International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 4, Issue 12, December 2015

A Survey on Optimization Techniques in Wireless Sensor Networks

[1]P.Hemalatha, [2]Dr.J.Gnanambigai

***Abstract*— In recent years, with MEMS technology nodes in the sensor networks are small in size and it is used in many applications. The major issues in Wireless Sensor Networks (WSN) are energy consumption, node deployment, localization of nodes, task allocation, network lifetime etc. In order to optimize the issues in WSN, new mechanisms have been implemented using behavior certain animals like bird, bee, bat etc. These systems are called bio-inspired systems. In this paper we aim to provide survey on various optimization techniques in WSN.**

***Index Terms*— Bio-inspired systems, Micro Electro Mechanical System-MEMS, Optimization techniques, Wireless Sensor Networks.**

I. INTRODUCTION

Wireless sensor network is wireless network with spatially distributed self organized nodes which is used to monitor the physical parameters like temperature ,pressure, humidity etc. Sensor nodes cooperatively collect the information and passed it to the base station. Each sensor node is equipped with three subsystems: communication subsystem, sensing subsystem, processing subsystem [1]. The communication subsystem has transceiver which is used to exchange the sensed information to the external world. The sensing unit has two basic units: sensors and ADC. The processing unit has processor which is used to perform the local computation of the sensed information. Power unit gives power to the sensing unit, processing unit, communication unit. Each node has additional two components: Location finding, Mobilize. Location finding is used if the user wants to find the location of the sensor nodes and mobilize is used to move the sensor nodes to carry out the assigned tasks. The architecture of sensor network is shown in Fig 1.

In recent years, WSN has drawn many research works predominantly due to its plenty of applications in various fields. This includes Environmental monitoring, Health monitoring, Military tracking, Animal tracking and monitoring. For example, a doctor can remotely monitor the patient's physiological data by sensor networks. Sensor networks can also be used to detect foreign chemical agents in the air and the water. They can help to identify the type, concentration, and location of pollutants [1].In essence, sensor network will provide the end user with intelligence and a better understanding of the environment.

Manuscript received Dec, 2015.

***P.Hemalatha**,PG student, M.E., Communication Systems, Department of ECE, KSR College of Engineering,Tiruchengode,Namakkal,Tamilnadu, India.*

***J.Gnanambigai**, Assistant Professor, Department of ECE, KSR College of Engineering,Tiruchengode, Namakkal, Tamilnadu, India..*

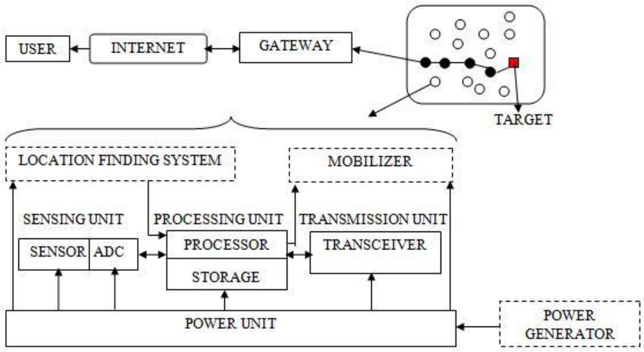

Fig.1. Architecture of wireless sensor networks

MANET (Mobile Ad-hoc Network) and sensor networks are two types of the Ad-hoc networks. MANET is a self configuring infrastructure less networks which consists of devices that are in mobile condition. Sensor networks are deployed in specific geographical regions for various applications like tracking, monitoring and sensing. These two networks have similar characteristics like both are a distributed network, multi-hop routing, self management; nodes in both networks are battery powered etc. The difference between two networks is that MANET is designed for distributed computing while WSN are mainly used to gather information. MANET use public key cryptography while WSN use symmetric key cryptography. Sensor nodes are very cheap in WSN when compared with nodes in MANET. Redundant deployment makes data centric protocol very important in WSN while in MANET address centric protocol is used [3]. The basic goals of a WSN are to: (i) Monitor the object or a specific area (ii) Detect the occurrence of events and record it (iii) Measure the required parameters.

The rest of this paper is organized is as follows: Section 2 contains routing challenges in wireless sensor networks, Section 3 contains need for optimization and various optimization techniques in WSN, Section 4 contains papers related with optimization techniques.

