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Cluster Head Selection using Particle Swarm Optimization in Wireless Sensor Network

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ABSTRACT: Wireless Sensor Network(WSN) are very popular as they are low cost solutions to many real-world challenges with limited computational power, battery life and memory resources. Past few years have witnessed increased in the potential use of wireless sensor network (WSN) such as military surveillance, tracking and monitoring, disaster management and combat field reconnaissance. Sensor nodes involved in these applications are remotely deployed in large numbers. These autonomous nodes are used to monitor an environment. Many issues in WSN are formulated as multidimensional optimization problem and solved through bio-inspired techniques. The main problem in WSN is the lifetime of network. To support scalability, nodes are often grouped in clusters having a leader, often referred as cluster head (CH). A CH is responsible for not only sending data to base station but also assist the general nodes to send sensed data to target nodes. The energy consumption of CH is greater than general nodes. Therefore CH selection will affect the lifetime of WSN. The paper proposes an approach for improving network lifetime by using Particle swarm optimization based clustering routing in WSN. So in this paper, global optimal cluster head are selected and Gateway nodes are introduced to decrease the energy consumption of the CH while sending aggregated data to the Base station (BS).

KEYWORDS: Wireless Sensor Network, Leach, Meta-heuristics Techniques, Particle Swarm Optimization.

I. INTRODUCTION

1.1INTRODUCTION TO WSN

Research and commercial interest in the area of wireless sensor networks (WSNs) are increasing nowadays and the projects funded by NSF, Defense Advanced Research Projects Agency (DARPA) (Kumar and Shepherd 2001) through its SensIT (Sensor Information Technology), NEST (Networked Embedded Software Technology), MSET (Multi Sensor Exploitation), UGS (Unattended Ground Sensors) etc., are increased due to advances in Wireless Communication and Electronics over the last few years.

The National Research Council report, (Estrin et al 2001) reports that the use of sensor networks throughout society could well dwarf previous milestones in the information revolution and the Globalfuture identified WSNs as one of the "10 emerging technologies that will change the world" (MIT Technology Review 2003; Coy et al 1999). Tiny computers that constantly monitor ecosystems, buildings, and even human bodies could turn science on its head (Declan Butler 2006). Hence the WSN plays a vital role in commercial and military applications. Sensor networks with micro electro mechanical systems (MEMS) and nanotechnology will greatly reduce the size of the nodes and enhance the capabilities of the network. Potential applications of sensor networks are, for example monitoring of ocean temperature to enable more accurate weather prediction, detection of forest firesThe optimal election and re-election of

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CHs, and cluster maintenance are the main issues to be addressed in designing of clustering algorithms. Hence this thesis proposes methods for selection of cluster head based on meta-heuristic algorithms like Firefly Algorithms (FA), Artificial Bee Colony Algorithms (ABC), Particle Swarm Optimization (PSO) and Shuffled frog leap algorithms (SFLA) for increasing the lifetime of the WSN. The following sections will discuss the architecture of WSN and related issues and challenges in it (Michael et al 2000).

1.2WSN ARCHITECTURE

The basic block diagram of a wireless sensor node is presented in Figure 1.1.It is mainly made up four basic components (Martinez et al 2004):

1. Sensing Unit
2. Processing Unit
3. Transceiver Unit
4. Power Unit

1.2.1Sensing 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.

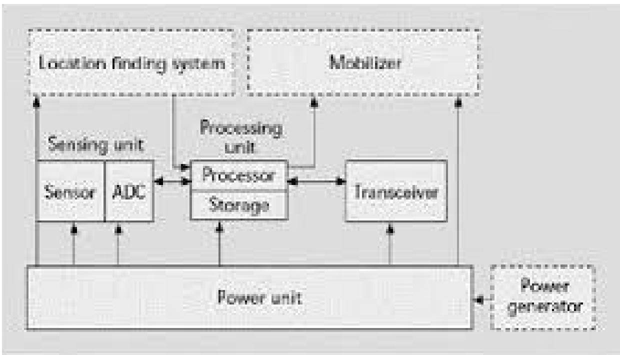

Fig 1.1 : WSN Architecture

1.2.2Processing 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.

1.2.3Transceiver 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. Thus, it is important to completely shut down the radio rather than set it in the idle mode when it is not transmitting or receiving due to the high power consumed. Another influencing factor is that, as the radio's operating mode changes, the transient activity in the radio electronics

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causes a significant amount of power dissipation. The sleep mode is a very important energy saving feature in WSN (Culler et al 2004).

1.2.4 Battery

The battery supplies power to the complete sensor node. It plays a vital role in determining sensor node lifetime (Gautam et al 2009). The amount of power drawn from a battery should be carefully monitored. Sensor nodes are generally small, light and cheap, the size of the battery is limited (Freris et al 2010).

