LIFE TIME IMPROVEMENT IN WIRELESS SENSOR NETWORKS USING META-HEURISTIC ALGORITHMS

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ABSTRACT

Wireless Sensor Network is a special type of wireless ad-hoc networks, which is the collection of distributed autonomous sensor system for physical or environmental monitoring by using radio frequency deployed in Infrastructure-lessenvironment. Sensor node in WSN is small in size and collects data from its surrounding and forwards the data to the sink node by using radio frequency. Sink node in the sensor networks collects the data from sensor nodes and by applying aggregation techniques on huge collection of data to reduce the consumption in the channel forwards to the gateway.Gateway in the sensor networks provides the communication links between wireless and wired network. Clustering approaches prolong the network lifetime with load balance network. Cluster head selection process is pivotal for clustering algorithms. Clustering and cluster-head selection using meta-heuristics will give immense results when compare with other search algorithm.

*Keywords:- Wireless Sensor Network, Leach, Meta-heuristics Techniques, Firefly Algorithm***.**

Introduction to Wireless Sensor network

A Wireless Sensor Network consists of multiple detection stations called sensor nodes, from a few to several hundreds or even thousands, where each node is connected to one or sometimes several sensors. Every sensor node is equipped with a transducer, microcomputer, transceiver and power source. The transducer generates electrical signals based on sensed physical effects and phenomena. The microcomputer processes and stores the sensor output. The transceiver receives commands from a central computer and transmits data to that computer. The power for each sensor node is derived from a battery. The positions of sensor nodes in network need not be engineered or predetermined i.e. nodes are random deployment in inaccessible terrains or hazardous environments. The sensor node is a multi-functional, energy efficient wireless device. The applications of motes in industrial are widespread. A collection of sensor nodes collects the data from the surroundings to achieve specific application objectives. In contrast with sensor networks, Ad hoc networks will have fewer nodes without any structure. In Wireless sensor networks there are two kinds of wireless nodes; sensor and base station nodes. The main function of the base station relies on managing the actions executed to provide reliable and efficient sensing support. It provides a gateway to other networks or acts as a data storage processing data in a powerful way. It even acts as an access point to human interface for human interaction, and is capable of broadcasting control data in the network or removes data from it[1]. The base station node will calculate and send the even source, its position and a timestamp to the analysis center. If an alert is received by the base station regarding a target, an identity of the target will be allocated allowing all related alerts getting appropriate management.

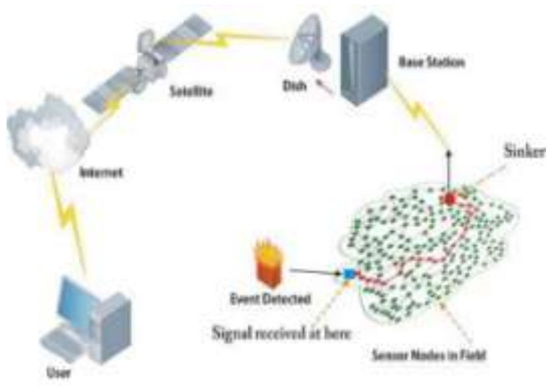

Fig 1: Wireless Sensor Network

Architecture of Wireless Sensor Network

WSN is dynamic which can consist of various types of sensor nodes. The environment is heterogeneous in terms of both hardware as well as software. The sensor node construction focuses to reduce cost, increase flexibility, provide fault tolerance. Improve development process and conserve energy. The structure of sensor node consists of sensing unit (sensor and analog to digital converter), processing unit (processor and storage), communication unit (transceiver), and power supply unit[1]. The major blocks shown in Fig. 2 a concise description of different unit is as follows:

Sensing Unit : Sensing units are usually composed of two subunits: sensors and Analog to Digital Converters (ADCs). Sensor is a device which is used to translate physical phenomena to electrical signals. Sensors can be classified as either analog or digital devices. There exists a variety of sensors that measure environmental parameters such as temperature, light intensity, sound, magnetic fields, image, etc. The analog signals produced by the sensors based on the observed phenomenon are converted to digital signals by the ADC and then fed into the processing unit.