II. ROUTING CHALLENGES IN WIRELESS SENSOR NETWORKS

WSN is used in many applications. In these applications, nodes may be of heterogeneous or homogeneous or it may be mobile nodes, number of nodes deployed may be varied etc.

ISSN: 2278 – 1323

In order to meet these criteria, the following important design issues of the sensor network have to be considered.

A. Fault Tolerance

Fault tolerance is the ability to sustain sensor network functionalities without any interruption due to sensor node failures.

B. Scalability

Sensor node deployment depends on the nature of the application. The number of nodes varies with hundreds, thousands or even more. To handle network scalability, routing algorithm should have the capability to cope with scalable network.

C. Power Consumption

Each sensor node is equipped with limited power source. Replacement of power source is impossible in sensor networks. Node lifetime is strongly dependent on its battery lifetime. Lack of power leads to network partitioning and topology may also change. Power management is an important task in WSN.

D. Data Delivery Models

Data delivery model represents that the data is sensed from the object or area, measure the physical parameters and report it to the sink depends on the applications. Data delivery model can be categorized as continuous, event driven, query-driven and hybrid.

E. Data Aggregation/Fusion

It is the process of gathering of data from different sources at certain point and combined it by a certain aggregation function like suppression, min, max etc.

F. Quality of Service (QoS)

The quality of service includes the length of network lifetime, reliability, energy efficiency, and position of nodes, delay. These factors will affect the selection of routing protocols for a particular application. In some applications the data should be delivered within a certain period of time from the moment it is sensed.

G. Node Deployment

The deployment of node is depends on the application. The deployment may be deterministic or self-organizing. In deterministic situations, the sensors are manually placed and a pre-determined path is used to route the packets. However in self organizing systems, the sensor nodes are placed randomly and they create an infrastructure in an Ad-hoc manner.

III. NEED FOR OPTIMIZATION

Optimization is a process of making a design, system or decision as fully perfect, functional or effective as possible. In other words finding an alternative with the most cost effective or highest achievable performance under the given limitations, by increasing the desired factors and reducing undesired ones. The word optimum means "maximum" or "minimum" of certain factors which depends on application. An optimal solution is reached by selecting an efficient optimizer. There exist a number of optimization algorithms including derivative-based algorithms, derivative-free algorithms and bio-mimetic algorithms.

Derivative-Based Algorithms

It is also known as gradient- based algorithms which use the information of the derivative. The examples of this strategy are Newton's method, hill climbing, conjugate gradient method.

Derivative-Free Algorithms

This type of algorithm requires only the value of the objective function, not the information of the derivative. The examples of these algorithms are Hooke-Jeeves pattern search method, trust-region method and the Nelder-Mead downhill simplex method.

Bio-Mimic Algorithms

Modern optimization algorithms are often nature-inspired/bio-mimetic, and they are suitable for global optimization. Some of them are Particle Swarm Optimization (PSO), Genetic Algorithm (GA), Ant Colony Optimization (ACO), Cuckoo Search (CS), Bat Algorithm (BA), etc. The right choice of an optimization algorithm can be crucially important in finding the right solutions for a given optimization scenario.

Particle swarm optimization (PSO)

The Particle Swarm Optimization is a population based optimization technique, introduced by Kennedy and Eberhert in 1995. The model of this algorithm is based on the social behavior of bird flocking. It works through initializing population of random solutions and searching for the optima by updating generations.

In PSO, each single solution is a "bird" in the search space which is called as "particle". Each particle having fitness value which is evaluated by fitness functions and also has velocities to direct the particle to fly. The particles fly through the problem space by following the current optimum particles [6]. The mechanism of PSO is shown in Fig.2.

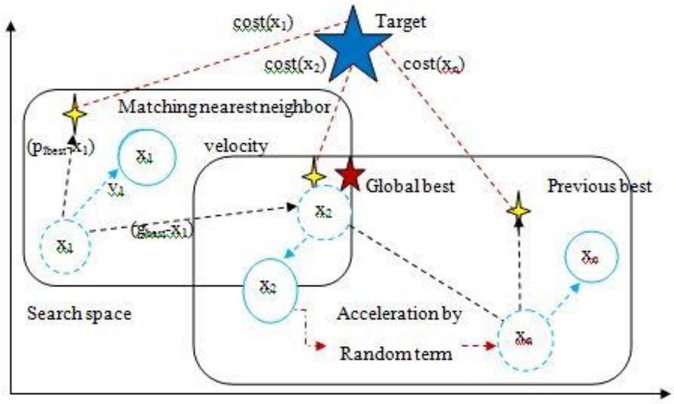

Fig.2. Mechanisms of PSO

In every generation, each particle is updated by following two

ISSN: 2278 – 1323

"best" values. The first one is *pbest* and the second one is *gbest.* The velocity and position of ach particle is updated according to the following equations.