1.3. Introduction to LEACH

The sensor nodes are independent radio devices distributed randomly, which diffuse data in a cooperative manner, which make it easy for deployment in challenging environments. Distance between the communicating nodes is the major factor of energy dissipation (Wang et al 1999) apart from the internal signal processing by electronics. Also, the energy dissipation depends upon the square of the distance between source and sink, which is a non-linear dependency.There are few nature inspired meta-heuristic optimization algorithm used recently for proper cluster head selection in order to provide energy efficient communication (Kang Seok Lee &Zong Woo Geem 2004). These optimization algorithms are used to find the optimal solution for the given nonlinear functions. The energy optimization algorithms available in literature include Particle Swarm Optimization (PSO) (Kennedy &Eberhart 1995)[1] and Artificial Bee Colony (ABC) algorithm (Karaboga& Basturk2007). Although these algorithms are computational complex, they provide better performance than LEACH protocol. Also, the lifetime of a sensor network can be viewed as the time duration from the beginning of data transmission to the first node death. Hence, the primary objective of these optimization algorithms is to prolong the network lifetime by selecting appropriate cluster head.

Due to the fact that the sensor node has limited electronics and processing ability the energy aware routing is best suitable for data gathering by sensor node. The protocol running on the network should be real time and fast executing. To meet above requirement the proposed protocol is introduced which is based on the flashing behavior of a social insect called firefly. It is also used in many other optimization problems. In this chapter, the optimization of firefly is used (Senthilnath et al 2011) to increase the network lifetime. The proposed algorithm is compared with LEACH, DT and firefly algorithm. Simulated result shows that the lifetime is improved using firefly algorithm through optimization. Proposed algorithm is developed as the distributed routing method which dynamically configures the cluster heads for the one round of communication. In each round all the sensor node transmits the collected data to their cluster head which perform the data aggregation and diffuse the aggregated data to the base station. The base station executes the optimization process which is more sophisticated than the sensor nodes and considered to have an unlimited power supply.

Further sections of this chapter describe the proposed a new method for selecting cluster heads using firefly algorithm to overcome the drawback of selecting the CH in LEACH.

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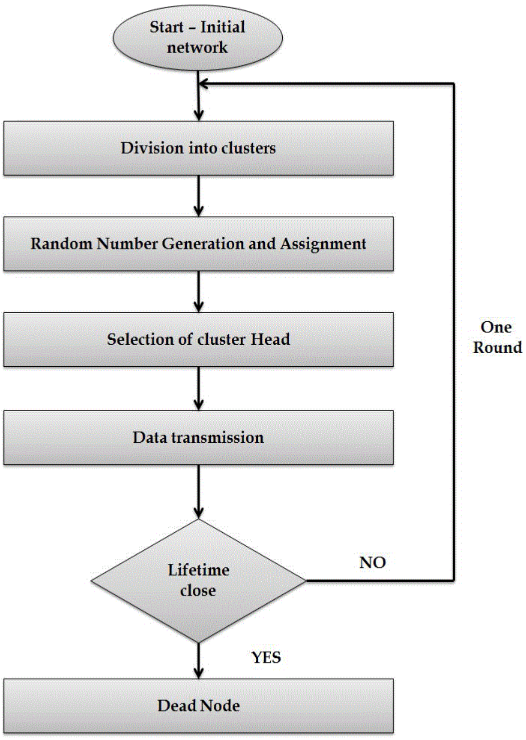

Figure 1.3.1: Flow chart of Leach

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 phase2. 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.[2]

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.

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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.[3]

1.4 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).

II. RELATED WORK

Wireless Sensor Networks :Characteristics and Architectures Muhammad R Ahmed, Xu Huang, Dharmandra Sharma and Hongyan Cui [4] gives the idea of 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. 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

The Architecture of Wireless Sensor Network, its Issues and Applications Dibya jyoti Saikia [5]proposes that the wireless sensor networks are defenseless to security threats. As wireless sensor technology improves; an increasing number of organizations are using it for a wide range of purposes. WSNs enable new applications and require non-conventional paradigms for protocol design due to several constraints. Presently, WSNs are beginning to be organized in an enhanced step. It is not awkward to expect that in 10 to 15 years that the world will be protected with WSNs with entree to them via the Internet. This can be measured as the Internet becoming a physical

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network. This technology is thrilling with infinite potential for many application areas like medical, environmental, transportation, military, entertainment, homeland defense, crisis management and also smart spaces. This paper concludes the architecture, issues and applications concerning WSN.