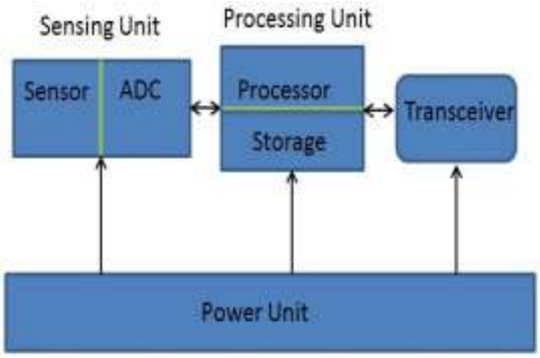

Fig 2: Architecture of Wireless Sensor Network

Processing Unit: The processing unit mainly provides intelligence to the sensor node. The processing unit consists of a microprocessor, which is responsible for control of the sensors, execution of communication protocols and signal processing algorithms on the gathered sensor data.

Transceiver Unit: The radio enables wireless communication with neighboring nodes and the outside world. It consists of a short range radio which usually has single symmetric channel. There are several factors that affect the power consumption characteristics of a radio, which includes the type of modulation scheme used, data rate, transmit power and the operational duty cycle. Similar to microcontrollers, transceivers can operate in transmit, receive, idle and sleep modes. An important observation in the case of most radios is that, operating in idle mode results in significantly high power consumption, almost equal to the power consumed in the receive mode.

Power unit:The task of the power unit is to provide the energy to the sensor node for monitoring the environment at a low cost and less time. The life of the sensor depends on the battery or power generator which is connected to the power unit. Power unit is required for the efficient use of the battery.

The most common WSN architecture follows the OSI architecture Model. The architecture of the WSN includes five layers and three cross layers. Mostly in sensor network we require five layers, namely application, transport, network, data link & physical layer. The three cross planes are namely power management, mobility management, and task management. Figure 3 shows a typical architecture of WSN.

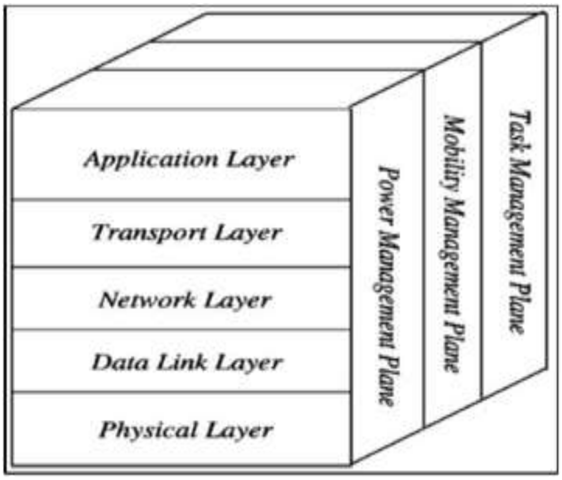

Fig 3: WSN Architecture

A. Application Layer: The application layer is liable for traffic management and offers software for numerous applications that convert the data in a clear form to find positive information. Sensor networks arranged in numerous applications in different fields such as agricultural, military, environment, medical, etc.

B. Transport Layer: The function of the transport layer is to deliver congestion avoidance and reliability where a lot of protocols intended to offer this function are either practical on the upstream. These protocols use dissimilar mechanisms for loss recognition and loss recovery. The transport layer is exactly needed when a system is planned to contact other networks. Providing a reliable loss recovery is more energy efficient and that is one of the main reasons why TCP is not fit for WSN. In general, Transport layers can be separated into Packet driven, Event driven. There are some popular protocols in the transport layer namely STCP (Sensor Transmission Control Protocol), PORT (Price-Oriented Reliable Transport Protocol and PSFQ (pump slow fetch quick).