$$v_{id}^{new} = w \times v_{id}^{old} + c_1 r_1 (pbest_{id} - x_{id}) + c_2 r_2 (gbest_{id} - x_{id}) \quad (1)$$

$$x_{id}^{new} = x_{id}^{old} + v_{id}^{old} \quad (2)$$

where d = 1, 2, ..., D, i = 1, 2, ..., N and N is the swarm size and n = 1, 2, ... denotes the iteration number. Two random numbers r_1, r_2 which are uniformly distributed in [0, 1] ensure good coverage. They also ensure the avoidance of falling into local optima which was a problem of the classical approaches. The inertia weight w manipulates the trade-off between exploration and exploitation abilities of the flying points. Another two important parameters are c_1 (self-confidence factor) and c_2 (swarm confidence factor).According to PSO, velocity and acceleration is changed to its *pbest* and *gbest* locations [6].

Ant Colony Optimization (ACO)

The Ant Colony Optimization algorithm is inspired from the food searching behavior of ants. When ants are in search of their food, they deposit the pheromone on the way which makes route for them. This pheromone is nothing but the liquid which evaporates as time passes. Therefore the pheromone concentration on the path is nothing but indication of probability usage of the path [7]. Due to its dynamic and probabilistic nature, this algorithm is used for mobile ad-hoc networks where topology changes frequently. The mechanisms for finding shortest path using ant colony are shown in Fig.3. (A) Ants in a pheromone trail between nest and food. (B). An obstacle interrupts the trail. (C). Ants find two paths to go around the obstacle. (D). A new pheromone trail is formed along the shorter path.

In this algorithm new routes(shortest) are created by using two artificial ants, forward ant (Fant) packet and backward ant (Bant) packet, which establishes the pheromone track to source node and sink node respectively.

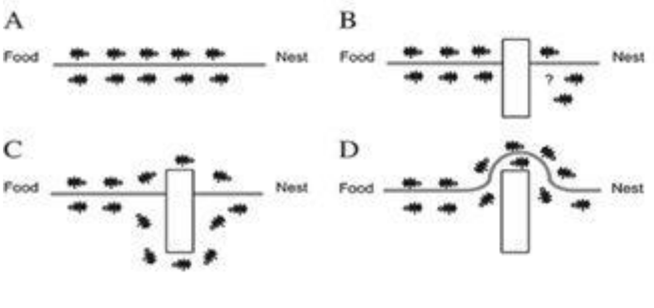

Fig.3. Ant colony mechanisms

Here pheromone value is calculated by number of hops to reach the node that means pheromone is function of number of hops visited by artificial ant. Sender broadcasts the Fant to all its neighboring nodes [7]. The node receiving this packet for first time creates a record of Destination Address (DA), Next hop (NH), Pheromone value (PH) in its routing table. The node takes source address (SA) of Fant as destination address, the address of previous node (PNA) as next hop, and computes the pheromone value depending upon the number of hops Fant needed to reach the node. Then the node relays the Fant packet to neighboring node till Fant reaches the destination.

Duplicate Fants are identified by unique sequence number and destroyed by nodes. When Fant reaches the destination node, it extracts the information of Fant and destroyed it. Then destination node creates the Bant packet and broadcasts to its neighboring nodes. Bant does the same task as the Fant. This shows that Fant establishes the track for destination and Bant establishes track for source node. When sender receives the Bant from the destination node, the both side paths are established and data packets can be sent. Sometimes at intermediate node ant creates two paths so multipath routing is supported by the ant colony routing algorithm.

Artificial Bee Colony Optimization (ABC)

The Artificial Bee Colony (ABC) algorithm was proposed by Karaboga in 2005. It is a swarm-based artificial intelligence algorithm which is inspired by the intelligent foraging behavior of honey bees. It consists of three bee groups and food sources. The solution to the optimization problem is the position of a food source and quality of the solution is the amount of food source. Onlookers, Scouts, and Employed bees are the three bee groups. The employed bee finds the path to the food source and takes an amount of food from the source and unloads the food into a food store. The bees, after unloading the food, performs a dance called waggle dance, which contains information about the position of the food source, direction and distance in which the food will be available etc. The information about all the current rich sources is available to an onlooker bee.

