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Review of Multi-Heuristic Bio-Inspired Routing Algorithms for Wireless Sensor Networks

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ABSTRACT: Wireless Sensor Network (WSN) is a growing field in various domains particularly in Internet of Things (IOT). Recent advances in WSN have led to use many optimization algorithms in routing protocol or many new routing protocols for sensor networks. Various optimization algorithms are used to optimize the routing parameters based on network scenario. In this paper, different optimization algorithms are reviewed which are based on Nature for solving many difficult problems and complex tasks. The collection of these algorithms is called as Bio-Inspired Algorithm (BIA) which is meta-heuristic. This paper widely gives the view about Bio Inspired Algorithm where in which domain it was implemented and uniqueness of the specific domain are detailed in the wireless network domain.

KEYWORDS: Wireless Sensor Network, routing protocols, Bio Inspired Algorithms.

I. INTRODUCTION

Wireless sensor network (WSN) [1] refers to the group of sensors for recording and monitoring the physical environment conditions and the collected data are organized at a central location. Wireless sensor network is grown as a potential domain in networking. In wireless sensor network, networking layer has meant to have a vital role. The network layer plays a vital role in transferring variable-length network packets from a source via one or more networks to the destination host. Within the service layer of OSI (Open

System Interconnection) network architecture, the network layer handles the service requests from the transport layer as shown in the figure 1 and issues service requests to the data link layer, it also include connectionless communication.

Routers prevent broadcast propagation and use more intelligent forwarding algorithms than bridges, routers provided more efficient use of bandwidth which results in flexibility, optimal path selection and also provides ease of implementation of load balancing across multiple paths in most networks when using routing

A routing protocol sets rules for routers how to communicate with each other, casting information in a specific route between any two nodes on a computer network, it provides appropriate addressing information in its network layer to allow a packet to be forwarded from one network to another. Routers perform traffic directing functions on the internet. Some of the routing protocols are interior gateway protocol, exterior gateway protocol etc

Interior gateway protocol exchange routing information within a single routing domain. Exterior gateway protocols exchange routing information between autonomous systems. Some basic parameters in networking domains are

(i) Overhead
(ii) Delay
(iii) Route quality
(iv) Route establishment
(v) Recovery time
(vi) Packet delivery/loss
(vii) Optimal route finding

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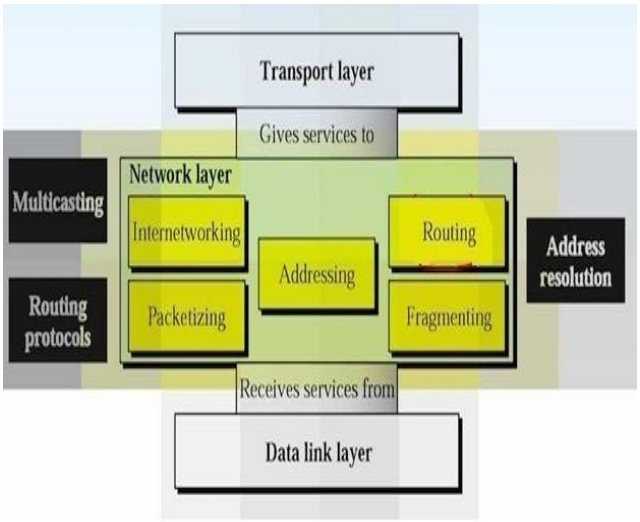

Fig: 1 Network layer

Optimization comes to have good results in all the metrics. Networks optimization must be able to ensure optimal usage for system resources. Improve productivity as well as efficiency. The Network optimization often works in traffic shaping, redundant data elimination, data caching and streamlining of protocols. In networking the nodes communicate in multi hop routing technique. In multi hop routing the transmission of packets are not well defined and overheads cannot be achieved. To overcome these issues Bio Inspired Algorithms are utilized. Section 2 deals brief introduction on BIA and its classifications. Section 3 discusses about the result of all the algorithms and in section 4 conclusions and future work of this paper is focused.