C. Network Layer: The main function of the network layer is routing, it has a lot of tasks based on the application, but actually, the main tasks are in the power conserving, partial memory, buffers, and sensor don't have a universal ID and have to be self-organized. The simple idea of the routing protocol is to explain a reliable lane and redundant lanes, according to a convinced scale called metric, which varies from protocol to protocol. There are a lot of existing protocols for this network layer, they can be separate into; flat routing and hierarchal routing or can be separated into time driven, query-driven & event driven.

D. Data Link Layer: The data link layer is liable for multiplexing data frame detection, data streams, MAC, & error control, confirm the reliability of point–point (or) point– multipoint.

E. Physical Layer: The physical layer provides an edge for transferring a stream of bits above physical medium. This layer is responsible for the selection of frequency, generation of a carrier frequency, signal detection, Modulation & data encryption. IEEE 802.15.4 is suggested as typical for low rate particular areas & wireless sensor network with low cost, power consumption, density, the range of communication to improve the battery life.

Applications of Wireless Sensor Networks:

There are numerous applications of WSNs in industrial automation, traffic monitoring and control, medical device monitoring and in many other areas[2]. Some of applications are discussed below:

Fig 4: WSN Applications

LEACH (Low Energy Adaptive Clustering Hierarchy) Protocol:-

In order to extend the network lifetime, many routing protocols have been devised. One of these is network clustering, in which network is partitioned into small cluster and each cluster is monitored and controlled by a node called cluster-head.

LEACH stands for Low-energy adaptive clustering hierarchy. It is first proposed by Wendi B. Heinzelman in the year 2000. It is a clustering-based protocol that minimizes energy dissipation in sensor networks. The reason we need these type of network protocol such as LEACH is due to the fact that a node in the network is no longer useful when its battery dies. This protocol allow to planetary out the lifespan of the nodes, allow it to do only the minimum work, when it needs to transmit data[3]. The main determination of leach is to randomly select sensor nodes as cluster-heads, so the high-energy dissipation during the communication with the base station is spread to all sensor nodes in the sensor network.

All nodes in the network organize themselves into local clusters, with one node in the local cluster acting as cluster head. All nodes communicate only to the cluster head, and the cluster head conveys data to the base station. Nodes with higher capability advertise themselves as cluster heads, other nodes join the cluster head which is nearest to them. As cluster head has to spend lot of energy ,after certain time, randomized rotation of the cluster head is done, so that only node does not drain its energy. Every cluster head will prepare a schedule, to each of its members. The members communicate with the head only during that duration and sleep for the rest of the time.LEACH operations can be divided into two phases:-

1. Setup phase
2. Steady phase

In the setup phase, the clusters are formed and a cluster-head (CH) is chosen for each cluster. While in the steady phase, data is sensed and sent to the central base station. The steady phase is longer than the setup phase. This is done in order to minimize the overhead cost.

1.Setup-phase:- During the setup phase, a predetermined fraction of nodes, p, choose themselves as cluster-heads. This is done according to a threshold value, T(n).

The threshold value depends upon the desired percentage to become a cluster-head- p, the current round r, and the set of nodes that have not become the cluster-head in the last 1/p rounds, which is denoted by G.

The formulae is given as follows:-

$$T(n) = \frac{p}{1 - p * \left(r * mod \frac{1}{p}\right)} \forall n \epsilon G$$

Every node wanting to be the cluster-head chooses a value, between 0 and 1. If this random number is less than the threshold value, T(n), then the node becomes the cluster- head for the current round. Then each elected CH broadcasts an advertisement message to the rest of the nodes in the network to invite them to join their clusters. Based upon the strength of the advertisement signal, the non-cluster head nodes decide to join the clusters. The non-cluster head nodes then informs their respective cluster-heads that they will be under their cluster by sending an acknowledgement message. After receiving the acknowledgement message, depending upon the number of nodes under their cluster and the type of information required by the system (in which the WSN is setup), the cluster-heads creates a TDMA schedule and assigns each node a time slot in which it can transmits the sensed data.