The new position of food sources are discovered by the onlookers and scout bees, they change their status to employed bee and visit the position of food source. The exploration and exploitation processes must be carried out simultaneously in a search process. Onlookers and employed bees perform the exploration process while scouts control the exploitation process.

The positions of the employed, onlooker, and scout bees are changed due to repeated cycles of the search processes (cycle = 1, 2, …, MCN), where MCN is the maximum cycle number of the search process. Depends on the local information the employed bee changes its position in her memory and tests the nectar amount of the new position (modified solution). The bee stores its new position and deletes its old one if the nectar amount is higher than that of previous one or it keeps the position of the previous one in their memory [2]. The probability P_i of selecting a food source by onlooker bees is calculated as follows:

$$p_i = \frac{fitness_i}{\sum_{i=1}^{E_b} fitness_i} \quad (3)$$

Where, $fitness_i$ is the fitness value of a solution i, and E_b is number of position of the food source or half of the colony size.

ISSN: 2278 – 1323

Bat Swarm Optimization (BSO)

Bat Swarm Optimization Algorithm (BSO) is developed by Xin-She Yang (2010a).It is an efficient meta-heuristic population based soft computing algorithm. This algorithm is naturally inspired from the social behavior of bats. They are the only mammals with wings and they also have special function of echolocation for detecting the prey, avoiding the obstacles, and locating their roosting crevices in the dark. They emit a very loud sound pulse and listen for the echo that bounces back from the surrounding objects.The echolocation system variables are initialized and the initial solutions is consider to be the initial location of all bat swarm. The values of pulse and loudness as well as the value of the frequency are set randomly. Bats try to find the best optimized solution through the number of iterations. Bats solutions are automatically updated to find the better solution. The pulse emission rate and loudness are updated according to their best solution. Solutions keep updated as a result of the continuous flying iterations till the termination criteria are satisfied [5]. Finally, when all criteria successfully met the best so far solution is visualized. While initialization of bat population produced randomly, new solutions can be generated by the motion of bats with the following functions:

$$f_i = f_{min} + (f_{max} - f_{min})\beta \quad (4)$$

$$v_i^t = v_i^{t-1} + (x_i^t - x^*) f_i \quad (5)$$

$$x_i^t = x_i^{t-1} + v_i^t \quad (6)$$

Where
β: Random vector drawn from uniform distribution ∈ [0, 1].
*x**:Current global best location (solution) which is located after comparing all the solutions among all the bats.
f_i :Frequency which is drawn uniformly from [f*min*, f*max*]

A random walk with direct exploitation is used for the local search that modifies the current best solution according to the equation:

$$x_{new} = x_{old} + \in A^t \quad (7)$$

Where;
∈: is a random number ∈ [-1, 1].
A^t: is the average loudness of all the best at this time step.
r_i: is the rate of pulse emission.

For each bat, as soon as the prey found, the bat loudness decrease and the pulse emission rate increase. Both loudness and pulse emission expressed mathematically as follows:

$$A_i^{t+1} = \alpha A_i^t \quad (8)$$

$$r_i^{t+1} = r_i^0 [1 - \exp(-\gamma t)] \quad (9)$$

$$A_i^t \to 0, r_i^t \to r_i^0 \quad \text{as} \quad t \to 0 \quad (10)$$

Where
α: is constant 0 < ∝ < 1
γ : is constant γ > 0

For simplicity, use the following approximate or idealized rules [6]
a) All bats use echolocation to sense distance, and they also ‘know’ the difference between food / prey and background barriers in some magical way;

b) Bats fly randomly with velocity v_i at position x_i with a frequency f_{min}, varying wavelength λ and loudness A_0 to search for prey. They can automatically adjust the wavelength (or frequency) of their emitted pulses and adjust the rate of pulse emission r Є [0, 1], depending on the proximity of their target;

c) Although the loudness can vary in many ways, we assume that the loudness varies from a large (positive) A_0 to a minimum constant value A_{min}.