II. BIO-INSPIRED ALGORITHMS

A Bio inspired algorithm (BIA) [2] is an algorithm which is inspired from biological phenomena in order to aid in computation. The complexities and optimization found in natural phenomena are mimic by using this algorithm in order to solve computationally similar problems. It basically involves the steps of growth, survive and reproduction these process can be used in routing domains.

BIA's are most commonly separated into three groups as Evolutionary Algorithm (EA), Swarm Intelligence (SI) and Ecology. The main distinction between these two groups is that the group which is inspired by evolutionary phenomena, such as reproduction and mutation, are known as EA, whereas SIs are more commonly an inspiration involving local agents working in an environment ("swarming") to produce a type of global intelligence, such as ant colonies and bee colonies. Ecology algorithm deals and inspired from the whole ecosystem of any species.

Evolutionary Algorithm is subdivided into three types

- Genetic Algorithm
- Evolution Strategy
- Genetic Programming

Swarm based are subdivided into

- Human Immune System
- Convergent Social Phenomenon
- Nature river System

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The inner division of this swarm based algorithm is shown in the figure: 2

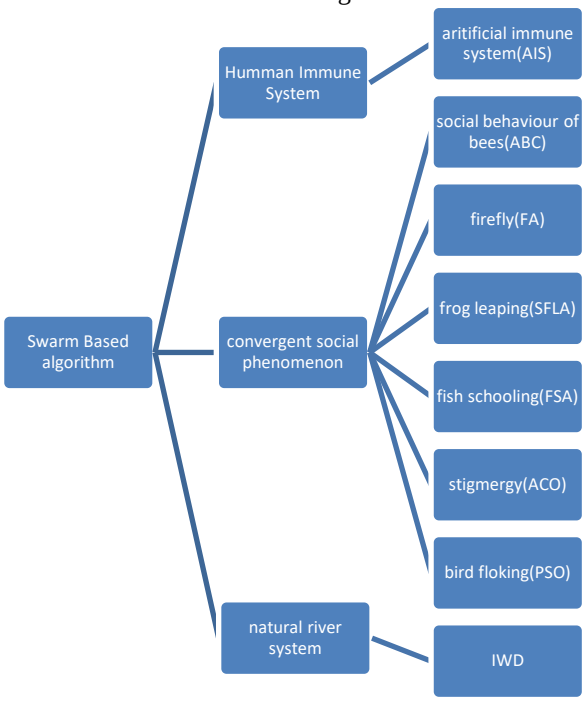

Fig: 2 Classification of bio-inspired algorithms

A. GENETIC ALGORITHMS:

GAs are a type of EA that aim to provide solutions in the same way as can be found in the process of natural selection within an environment [3] . GA can also be used in multicast routing [4]. The basic process of a GA can be broken into the following steps:

- **Initialization:**

  The algorithm started to create the sequence of new population. The algorithm uses the individuals in the current generation to create the next generation.
- **Creation of new population:**
  a) Each members are evaluated by computing its fitness value
  b) The raw fitness value coverts to usable range of values.
  c) Select the members based on the expectation.
  d) The individuals with lower fitness level are passed to next population.
  e) The current population of the children are replaced by the next generation
- **Fitness test:**

  The fitness function determines how fit an individual is (the ability of an individual to compete with other individuals). It gives a fitness score to each individual. The probability that an individual will be selected for reproduction is based on its fitness score.
- **Selection:**

  The idea of selection phase is to select the fittest individuals and let them pass their genes to the next generation. Two pairs of individuals (parents) are selected based on their fitness scores. Individuals with high fitness have more chance to be selected for reproduction.
- **Cross over:**

  Crossover is the most significant phase in a genetic algorithm. For each pair of parents to be mated, a crossover point is chosen at random from within the genes.

