proceeds to swim in the same guidance. When it moves to destructive condition, it swims in the opposite direction. Intention of BFO is to minimize the cost of bacteria movement. The movement of bacteria is represented by (3)

$$\theta^i(j+1,k,l) = \theta^i(j,k,l) + c(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}} \quad (3)$$

D. Genetic Algorithm Optimization (GA)

GA [4] is modelled from Darwin's theory. Specific individual solution in the state has set of chromosomes

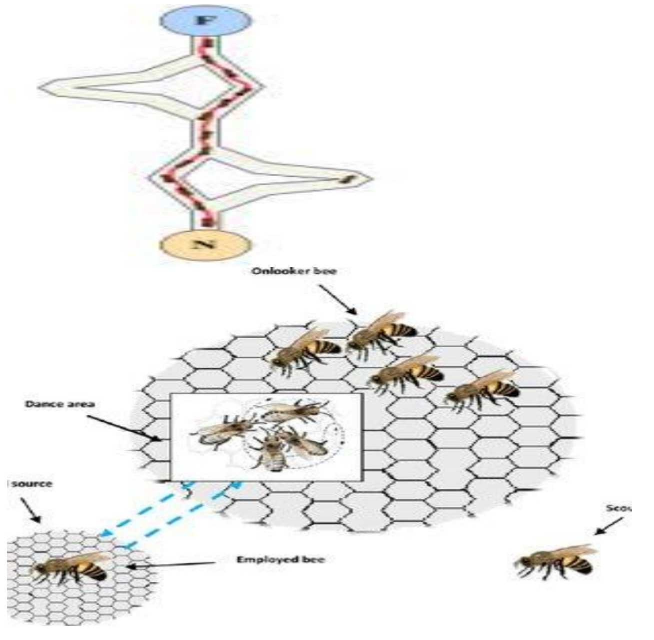

Fig.1 ACO and ABC illustration

Each chromosome has set of parameters known as genes. The purpose is to find the best genes In GA there are three major steps: evaluation, selection and recombination. The fitness values of each individual chromosome in the population are evaluated in the evaluation phase. The parents with best fitness are selected in selection phase and a new population is created in recombination phase. GA has evolution operators such as crossover and mutation to assist the fitness solution. Exact offspring of parents or new offspring is created based on the crossover probability. Permutation encoding is used in routing problem. The importance of GA depends on the competence value. The fitness function is accomplished to increase the lifetime of network, which classifies whether particular chromosome is fit or not. The GA outcome identifies the proper cluster head for network.

$$f(c) = \sum_{i=1}^{N} d_i{}^2 \quad (4)$$

Where the fitness cost function (4) is sum of all distances from cluster head to sink.

E. Particle Swarm Optimization (PSO)

PSO [5] encourages the social grace of flocking birds. Each bird in the solution space is known as particle. All birds have fitness value which is calculated based on the fitness objective function. The fitness function depends on the velocity of the bird and distance of the bird from the prey. Around a number of iterations, a group of bird'sfitness value is adjusted to the bird of best fitnesswhose value is nearest to the target. The bird with maximum fitness is known gbest. The individual fitness value of each bird in search space is represented as pbest. The particle position (pbest) is updated using

$$p_i(t+1) = p_i(t) + v_i(t) \quad (5)$$

Where i is the individual particle in space at position p and velocity v. PSO guarantees best Quality of Service (QOS) in solving routing problems in WSN.

F. Group Search Optimization (GSO)

GSO [6] is confide on the scrounger model behaviour of animal. The attempt to find resources like water, nest and food create progress in animals. Scrounging specify how animals locate resources by adhering with others. Fortunate animals that have learned the location of food will be the producer and others will be the scroungers. Basically producer has high fitness value and scrounger has comparatively less value. Scrounger follow producer in order to meet objective function. Scanning is done at the end of each iteration to find the promising producer. If scrounger finds better producer with high fitness than current producer it would swap the producer. Besides producer and scrounger there are rangers that move randomly outside the boundaries to avoid local minima. For distributed searching space random walks are most efficient searching solution. Good scanningis crucial to solve localization problem. The location detection facility is essential in routing. This also increases the lifetime of network by avoiding undesirable routes.

G. Chicken Swarm Optimization (CSO)

This algorithm [7] represents the foraging behaviour of chicken. The population of chicken is sub-divided into groups. Each group consists of leading rooster, hens and chicks. The chicken with best fitness value is elected as a rooster. All other in the group should follow rooster.