2.Steady phase :-During the steady phase, the sensor nodes i.e. the non-cluster head nodes starts sensing data and sends it to their cluster-head according to the TDMA schedule. The cluster-head node, after receiving data from all the member nodes, aggregates it and then sends it to the base-station.

Advantages of LEACH

LEACH is a complete distributed routing protocol in nature. Hence, it does not require global information. The main advantages of LEACH include the following:

1) Concept of clustering used by LEACH protocol enforces less communication between sensor nodes and the BS, which increases the network lifetime.

2) CH reduces correlated data locally by applying data aggregation technique which reduces the significant amount of energy consumption.

3) Allocation of TDMA schedule by the CH to member nodes allows the member nodes to go into sleep mode. This prevents intra cluster collisions and enhances the battery lifetime of sensor nodes.

4) LEACH protocol gives equal chance to every sensor node to become the CH at least once and to become a member node many times throughout its lifetime. This randomized rotation of the CH enhances the network lifetime.

Disadvantages of LEACH

However, there exist some disadvantages in LEACH which are as follows:

1) In each round the CH is chosen randomly and the probability of becoming the CH is the same for each sensor node. After completion of some rounds, the probability of sensor nodes with high energy aswell as low energy becoming the CH is the same. If the sensor node with less energy is chosen as the CH, then it dies quickly. Therefore, robustness of the network is affected and lifetime of the network degrades.

2) LEACH does not guarantee the position and number of CHs in each round.

Formation of clusters in basic LEACH is random and leads to unequal distribution of clusters in the network. Further, in some clusters the position of the CH may be in the middle of the clusters, and in some clusters the position of the CH may be nearthe boundaries of the clusters. As a result, intra cluster communication in such a scenario leads to higher energy dissipation and decreases the overall performance of the sensor network.

3) LEACH follows single hop communication between the CH and the BS. When the sensing area is beyond a certain distance, CHs which are far away from the BS spend more energy compared to CHs which are near to the BS. This leads to uneven energy dissipation which ultimately degrades the lifetime of the sensor net.

Direct Transmissions(DT):

Using a direct communication protocol, each sensor sends its data directly to the base station. If the base station is far away from the nodes, direct communication will require a large amount of transmit power from each node. This will quickly drain the battery of nodes and reduce the system lifetime. However the only reception in this protocol occur at the base station, so if either the base station is close to the nodes, or the energy required receiving data is large, this may be an acceptable (and possibly optimal) method of communication (Wang et al 1999).

Meta-Heuristics Techniques:-

In recent years, optimization is a booming research area for providing an optimal solution to complex real-time problems. Multi-dimensionality, multi-modality, multi objective, differentiability and different combinatorial characteristics are coped with these problems. The demand for solving real-time problems has attracted many researchers to develop fast, accurate and computationally powerful optimization algorithms[4]. Researchers from various domains have introduced many numerical optimization techniques to attain better solution for these problems. Historical problem solving techniques are classified into two techniques: Extract and Heuristics methods. Logical and mathematical programming are involved in Extract methods to solve NP complete problems whereas heuristics method seems to be superior in solving NP-hard and complex optimization problems.

Meta-heuristic are refined scientifically to find an optimal solution that is "good enough" in a computing time that is "small enough". Meta-heuristic optimization algorithms are aids to solve
wide range of real-time problems due to its

A. simplicity and easy to implement,
B. does not need slope information,
C. avoid local optima,
D. Can be exploited in an ample range of problems wrapping different disciplines.

Methods of optimization are not used for their impracticality in complicated real life situation. Nature-inspired meta-heuristic algorithms like Particle Swarm Optimization (PSO), Genetic Algorithm (GA), Ant Colony Optimization (ACO) and Firefly Algorithm (FA) are considers as powerful algorithms for optimization.In 1989, Goldberg published a well-known book on genetic algorithms. Dorigo(1992) completed his PhD thesis, in which he described his innovative work on ant colony optimization.One pioneer contribution is the proposition of the particle swarm optimization by Kennedy &Eberhart(1995).