- **Stopping:**

  The algorithm stops when the criteria Mets time limit, fitness limit, stall generation, stall time limit, stall test, function tolerance, constrain tolerance. We can set the value of this parameter as stopping criteria figure 3 shows the flowchart of genetic algorithms [5].

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[6] In this paper the implementation of Genetic Algorithm is surveyed. The main optimal solution for the Genetic Algorithm is for the use of FJSSP (Flexible Job Shop Scheduling Problems) [7]. Even though it is best in this domain it has the draw back as largely energy consumption and the security provided for this in wireless sensor network are less.

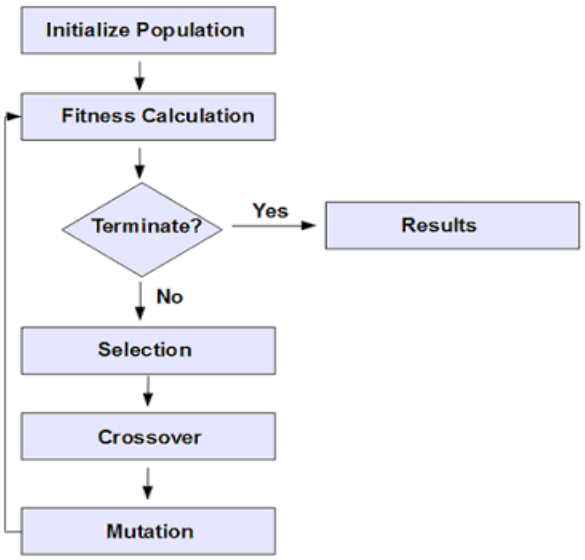

Fig: 3 flowchart of GA

Application in Wireless Networks:

1) Wireless Node Placement
2) Bandwidth Allocation
3) Channel Assignment/Allocation , power system allocation
4) scheduling multi core systems
5) predicting load settlement behavior

B. ANT COLONY ALGORITHM

Another popular algorithm of the SI is an ACO algorithm [8]. In real ants they will segregate a kind of chemical known as pheromone, which can be used for communication, the receiving ants follow the pheromone. [9]

- **Principle:**

Initially the ants are all originated in colonies and they need to find food for their location and they have to bring the food back to the home. In the beginning the ants move randomly and it will lay down the trail, the will attracts the ant to move towards its position after sometimes the path with the better performing path will be selected based on the strength of pheromone. The path with the poor performance will get evaporated and eventually the ant will follow the optimal path.

- **Construction**: iterative building of solutions by "ants", simulating the foraging behavior of ants
- **Pheromone Update**: trails updated according to appropriate pheromone calculation function, with "better" trails leaving probabilistically higher levels of pheromone; over time, pheromone levels naturally drop if not updated (to allow the "ants" to forget the worse trails)
- **Daemon Actions**: an optional step which updates based on global perspective
- **Termination**: once the stopping condition(s) is met, the algorithm exits. Figure 4 shows process of finding the shortest path.

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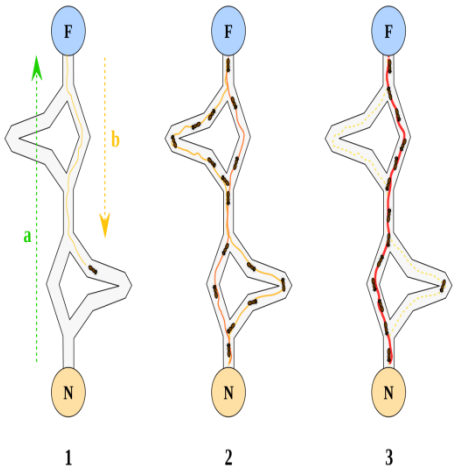

Fig: 4 Behavior of ants

In ACO, the Construction, Pheromone Update, and (potentially) Daemon Actions steps are repeated continuously until the Termination step is met [10]. At each iteration, the possible trails are evaluated, with the better trails leaving stronger pheromones (as shown in the fig 5) and the worse trails leaving continually weaker pheromones, thereby converging at the optimal for the solution set.