Lifetime improvement with LEACH Protocol Khushboo Manohar, A.I.Darvadiya [6] explained us that sensor networks have recently come into prominence because they have hold the potential to revolutionize many segments. As we know that wireless sensor network suffers from excessive packet loss, over hearing, retransmission of the packet due to node mobility and constant energy dissipation. Routing protocol techniques is one of the research area in wireless sensor network. So by crafting an efficient routing algorithm to improve the network lifetime. In this paper, we are drawing a new technique for cluster-head selection by analyzing the lasting energy of the node and also considering the type of communication between the nodes and cluster-head. This technique is compared with the conventional LEACH.

Enhancing the Performance of LEACH Protocol in Wireless Sensor NetworksYun Li, Nan Yu, Weiyi Zhang, Weiliang Zhao, Xiaohu You, Mahmoud Daneshmand [7] gives the idea of LEACH(Low Energy Adaptive and Clustering Hierarchy) LEACH protocol is one of the clustering routing protocols in wireless sensor networks. The advantage of LEACH is that each node has the equal probability to be a cluster head, which makes the energy dissipation of each node be relatively balanced. In LEACH protocol, time is divided into many rounds, in each round, all the nodes contend to be cluster head according to a predefined criterion. This paper focuses on how to set the time length of each round, to prolong the lifetime of the network and increase throughput, which is denoted as the amount of data packs sent to the sink node. The functions of lifetime and throughput related to the time length of each round are deduced. These functions can be used to enhance the performance of cluster-based wireless sensor networks in terms of lifetime and throughput.

An Approach to Increase the Wireless Sensor Network LifetimeNikhil Marriwala, PriyankaRathee [8] Minimizing energy dissipation and maximizing network lifetime are important issues in the design of applications and protocols for sensor networks. In this paper there is improvement of lifetime of wireless sensor network in terms increasing alive nodes in network by using a different approach to select cluster head. The cluster head selection is based on the basis of maximum residual energy and minimum distance and chooses a optimal path between the cluster heads to transmit to the base station.

LEACH-I Algorithm for WSNMonika, SnehaChauhan, Nishi Yadav [9] Major focus lies on increasing the network lifetime so that the battery need not to be replenished soon. Clustering sensor nodes is an effective technique for achieving this goal. we introduce an energy efficient clustering algorithm for sensor networks based on the LEACH protocol. LEACH (Low Energy Adaptive Clustering Hierarchy) is one of popular cluster-based structures, which has been widely proposed in wireless sensor networks. The proposed protocol LEACH-I (Improved LEACH algorithm) have aided facility that it reduces the consumption of the network resource as compare to LEACH algorithm in each round. The proposed protocol is simulated and the result shows a significant reduction in network energy consumption as compared to LEACH. Our major focus is based on maximizing node-degree that is defined as the number of alive nodes that lie within the transmission range of a given node is more as compare to LEACH algorithm.

Heterogeneous LEACH Protocol for Wireless Sensor NetworksNishi Sharma, VandnaVerma[10]gives the idea of wireless sensor networks are networks of large number of tiny, battery powered sensor nodes having limited on-board storage, processing, and radio capabilities. Nodes sense and send their reports toward a processing center which is called base station. Since this transmission and reception process consumes lots of energy as compare to data processing, Designing protocols and applications for such networks has to be energy aware in order to prolong the lifetime of the network. Generally, real life applications deal with such Heterogeneity rather than Homogeneity. In this paper, a protocol is proposed, which is heterogeneous in energy. We analyze the basic distributed clustering routing

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protocol LEACH (Low Energy Adaptive Clustering Hierarchy), which is a homogeneous system, and then we study the impact of heterogeneity in energy of nodes to prolong the life time of WSN.

Cluster-head election Techniques for energy efficient routing in Wireless Sensor Network –An updated Survey Ankit Thakkar [11] proposed energy efficient protocol design is a prime concerned for wireless sensor networks. Many techniques have been developed to extend the lifetime of Wireless Sensor Networks. This paper focuses on energy conservation in wireless sensor network using hierarchical routing techniques. In a hierarchical routing, few nodes elect themselves as cluster heads for a specific duration and serves to the remaining nodes.

Improved LEACH Protocol using vice Cluster in Wireless Sensor NetworksPriti K. Hirani, Manali Singh [12] tell us that a sensor network consists of hundreds of sensor node which has similar energy, memory and process capacity. Wireless sensor network is one of the major emerging field comes under the sensor network. These kind of network is having the more challenges because of GPS (Global Positioning System).Clustering mechanism in sensor network under the restrictions of floating nodes, localization and lesser transmission speed. LEACH protocols are considered as the most popular routing protocol, which has batter performance and saving the energy consumption. A lot of research on protocol to improve the network lifetime. Each node will alive neighbor node as well as the base station will communication to cluster head. We have defined the cluster head selection base on condition of distance, energy and maximum connectivity level between the nodes.