The goal of meta-heuristic algorithm is to make use of heuristic approach. Meta-heuristics have been regarded as successful because of four main reasons: simplicity, flexibility, derivation free mechanism, and local optima avoidance. By applying meta-heuristic algorithms we are optimizing the energy consumption in wireless sensor network.

Particle Swarm optimization (PSO)was introduced by Kennedy and Eberhart and mainly intended for simulating the behavior of bird flocking. It is a population based stochastic optimization technique. The algorithm was simplified, effective and efficient optimization techniques. In PSO, each single solution is a 'bird' in search space. A global fitness function is used by all the particles in the swarm .It evaluates the fitness of each particle and have velocity which directs the flying of the particles. The particles fly through the problem space by following the current optimal particle[5]. Each particle's movement is influenced by its local best known position and is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles[6].

Firefly Algorithm (FA) is an optimization problem is the solution for finding the best solution from all feasible solutions. Firefly algorithm (proposed by Xin-She Yang) is a multimodal nature inspired meta-heuristic algorithm developed in 2007 at Cambridge University. It is based on flashing behavior of fireflies. Almost every species of fireflies produces unique small rhythmic flashes and the flashes are being produced by a process of bioluminescence. . The function of the flashing light is to attract partners (communication) or attract potential prey and as a protective warning toward the predator[7].

Genetic algorithm (GA) is a meta-heuristic optimization technique, which produces many fruitful results in the engineering field. It is structured yet randomized search technique which primarily works based upon the following three genetic operators called selection, crossover, and mutation[8].

Ant Colony Optimization (ACO) is a recent meta-heuristics approach for solving hard combinatorial optimization problems and an iterative algorithm. At each iteration, a number of artificial ants are considered. The first ACO algorithm is Ant System (AS). In the later years, elitist strategy for ant system (EAS), AS_rank, Max-Min AS, ant colony system (ACS) was proposed. The inspiring source of ACO is the pheromone trail laying and following behavior of real ants which use pheromones as a communication medium. ACO is based on the indirect communication of a colony of simple agents, called (artificial) ants, mediated by (artificial) pheromone trails[9]. The pheromone trails in ACO serve as a distributed, numerical information which the ants use to probabilistically construct solutions to the problem being solved and which the ants adapt during the algorithm's execution to reflect their search experience. The main concept of Ant Colony Optimization is to minimize the path and power consumption.

Artificial Bee Colony Optimization (ABC) is a swarm-based artificial intelligence algorithm which is inspired by the intelligent foraging behavior of honey bees. The position of a food source denotes a possible solution to the optimization problem and the nectar amount of a food source represents the quality of the associated solution. The ABC algorithm has three types of bees: onlookers, scouts, and employed bees .The bee which carries out random search is known as a scout. The bee which is going to the food source and visited by it previously is employed bee. The bee which is waiting on the dance area is an onlooker bee[10].

Proposed System

In this paper we proposed a Firefly Algorithm (FA) introduced by Yang (2009) can be considered as an unconventional swarm-based heuristic algorithm for constrained optimization tasks inspired by the flashing behavior of fireflies.Firefly is an insect that mostly produces short and rhythmic flashes that produced by a process of bioluminescence. The function of the flashing light is to

attract partners (communication) or attract potential prey and as a protective warning toward the predator. Thus, this intensity of light is the factor of the other fireflies to move toward the other firefly.The light intensity also the influence of the air absorb by the surroundings, thus the intensity becomes less appealing as the distance increase (Yang, 2010).

Firefly algorithm was followed three idealize rules,

1) Fireflies are attracted toward each other regardless of gender.

2) The attractiveness of the fireflies is correlative with the brightness of the fireflies, thus the less attractive firefly will move forward to the more attractive firefly.

3) The brightness of fireflies is depend on the objective function (Yang, 2010).