Genetic Algorithm (GA)

GA can be viewed as an optimization method which is based on the Darwinian principles of biological evolution, reproduction and “the survival of the fittest”, pioneered by Holland and his colleagues in the 1960s and 1970s.It is an evolutionary algorithm which is categorized as a global search heuristic. It uses random search in the decision space via selection, crossover and mutation operators in order to reach its goal [8]. Selection mechanism selects individuals (parents) for crossover and mutation. Crossover exchanges the genetic materials between parents to produce offspring, whereas mutation incorporates new genetic traits in the offspring. Elitism is an operator of GA which is used to store the best or elite chromosomes with best fitness values for the next generation.

GA are implemented and presented using simulations. The abstract representation of population is known as chromosomes and the candidate solutions are known as individuals or phenotypes. Handling complex problems and parallelism are the two advantages of GA. In GA, binary strings consisting of 0’s and 1’s are used to code and quantize the solutions. The evolution initiates from a population of randomly generated individuals. In each successive generation, the fitness of every individual is evaluated and multiple individuals are selected based on their fitness value. They form a new population by possible combinations and mutations. The new population is then used in the next generation and repeatedly modifies it to produce a new generation of chromosomes. The stopping criteria of GA could be either a predefined number of iterations or convergence during a predefined number of iterations.

IV. Related Papers

Caputo, Grimaccia, Mussetta and Zich [4] address the problem of network lifetime. They proposed a new hybrid techniques based on evolutionary algorithms to optimize the

ISSN: 2278 – 1323

issues in WSN. In this paper genetic algorithm and particle swarm optimization is combined and produce a new hybrid technique called Genetical Swarm Optimization (GSO) technique to maximize the network lifetime. GSO is a hybrid evolutionary algorithm which combines the properties of GA and PSO to overcome the premature convergence.

In paper [5], the author addresses the problem of increasing the lifetime of the sensors network by finding the optimal sink position. Sensor node is equipped with non rechargeable batteries. Once they deployed, it is impossible to replace or recharge the battery. The basic thing behind the WSN is to optimize the consumption of energy, so as to increase the network lifetime. In this paper, it is achieved by using one bio-inspired approach called Particle Swarm Optimization (PSO) techniques. In multi hop communication, the sensory data collected by all the nodes will send the data to the Base Station (BS) through the node close to BS and it will die quickly. In order to avoid this, relay nodes are introduced. It will reduce the burden of the data traffic on the sensor nodes. Hence the consumptions of energy by the sensor nodes decrease and the lifespan increases. The optimal location of the sink with respect to those relay nodes is found by using the PSO based algorithm.

In [6], BAT algorithm is used to find the position of the sensor nodes. The goal of localization is to find the geographical coordinates of the sensor node with the help of anchor nodes. In many applications node location is inherently one of the system parameter. Node localization is required to report the time of events happen, where to report the events, assist group querying of sensors, routing and to answer questions on the network coverage.

In [9], two optimization techniques is used to increase network lifetime. Particle swarm optimization and Ant colony optimization technique is used to find suitable location of the sensor nodes. Scheduling the sensor node is used to achieve the target coverage level.

Network lifetime is the major challenge in design of WSN. Recently bio inspired optimization techniques are introduced to solve this problem effectively. In [10], a newly meta-heuristic population based soft computing algorithm as an optimization technique to extend the WSNs lifetime. In this paper bat swarm optimization is used to select the optimal cluster head. Fitness function is calculated and it is used to minimize the intra cluster compactness with minimum distance between nodes in same cluster.

In [11], Enhanced optimized energy efficient routing protocol (E-OEERP) is proposed to prevent the formation of residual nodes. This is achieved by using particle swarm optimization (PSO) and gravitational search algorithm (GSA). During cluster formation some of the nodes are not a member of any cluster. Such nodes are called as residual nodes or individual nodes which require high energy for data transmission or it may send many control packets to find the optimal routing path. In E-OEERP, PSO is responsible for cluster formation and cluster head election. GSA is responsible for finding the next best hop by considering the parameters like position of the node, velocity and force between the cluster heads.

A fundamental problem in designing sensor network is localization i.e. determine the location of sensors. In [12], this is achieved by using range free localization method namely Mobile Anchor Positioning (MAP) which gives approximate solution. In order to reduce the location error three heuristics approaches are applied to the results given by MAP. The three heuristics are Bat optimization algorithm with MAP (BA-MAP), Modified cuckoo search with MAP (MCS-MAP), Firefly optimization algorithm with MAP (FOA-MAP).