The chick has worst fitness value. Rest is chosen to be hens. Hens have independence to choose the group and it takes place in a random manner. The relationship between hen and chicks (mother-child relationship) is also assumed in a random process. The dominance and hierarchical relationships are maintained fixed. While searching for food each member in the group has different roles. Rooster has the priority to access the food and also the responsibility to safeguard others in group.Hens follow rooster during the exploration of food and it abduct the food of other. Chicks succeed their mother. This algorithm is used in sensor network for load balancing criteria. The foraging behaviour of chicks following mother is given in below equation where $x_{i,j}$ initates the position of chick, $x_{m,j}$ denotes the position of mother and r represents a random number that illustrate the degree of following mother in the below equation (6)

$$x_{i,j}^{t+1} = x_{i,j}^{t} + r * (x_{m,j}^{t} - x_{i,j}^{t}) \qquad (6)$$

H.Firefly Algorithm

Fireflies [8] are insects that induce luminance in night. They use this bright light to attract other flies or prey. The attractiveness is proportional to the brightness. If the brightness decreases, distance increases. Here each firefly represents data forwarding path. The objective function is associated with the attractiveness. To find the route between from one CH to other firefly algorithm is used. The fitness solution is calculated based on residual energy of two fireflies and Euclidian distance between them. The firefly moves randomly based on randomization parameter $\alpha\varepsilon_i$ which is represented as in below equation (7)

$$x_i(t+1) = x_i(t) + \alpha\varepsilon_i \qquad (7)$$

I. Cuckoo Search Algorithm (CS)

It [9] is modelled on the lifestyle and aggressive reproduction strategy of cuckoo species of birds. Cuckoo lays egg in randomly chosen nest. The best quality nest with highest number of eggs is carried out to the next iteration. The host bird finds the egg with a probability and if the host bird finds the unusual egg in it will throw away the egg or leave the nest. The algorithm ensures whether the best eggs survive .The aim of CS is to find the superlative nest with highest quality of eggs which has to be selected as next hop. It is measured by the fitness function F (8). E_{CH_i} represents residual energy of cluster head. d_s denotes the distance between cluster head and base station. N_i is the size of the nest i. β, γ depicts the attraction of cuckoo bird towards particular nest

$$F_i = \frac{E_{CH_i} + \gamma * N_i}{\beta * d_s} \qquad (8)$$

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This algorithm [10is fascinated from the foraging behaviour of bats. Bats are mammals with wings and they possess echolocation (determines the location of target by calculating the time it takes for an echo to return from it) capability. Bat emit solar signal to find the potential prey. This signal comes back if it hits an object. Bats use this signal to interpret the size of the target and location of the target. Bats use intelligent and calculate the time delay between emission and detection of signal. Bat algorithm is used for clustering in WSN. The fitness solution is given in below equation (9)

$$x_{new} = x_{old} + \partial A^t \qquad (9)$$

where $\partial \in [-1,1]$ is a random number and A^t is the average loudness of all the best solution at time t.

K. Shuffled Frog Leaping Algorithm (SFLA)

This algorithm combines local search and global information exchange process. It is based on modelling the behaviour of a group of frogs when searching for location which has the at most amount of food. The population of frogs are divided into groups known as memeplexes. Each sub group perform searching and after searching they shuffle information with other groups. Once local exploration is done all frogs are shuffled together to attain global evolution. This process is repeated until the objective is met. This algorithm is used in clustering. The population is divided into m memeplexes, each containing n frogs hence P=m*n, Frogs with best and worst fitness are described as Xb and Xw and Di is change in frog position. The new position is updated by the below equation (10)

$$New\ position = Xw + Di \qquad (10)$$

L. Squirrel Search Algorithm (SSA)

The process begins when flying squirrel starts foraging behaviour. The behaviour of squirrel changes according to the season. During summer season they stay active and search food by gliding from one tree to other. They tend to store more food for winter days. During winter they remain inactive. Their energy level is directly proportional to the food they consumed. The storage of food for future needs is considered to be the objective function. The trait of food depends on the fitness value of type of trees. They move from acorns to hickory nuts. The acorns are considered to be the worst fitness value and hickory nuts to be the highest fitness one. In routing squirrel search can be used in election of CH. The fitness location of cluster head is based on the energy level of searching node.