In the standard firefly algorithm, there are two important points. One is the formulation of the light intensity and another is the change of the attractiveness. Firstly, we can always assume that the brightness of the firefly can be determined by the encoded objective function landscape. Secondly, we should define the variation of light intensity and formulate the change of the attractiveness. In the simplest case for maximum optimization problems, the brightness (I) of a firefly at a particular location x can be chosen as

$$\boldsymbol{I(x) \propto f(x)}$$

The attractiveness β is relative: it should be seen in the eyes of the be orderor judged by other fireflies. Thus,it will vary with distance r_{ij} between firefly I and firefly j. So the attractiveness is vary with the degree of absorptioni.e. the light intensity I(r) varies according to the inverse square law given as

$$\boldsymbol{I(r) = \frac{I_s}{r^2}}$$

Where

I_s =Intensity at the source.

r =distance between fireflies.

As we know the attractiveness is proportional to the light intensity seen by the adjacent fireflies. The attractiveness β of a firefly can now be defines using

$$\boldsymbol{\beta = \beta_0 e^{-\gamma r^2}}$$

Where

β =attractiveness of firefly

β_0 =attractiveness at r=0

γ =light absorption coefficient

As it is often faster to calculate $\frac{1}{1+\gamma r^2}$ than an exponential function, the above function can be defined as

$$\boldsymbol{\beta = \frac{\beta_0}{1+\gamma r^2}}$$

The distance(r_{ij})between any two fireflies i and j at $x_i$and x_j, the cartesian distance is given as the equation as

$$r_{ij} = \sqrt{\sum_{k=1}^{d}(x_{i,k} - x_{j,k})^2} \quad where$$

$x_{i,k}$ is the k[th]component of the spatial coordinate x_i of the i[th]firefly. In two dimensional case the equation becomes

$$r_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

The movement of a firefly 'I' is attracted to another more attracted firefly 'j' is determined by the equation

$$X_i = X_i + \beta_0 e^{-\gamma r^2}(X_j - X_i) + \alpha\epsilon_i$$

Where the attraction is the second determine is due to attraction and third term is randomization

β_0 =Attractiveness at r=0

α =Randomization parameters.

ϵ_i =vector of random numbers drawn from Gaussian distribution or uniform distribution.

Clustering Using Firefly Algorithm

Clustering is a popular data analysis technique to identify homogeneous groups of objects based on the values of their attributes[11]. For clustering, the energy of the nodes assumes to be similar to that of the light intensity of fireflies in FA algorithm. Also, the movement of the firefly in FAalgorithm is similar to the change in location of the cluster head. The movement of less attractive fireflies towards more attractive fireflies is similar to clustering of less energy nodes towards higher energy nodes.

Initially, 'k' cluster head are randomly selected with the given clustering probability. Subsequently, clustering will be done and communication takes place. Then, the first round go for energy based switching of cluster head. The nodes that have more energy are eligible forcluster head than node with less energy. If a node is a cluster head having less energy than other node in that cluster then that node become cluster head and again clustering will be done. After clustering get the fitness value of each optimization round and finally at the end of optimization round get the best set of cluster head which have better fitness value and final clustering donefor best fitness value. Fitness value is given by equations (1)

$$\frac{E_{CH}(K)}{\sum_{i=1}^{n} d^2{}_{ik+d^2}{}_{CH-BS}} \qquad (1)$$

here, k denotes number of the cluster head, 'n' signifies number of nodes in the cluster, ECH (k) is the energy of the cluster head, dik is the distance from cluster head to member nodes and $d_{CH-BS}$is the distance from cluster head to base station.

Methodology

The following Steps are implemented in Firefly algorithm:

1. Initialization of network.
2. Distribution of sensor networks.
3. Calculation of Energy based on number of rounds.
4. Selecting best CHs based on fitness value calculation are sorted in descending order.
5. Data transmission takes place to base station.