In [13], the author presents an optimal-distance based transmission strategy (ODTS) to achieve our goal on the basis of ACO. The main aim of this paper is to find the distance between the nodes which consumes energy efficiently and balance the energy among the nodes. In this way they increase the network lifetime. They propose a global optimal transmission distance mechanism to achieve energy depletion minimization for nodes with maximal energy consumption throughout the network. So, this mechanism further helps to extend the network longevity.

V. CONCLUSION

The issues and challenges of WSN are considered while designing sensor network. The aim of this paper is to provide an overview the state of the art research on the various bio inspired optimization approaches. There are various optimization techniques which are used to optimize the issues and challenges in the design of WSN.

REFERENCES

[1] I.F.Akyildiz, W. Su, Y.Sankarasubramanium, E.Cayirci, “Wireless sensor networks: A Survey”, Elsevier Comput.Netw. 38(4) (2002) 393-422.

[2] Fahad S. Abu-Mouti, Mohamed E. El-Hawary, “Overview of Artificial Bee Colony (ABC) Algorithm and Its Applications”, Systems Conference (SysCon), 2012 IEEE International.

[3] Rajashree.V.Biradar, V.C .Patil, Dr. S. R. Sawant, Dr. R. R.Mudholkar “Classification and Comparison of Routing Protocols in Wireless Sensor Networks”, Special Issue on Ubiquitous Computing Security Systems, Volume-4.

[4] D.Caputo, F. Grimaccia, M. Mussetta and R. E. Zich, “An Enhanced GSO Technique for Wireless Sensor Networks Optimization”, 2008 IEEE Congress on Evolutionary Computation (CEC 2008).

[5] Md Nafees Rahman, M A Matin, “Efficient Algorithm for Prolonging Network Lifetime of Wireless Sensor Networks”, ISSN1007-0214 01/12 pp 561-568 Volume 16, Number 6, December 2011.

ISSN: 2278 – 1323

[6] Sonia Goyal, Manjeet Singh Patterh, "Wireless sensor network localization based on BAT Algorithm", International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS) 13-192; © 2013.

[7] Sudarshan D Shirkande, Rambabu A Vatti, "ACO based routing algorithm for ad-hoc (WSN, MANET) networks: survey", 2013 International Conference on Communication Systems and Network Technologies.

[8] Loveneet Kaur, Dinesh Kumar, "Optimization techniques for routing in wireless sensor networks", International Journal of computer science and Information Technologies, Vol 5 (3), 2014, 4719-4721.

[9] S. Mini, Siba K. Udgata, and Samrat L. Sabat, "Sensor deployment and Scheduling for target coverage problem in wireless sensor networks", IEEE Sensors Journal, Vol.14, No.3, March 2014.

[10] Marwa Sharawi, E. Emary, Imane Aly Saroit, Hesham El-Mahdy, "Bat Swarm algorithm for wireless sensor network lifetime optimization", International Journal of Science and Research (IJSR), Volume 3 Issue 5, May 2014.

[11] Rejina Parvin, Vasanthanayaki C, "Particle Swarm Optimization based Clustering by preventing residual nodes in wireless sensor networks", IEEE Sensors Journal, 1530-437X (c) 2015 IEEE.

[12] S.Sivakumar, R.Venkatesan, "Meta-heuristic approaches for minimizing error in localization of wireless sensor networks", Applied soft computing 1568-4946/© 2015 Published by Elsevier B.V. (In press)

[13] Xuxun Liu, "An optimal-distance based transmission strategy for lifetime maximization of wireless sensor networks", IEEE Sensors journals, Vol.15, No.6, June 2015.

AUTHORS PROFILE

P.Hemalatha is pursuing her M.E in Communications systems, Department of Electronics and Communication Engineering from KSR college of Engineering. She obtained her Bachelor of Engineering degree in Electronics and communication engineering from University College of Engineering-Panruti campus, Panruti. She is interested in Wireless Sensor Networks.

Dr.J.Gnanambigai received her B.E(2001) and M.E degree from College of Engineering, Guindy, Anna University, Chennai in the year of 2007 and doctoral degree in the year of 2015. Currently she has been working as an associate professor in the Dept. of ECE, in KSR college of Engineering. She has published twelve papers in the international journal and more in the international and national conferences. She is a member of ISTE and student member of IEEE. Her area of interest includes with routing concepts in wireless sensor networks.

ISSN: 2278 – 1323