[8]This paper provides the solving process of multi objective ant algorithm. And while comparing this algorithm with others regarding solving quantity, solving efficiency and so on. It works well in solving the discrete combinatorial optimization problem [11]. It has supported the development of the WSN along with it improvement it has enable negligible path in the network.

Direction selection:

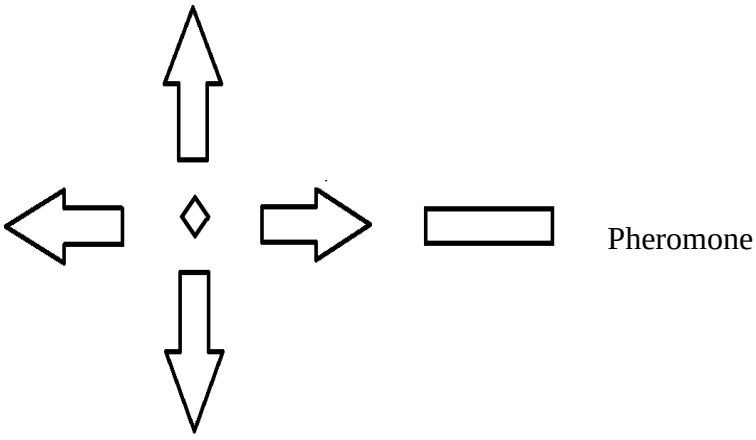

Fig: 5 path selection of ants

C. ARTIFICIAL BEE COLONY:

The next SI algorithm focuses on intelligent foraging behavior of honey bee [12].

- **Initialization**: population randomly distributed over problem space and food source produced for all employed bees
- **Update**: action determined by bee type, unused food sources are replaced by the new food sources found by scouts; the best food source is registered

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- **Employed bee**: goes to food source from memory; finds neighbor food source, evaluates this food source, and dances
- **Onlookers**: watches the employed bees and chooses a food source based on dance (via some probability function that generates the probability, Pi, for that particular food source - for an example); finds neighbor food source and evaluates this food source
- **Scouts**: finds new food source

- **Termination**: once the stopping condition(s) is met, the algorithm exits.

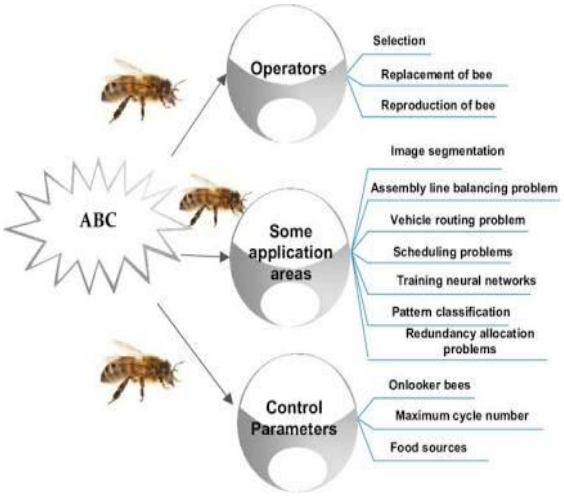

Fig: 6 Process of ABC

Once the Initialization step is completed, the algorithm repeats the Update step until the Termination condition(s) is met, at which point the algorithm exits. The various application of ABC in wireless sensor networks are 1) Energy Efficiency 2) Sensor Deployment 3) base station development 4) prediction of filled frame structure [13] 5) vehicle base station development [14].

In [15] gives total summary about the Artificial Bee Colony algorithms advantages theoretical conceptual clarity that this is the wide field of area which is to be researched more findings and experiments have to be performed based on this ABC, Particularly on the self adaptation of control parameter. In order to improve the performance of the ABC in terms of convergence, diversity is provided. Moreover like any algorithm this ABC also has some drawback like crossover as in GA the information distributed of good information between the solutions but not as required level thus the convergence of ABC becomes low.