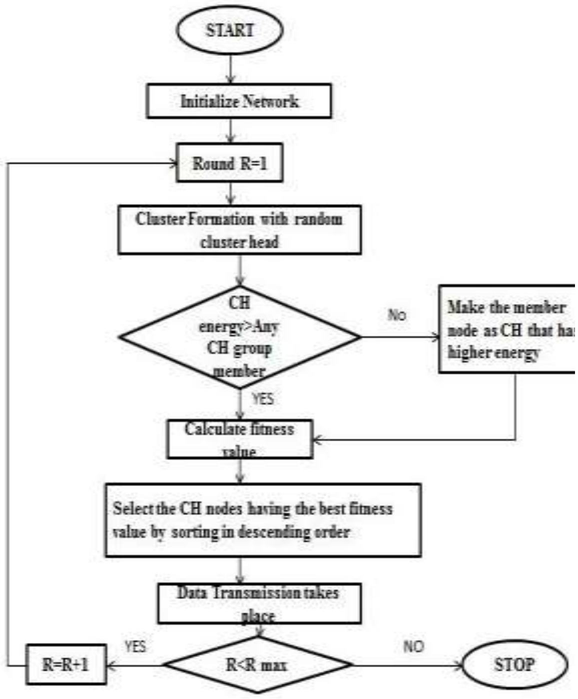

Fig 5 : Flow Chart of Firefly Algorithm

SIMULATION RESULT:-

The simulation is done using MATLAB. Let us assume the homogenous sensor network with 100 sensor nodes are randomly distributed in the 100m*100m area. The base station is located at the center (50, 50). We have set the minimum probability for becoming a cluster head (minimum probability) to 0.1 and initially energy given to each node is 0.5.

Parameters	Values
Field Dimensions (Xm,Ym)	100,100
No of nodes, n	100
Initial Energy, Eo	0.5Joules
Data Aggregation ,EDA	$5*10^{-9}$Joules
Eelec	$70*10^{-9}$Joules
Eamp	$120*10^{-12}$Joules
Max Rounds, r	100
Probability, p	0.1
No of Bits in frame, Kb	1024

Table 1: Simulation Parameters

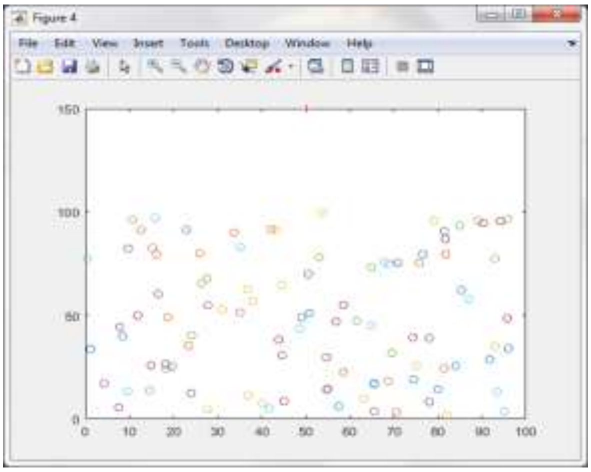

Fig6:A Snapshot which shows the Nodes initialization in the network i.e the nodes positioning in the 100 X 100 Environment and the Base Station was located at 50 X 150.

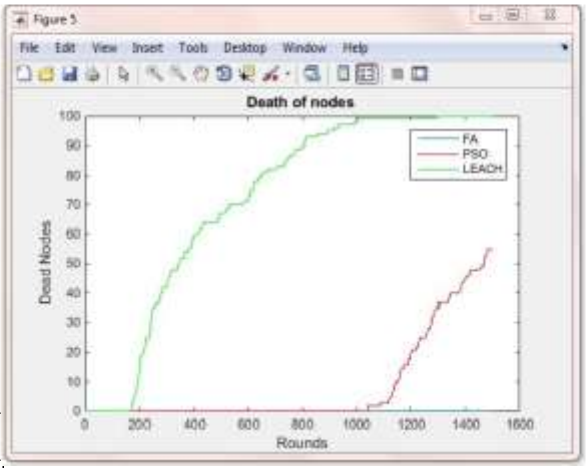

Fig 7:A Snapshot which shows the Dead nodes in the Network with respect to the Rounds. Initially there are 100 nodes. The above figure shows the death node count with respect to the number of rounds for Firefly algorithm LEACH and Particle Swarm Optimization (PSO).