M. Fish Swarm Algorithm

This algorithm mimics the swarm behaviour of fish. The environment with food is considered to be the solution space. Fish move in groups to avoid danger. When single fish finds food it communicates with others. The objective function is to find maximum food density. The searching space is contributed by the visual tendency of fish. The movement of fish from current position to fitness location (11) is calculated rand is a random number and s_{ind} is a weighted parameter. This is used in routing where a mobile node search nearest base station based on fitness value.

$$x_i^{t+1} = x_i^{t} + rand * s_{ind} \qquad (11)$$

N.Monkey Search Algorithm

Monkey climbs up the tree to search food. Finding best branch that leads to the fruit is local search criteria. Monkey keeps local solution in memory until it finds global solution. The monkey climbs up the tree targeting branches with better values. Monkey divides into group .Members in sub group communicate within and outside the group. They share solution space (location of food) by means of communication. The foraging behaviour is divided into phases like climb, watch, search and somersault. This algorithm can be used for inter-cluster and intra-cluster communication and also for analysis of cluster.

O. Crow Search Algorithm

This algorithm works based on the brainy behaviour of crows. Crows store excess food in hiding palace and restore when it is essential. Each crow has a capacity to memorize the hiding location. A crow follows another to know its veiling place. The following takes place in two phases like pursuit and evasion. In pursuit crow i follows crow j to find the hiding place of crow j and crow j does not know the presence of crow i. In evasion crow j knows about the presence of crow i so it moves randomly in order to protect the hiding place. The fitness of new position is calculated. If new position is feasible, the objective function is met. This algorithm is used by the node to find the unknown place with the help of nearby nodes.

P. Butterfly Search Algorithm

The fitness function is calculated based on the fragrance produced by the butterfly. This fragrance can be sensed by other butterflies and they can communicate with each other. The local search is characterized when it moves randomly to search a solution space. The global search is characterized when a butterfly could sense the fragrance of other. This algorithm is used to find the accurate position of node in sensor network.

Q. Elephant Herding Optimization

This algorithm was modelled from the herding behaviour of elephants. An elephant group is composed of several clans under the leadership of matriarch. A clan consists of female and clans. Female elephants tend to live with family, while male elephants persist in isolation. This can be represented by two operators-clan updating operator and separation operator. Exploitation phase refers the behaviour of clans while exploration phase represents male moving alone. Each member j of group i follows matriarch (ci) with best fitness solution (12)

$$x_{new,ci,j} = x_{ci,j} + \alpha\left(x_{best,ci} - x_{ci,j}\right) * r \quad (12)$$

Where $x_{best,ci}$ represents the current best position of matriarch, α demonstrates the impact on matriarch and r represents random number to improve diversity of population. This algorithm is used in node localisation problem in Wireless Sensor Network. This is also used to assist group of querying sensors, routing and network coverage.

R.Earthworm Optimization Algorithm

This algorithm represents the reproduction behaviour of earthworm. Earthworm reproduces in two types. In first type only one offspring is produced. In second type more than one offspring is produced. The earthworm with best fitness value (13) will be generated to the next generation. $x_{new\,i,j}$ present the advanced position of child earthworm, $x_{i,j}$ represents the old position of child earthworm, α represents the difference between parent and child position and constants max and min represents the boundaries.

$$x_{new\,i,j} = x_{max,j} + x_{min,j} - \alpha x_{i,j} \quad (13)$$

S. Whale Optimization Algorithm (WOA)

WOA represents the social foraging behaviour of humpback whales. It has acapability to dodge local optima and to attain global optima. The objective of WAO is to discover the search agent position. Once the search agent is discovered, others try to update their position towards best search agent. Whales use bubble-feeding net method. It creates bubbly spiracle net for encircling the prey. This algorithm is used to find nearest neighbour in WSN. It updates the position as in the equation (14) iteratively at each round and best fitness is chosen. Where t is current iteration $\vec{A}\&\vec{D}$ are coefficient vector and $\vec{X}$ is a position vector.

$$\vec{X}(t+1) = \vec{X}(t) - \vec{A}.\vec{D} \quad (14)$$

T. Grasshopper Optimization Algorithm (GOA)

It [models the behaviour of grasshopper. Swarming of grasshopper is mainly focused on searching food. Grasshopper movement varies on size. When it is larval phase, it takes small steps and when it is in adult phase it takes large steps. The large steps are taken in a random manner. The intent of the movement is to search food. The search space is bounded here. The mathematical formula defined for grasshopper movement is given below in the equation (15)

$$X_i = S_i + G_i + A_i \quad (15)$$

Where X denotes the location of grasshopper, S denotes the social interaction, G denotes the gravity experienced by the grasshopper and A denotes the Advection of wind.