D. SHUFFLED FROG LEAPING ALGORITHM:

Shuffled frog leaping algorithm is a meta-heuristic swarm-based optimization algorithm, which mimics the social behavior of memetics [16].

- **Initial population**:
  Individual frogs are equivalent to the GA chromosomes, and represent a set of solutions.

- **Sorting and distribution** :
  Frogs are sorted in descending order based on their fitness values, then each frog is distributed to a different subset of the whole population called a memeplex, the entire population is divided into m memeplexes, each containing n frogs

- **Memeplex evolution**:
  An independent local search is conducted for each frog memeplex, in what is called memeplex evolution.

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- **Shuffling**:
  After a defined number of memetic evolutionary steps, frogs are shuffled among memeplexes, enabling frogs to interchange messages among different memplexes and ensure that they move to an optimal position, similar to particles in PSO as shown in figure 7.

- **Terminal condition**:
  If a global solution or a fixed iteration number is reached, the algorithm stops.

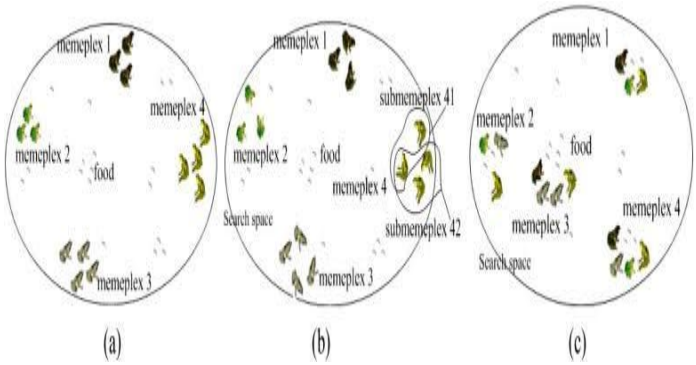

Fig: 7 illustration of shuffled frog leaping algorithm

It finds applications in WSN as 1) Multicast Routing Optimization 2) cognitive radio throughput 3) bio-medical data handling [17].

[18] In this paper there is improvement in the Shuffled Frog Leap Algorithm(SFLA) local search mechanism for clustering for the improvement of the problem of long single chain in multi-hop routing algorithm. So, that the result of this paper shows that it can balance the network energy and increase the network lifetime efficiently. However in this paper the end to end transmission delay and and packet level ratio is decreased due to the node redundancy and routing path loss.

E. FISH SWARM ALGORITHM:

FSA imitates three typical behaviors, defined as searching for food, swarming in response to a threat, and following to increase the chance of achieving a successful result, figure 8 shows the flowchart of FSA.

- **Searching**:
  It is an algorithm in which the fish starts searching for the food. So it travels in a random direction in terms of satisfaction for itself.

- **Swarming**:
  It aims in satisfying food intake needs, entertaining swarm members and attracting new swarm members. A fish located at $\mathbf{X_i}$ has neighbors within its visual. $\mathbf{X_c}$ identifies the center position of those neighbors and is used to describe the attributes of the entire neighboring swarm. If the swarm center has greater concentration of food than is available at the fish's current position $\mathbf{X_i}$ (i.e., $\mathbf{F_{Sc} < F_{Si}}$), and if the swarm ($\mathbf{X_c}$) is not overly crowded ($ns/n < \delta$), the fish will move from $\mathbf{X_i}$ to next $\mathbf{X_{i+1}}$, towards $\mathbf{X_c}$.

- **Following:**
  The behavior implies when a fish locates food, neighboring individuals follow. Within a fish's visual, certain fish will be perceived as finding a greater amount of food than others, and this fish will naturally try to follow the best one($\mathbf{X_{min}}$) in order to increase satisfaction(i.e., gain relatively more food[$\mathbf{F_{Smin}<F_{Si}}$] and less crowding [$\mathbf{nf/n < \delta}$]). **nf** represents number of fish within the visual of $\mathbf{X_{min}}$.