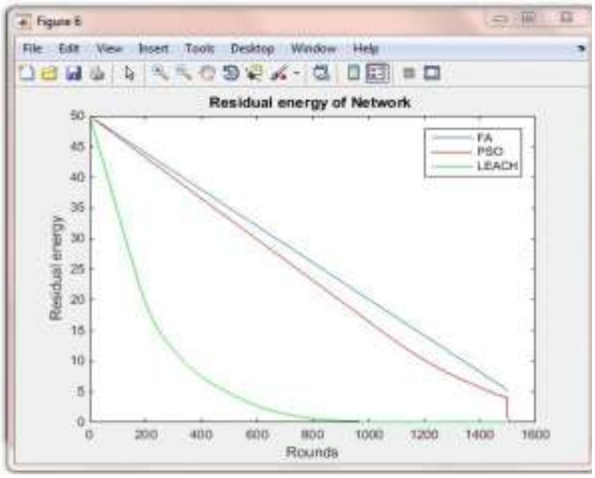

Fig 8: A Snapshot which shows the Residual Energy of the Network with respect to the Rounds. The Initial Energy of the nodes are 0.5J and there are 100 nodes. Firefly algorithm compares the alive nodes with LEACH and Particle Swarm Optimization (PSO). It is observed that nodes life time was increased in the Firefly algorithm, when it is compared with LEACH and Particle Swarm Optimization (PSO)less energy was consumed .

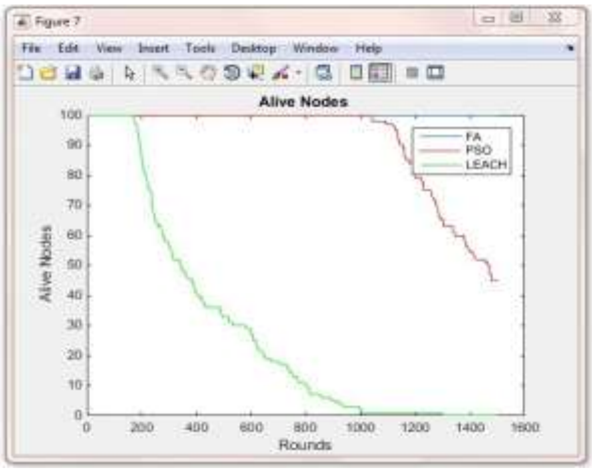

Fig9:A Snapshot which shows the Number of Alive Nodes with respect to the Rounds. Firefly algorithm compares the alive nodes with LEACH and Particle Swarm Optimization (PSO). It is observed that nodes life time was increased in the Firefly algorithm, when it is compared with LEACH and Particle Swarm Optimization (PSO).

Conclusion& Future Scope:

To maximize the network life time optimal cluster head selection is important. Cluster Head's require more energy than all other nodes because they perform processing, sensing, communication and aggregation. In case, the cluster head dies ion earlier, then the entire network becomes useless; since the CH cannot communicate with Base station. To obtain optimal cluster head, CH should be elected based on residual energy of each and every node. Therefore energy efficiency is maximized & network lifetime is also prolonged.

In our project, in order to achieve energy efficiency a new meta-heuristic based cluster head selection process is used i.e. Firefly based cluster head selection algorithm. We evaluated proposed technique and compared with LEACH and Particle Swarm Optimization (PSO). Our proposed technique is to perform better than these two clustering approaches. Proposed model can further improved by hybridizing these meta-heuristic algorithm to achieve better results to optimize the energy utilization and to improve the life time of the network in wireless sensor networks.

Here in this project we evaluated the Residual Energy (Remaining Energy) of the nodes and observed that the cluster head selection using Firefly meta-heuristic algorithm gives better results in improving the energy consumption. In Future we want to continue this research topic to further improving the energy efficiency and other QoS metrics by using various other nature inspired meta-heuristic algorithms and hybrid meta-heuristic algorithms.

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