U. Salp Swarm Algorithm

This algorithm is modelled from the social foraging behaviour of salps .Salps are small transparent jet propelled tubes. Muscles are contracted to pump water for progressive movement. Long chains of individual are formed for foraging. The first slap in the chain is the leader and other slaps must follow the leader. The target of the chain movement is to find a food source. The best fitness is offered to the leader position and others update their current position nearing to the fitness value. This algorithm is used for cluster head selection in Sensor network.

V. Krill Herd Optimization (KHO)

Krill is cornerstone of entire Antarctic Ocean. They are small and shrimp like crustaceans. KHO models the lifecycle of krill in ocean. This algorithm starts with initial set of population. At each iteration movement, optimization and diffusion are calculated.

Fig.2 Shape of Krill

Fig.3 Salp chain formation

The final displacement position is updated for all individuals. The algorithm bound when the objective is met. The movement is updated by three parameters: evolution caused by other individuals, foraging activity and random diffusion. The fitness function is the multiplication of distance value and density of krill in solution space. The movement of individual krill is represented by the below equation (16), new and old are the best and worst fitness value (velocity) of individual. Maximum induced speed is given by max.α is the best individual target direction and ω is the inertia weight of the motion

$$N_i^{new} = N^{max}\alpha_i + \omega_n N_i^{old} \quad (16)$$

W. Grey Wolf Optimization (GWO)

This algorithm represents the leadership hierarchy and hunting behaviour of grey wolf. Grey wolfs are classified as alpha, beta, delta and omega. Alpha is leader and it is important for decision making. Beta is inferior to alpha and helps alpha in choice forming. Delta overshadow omega and report to beta. Omega is the follower. Hunting process is guided by alpha. According to dominant hierarchy alpha have fittest solution. Update the fitness value of other types according to the alpha value. This technique is established in sensor network where sensor nodes are deployed in strict strategy.

III. ANALYTICAL STUDY ABOUT THE USE OF NIO

The following table 1 represent the various optimization algorithm used for different approaches in recent years. The prominent algorithms have been used repeatedly whereas the newly discovered algorithms are limited in usage. The nature-inspired algorithms have been used for routing optimization, cluster formation, cluster head selection, node localization, node deployment and load balancing. routing issues is explained. At present there are several nature inspired principles. The learning in Research work is carried out in a way to find efficient optimization principle. Several comparison papers prove to be more relevant. Same principle is used to solve different problems. Figure 5 represents the aspiration of these principles in route solving mechanisms. Majority of these principles is used to increase the lifetime of the network. Subsequently summarizing various principles a statistical analysis is made in different viewpoints. Though advanced techniques have been discovered still old techniques are given importance for problem solving. Figure 6 shows the percentage of usage of various techniques in recent years.

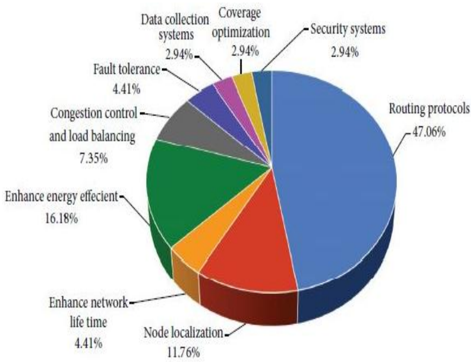

Fig.5 Purpose of NIO in Routing

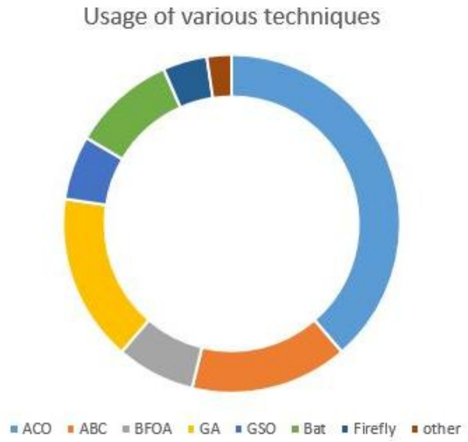

Fig.6 Percentage of mechanisms used

IV. CONCLUSION

In this paper we have a precise description of various techniques and also how these techniques resolved this domain will reach hike. There are some principles which are used less. In future more research must be done to bring advancement in other techniques. Though many issues in routing have been resolved with these principles, problems like sink coverage and guarantee delivery of data packets are unresolved. Besides security issues are unanswered.

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