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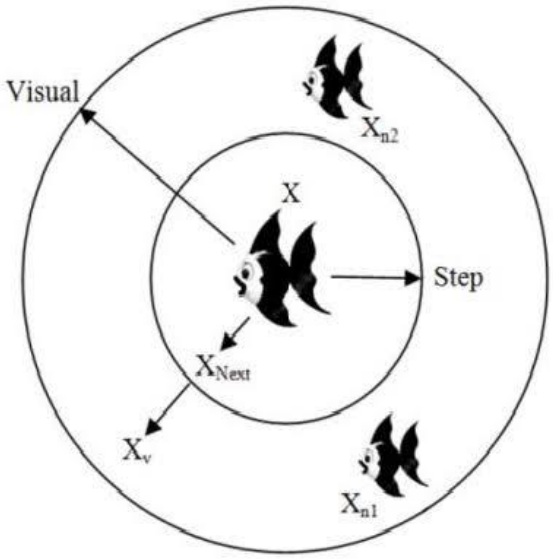

Fig 8 Operation of FSA

It has many applications in wireless sensor networks like

1) Visual distance, 2) max step length, 3) crowd factor
4) traffic control system [19],
5) optimization [20].

[21]In this paper that compared to all Swarm Intelligent algorithm this Fish Swarm Algorithm is more intelligent algorithm and thus it obtained more optimal result for more complex tasks compared to other Swarm intelligent Algorithm. Thus improvement of the FSA make use of in the domain like image processing, data mining, optimization etc., Thus it also has some advantages like high convergence speed, flexibility, error tolerance and High accuracy. And it has draw back in the local optimal points, advanced convergence and time consuming.

F.FIREFLY ALGORITHM:

The algorithm constitutes a population-based iterative procedure with numerous agents (perceived as fire flies) concurrently solving a considered optimization problem.

1) All fireflies are unisex and they will move towards more attractive and brighter ones regardless of their sex.

2) The degree of attractiveness of a firefly is proportional to its brightness. Also the brightness may decrease as the distance from the other fire flies increases due to the fact that the air absorbs light. If there is not a brighter or more attractive fire fly than a particular one it will then move randomly.

3) The brightness or light intensity of a fire fly is determined by the value of the objective function of a given problem [22]. This algorithm can be used to control the shape and size optimization. Figure 9 shows the flowchart of firefly algorithm.

[23] In this paper meta-heuristic Firefly Algorithm work is present and the result of the algorithms are presently compared with the Energy aware clustering Algorithm. In this also it shows improvement in the increased lifetime of the network and increased packet delivery ratio of the nodes in the network. Thus the loss of packet in the network communication is totally reduced but the time taken for the formation of the algorithm is more.

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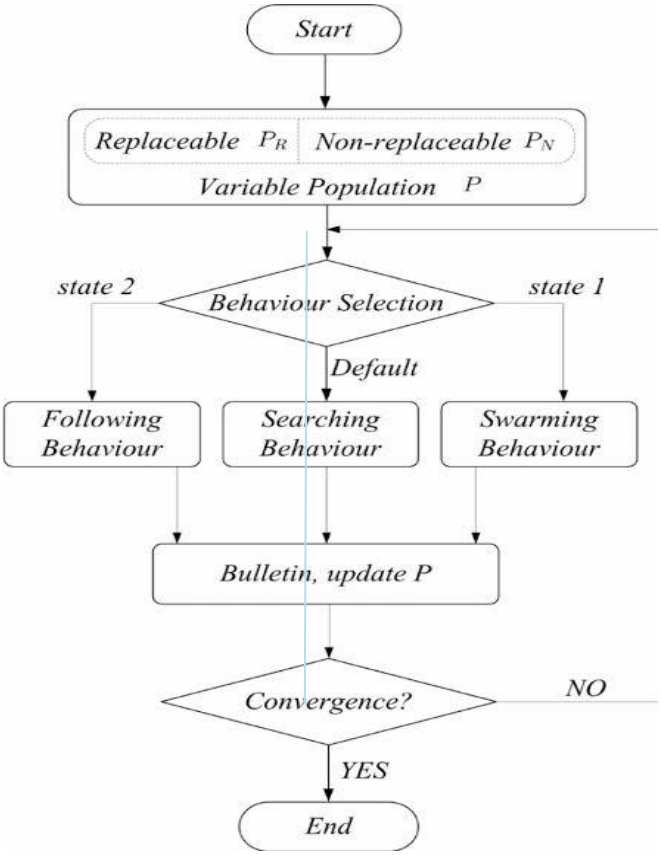

Fig: 9 flowchart of firefly algorithm

G. ARTIFICIAL IMMUNE SYSTEM:

Artificial immune system (AIS) [24] is inspired by the human immune system which is a highly evolved, parallel and distributed adaptive system that exhibits the following strengths: immune recognition, reinforcement learning, feature extraction, immune memory, diversity and robustness.

1. **Initialization** of antibodies (potential solutions to the problem). Antigens represent the value of the objective function f(x) to be optimized.

2. **Cloning**, where the affinity or fitness of each antibody is determined. Based on this fitness the antibodies are cloned; that is the best will be cloned the most. The number of clones generated from the n selected antibodies is given by: Nc =∑ round (β*j/i) i = 1, 2…….n , Where Nc is the total number of clones, β is a multiplier factor and j is the population size of the antibodies.
3. **Hyper mutation**: The clones are then subjected to a hyper mutation process in which the clones are mutated in inverse proportion to their affinity; the best antibody‘s clones are mutated lesser and worst antibody‘s clones are mutated most. The clones are then evaluated along with their original antibodies out of which the best N antibodies are selected for the next iteration. The mutation can be uniform, Gaussian or exponential. It as applications such as Network attack, multiple objective [25].

In this paper Artificial Immune System aims on solving the complex problems related to distributed and dynamic environment. This paper contain larger source about the immune system Algorithm, negative selection algorithm these all combined and uniquely led to the way of new application in the AIS. It serves as analogies in the department of new system.

H. PARTICLE SWARM OPTIMIZATION:

Particle Swarm Optimization (PSO) is a computational method that optimized a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. It solves a problem by having a population

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of candidate solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity [27].

1) Initialize the swarm by assigning a random position in the problem space to each particle.

2) Evaluate the fitness function for each particle.

3) For each individual particle, compare the particle‘s fitness value with its pbest . If the current value is better than the pbest value, then set this value as the pbest and the current particle‘s position, xi, as pi.

4) Identify the particle that has the best fitness value. The value of its fitness function is identified as guest and its position as pg.

5) update the velocities and positions of all the particles using (1) and (2).

6) Repeat steps 2–5 until a stopping criterion is met (e.g., maximum number of iterations or a sufficiently good fitness value) as shown in figure 10.

[25] In this paper we discuss about the Wireless Sensor Network in which it has the simple and complex problem related to the node deployment, data aggregation localization and energy aware clustering as optimization problem. The PSO is one of the popular technique to solve the optimization problem due to the simplicity and fast convergence but it has the disadvantage of using more memory due to that it may limit the implementation on resource-rich base station.

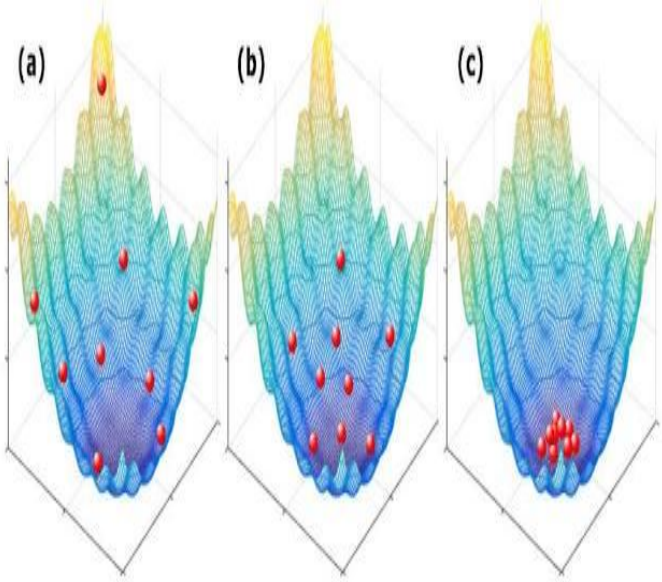

Fig: 10 Illustration of PSO

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TABULATION:-

Table 1: summary of various BIA

NAMEOF THE ALGORIHM	OPERATIONS	CONTROL PARAMETERS
GA	Crossover, mutation, selection, Inversion , Gene Silencing	Population size, max.generation number, cross over probability, mutation probability, length of chromosome, chromosome encoding
ACO	Pheromone Update and Measure, trail evaporation	number of ants ,iterations , pheromone evaporation rate, amount of reinforcement
ABC	Reproduction, replacement of bee, selection	number of food sources which is equ to the number of employed or onlooke bees (SN), the value limit, the maximum cycle number (MCN
SFLA	Replacement, shuffling	number of frogs P, number of memeplexes, and number of evolutionary iterations for each memeplex before shuffling.
FSA	Swarming ,following, searching	Visual distance,max step length ,crowd factor
FIREFLY	Behavior selection, decision making.	Attractiveness, randomization and absorption
AIS	immune operators(cloning, hyper mutation and selection based on elitism)	Antibody population size ,. Number of antibodies to be selected for hyper-mutation ,number of antibodies to be replaced, multiplier Factor β
PSO	Evaluation of fitness, updating velocity and position.	No. of particles, acceleration coefficients,inertia weight,neighbourhood size, no. of iteration

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III. RESULT AND FUTURE WORK

From the above surveyed papers each algorithm is specialized in a particular domain. Generally all these SI algorithm used for the optimization reason but on the each algorithm the optimization reason differs that explained as in the GA is utilized in the scheduling problem because it has more draw backs in the energy consumption field. Then ACO is preferred over other algorithm it has the load balancing and the optimal path identification the efficiency of this compared to other in this domain is more. The ABC algorithm is used for energy efficiency problem and base station problems but it has drawback of using it in convergence. SFLA it is more efficient in increasing the network lifetime and node redundancy.

FSA it is specialized in the error tolerance and speed convergence but the time taken for the iteration of the algorithm is more. FA due to the random movement in this algorithm over other it has less packet loss. AIS it has clone selection and immune selection mechanism so it is utilized in the Intrusion Detection System and Data Mining .PSO is often used in power management, optimal power flow problem, it has the defect on the dependency on the initial point parameter. Then concerning about future works the every algorithm needed to be improved in some ways the survey based on the swarm intelligent algorithm gives the more brief idea that ACO can be used on the load balancing of the networking field.

IV. CONCLUSION

From the above surveyed papers there are some algorithms listed above that each algorithm has some specific advantages. We can infer from the table that genetic algorithm its mostly used for the power system optimization problems, in ant colony algorithm used in robotics, load balancing and data mining, in artificial bee colonies used for the line balancing and for scheduling problem, in shuffled frog leap algorithm used in image sectors, in fish swarm algorithm used in geo technical engineering problem, in fire fly algorithm used for random route paths, in particle swarm optimization it used for web services so from that we can conclude that not one algorithm is the best this shows each algorithm has some specific domain to be dealt this shows that for our specific problem we can use specific algorithm.

The real analysis of the algorithm is usage of BIA in the routing protocols like vehicular routing MANET. In network domain the analysis of the algorithm done that we can use the optimal algorithm for load balancing problem. Many optimization techniques like Data Balancing, data gathering, energy management etc can be invoked in these algorithms in future for high efficiency.

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