III. IMPLEMENTATION AND PROPOSED ALGORITHM.

3.1 Particle Swarm Optimization

Particle Swarm Optimization is abbreviated as „PSO". It is a novel population-based stochastic search algorithm. This concept was given by Eberhart and Kennedy in 1995. It was influenced by the social behavior of bird flocking. It is a process of group communication to share individual knowledge. For example, when a group of birds or insects search food in the surroundings. It is not compulsory that all of them know where the food is. But if any member found a desired path to the food, the rest of the members will follow it quickly. In PSO, each member of the population is called a particle and the population is called a swarm. First of all, population is randomly initialized. The particles can move in any direction. Each particle remembers the best previous position of itself and its neighbors. Particles dynamically adjust their own position and velocity derived from the best position. Finally, all particles fly towards the best.

3.2 Principle of PSO : PSO contains the set of moving particles known as "Swarm". The following are the features of the particle:

- It has a position and a velocity.
- It remembers its best previous position found so far.
- It remembers its neighbours" best previous position.

Neighborhood can be defined as a physical neighborhood. It takes distances into account. In practice, distances are computed at each step, which makes it quite costly. At each step, the behavior of a given particle is a compromise between three possible choices:

- To follow its own way
- To move towards its previous best position
- To move towards the best neighbour

3.3 PSO Algorithm Parameters There are some parameters in PSO algorithm that may affect its performance. These are swarm size, number of iterations, Vmax, acceleration constants and velocity elements.

- Swarm size: Swarm size or population size is the number of particles „n" in the swarm. Large number of particles increases the computational complexity per iteration. Hence, makes PSO more time consuming. Various researchers use an interval of n ϵ [20, 60] for the swarm size.

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- Iteration numbers: PSO algorithm also depends upon number of iterations. A small number of iterations may stop the search process prematurely. While a large number of iterations make PSO complex and more time consuming
- Vmax: Vmax is an important parameter. It determines fitness between the present position and the target position. If Vmax is high, particles may overpass good solution. If Vmax is low, particles may not explore sufficiently.
- Acceleration Constants: The acceleration constants c1 and c2 represent acceleration terms that pull each particle towards pbest and gbest positions. If the values are low, the particles will move away from the target. If the values are high, the particles will move towards the target.
- Velocity Components: There are three velocity components.

a) The term w * vid is called inertia component. This component represents a momentum which prevents change in the direction of the particles. It forces them to move towards the current direction.
b)The term c1(pid – xid) is called cognitive component. It keeps a track of the best previous position of the particle. Therefore, it can backtrack to the previous best position whenever need arises.
c) The term c2(pgd – xid) is called social component. It records the best position of the whole group. Hence each particle can move towards best position found by the neighborhood particles.

3.4 Advantages of PSO

- It is simple to implement.
- It quickly converges to a good solution.
- It makes use of only primary mathematical operators.
- It is fast, cheap and efficient.
- There are few parameters to regulate.

3.5 Limitations of PSO The major drawback of PSO is „premature convergence". It does not give quality solution as the number of iterations is increased.

3.6 The PSO Algorithm

(i) Set parameters w_{min}, w_{max}, C_1 and C_2 PSO.
(ii) Initialize population of particle having population „P" (usually varies from 10 to 100) and velocities „V" (initial velocity is 10% of position).
(iii) Initialize$i$=1.
(iv) Fitness of particle is calculated using $Fxi=(Pxi)$, calculate best particle b index.
(v) Get $Pbestxi=Pxi$and $Gbesti=Pbi$.
(vi) $w=wmax-i*(wmax-wmin)/Maxit$where, Maxit varies from 500 to 10000.
(vii) Update velocity and position of particle
$V_{x,}{}^{i+1}=w*V_{x,y}{}^{i}+C1*rand*(Pbest_{x,y}{}^{i}-P_{x,y}{}^{i})$
$V^{i+1}{}_{x,y}= w* V^{i}{}_{x,y} +C1* rand()*(Pbest^{i}{}_{x,y} -P^{i}{}_{x,y})+C2 * rand()*(Gbest^{i}{}_{x,y} -P^{i}{}_{x,y})$ $Px,y^{i+1}=Px,y^{i}+V_{x,y}{}^{i+1}$
(viii) Fitness is evaluated using $F_x{}^{i+1}=(P_x{}^{i+1})$, calculate best particle b index.
(ix) Updating Pbest if $F_x{}^{i+1}<F_x{}^{i}$ Then $Pbest_x{}^{i+1}=P_x{}^{i+1}$ else $Pbest_x{}^{i+1}=Pbest_x{}^{i}$
(x) Updating Gbest if $F_{b1}{}^{i+1}<F_b{}^{i}$Then $Gbest^{i+1}=Pbest^{i+1}$, b=b1, else $Gbest^{i+1}=Gbest^{i}$.
(xi) If $i<Maxit$ then $i=i+1$ and moves to step(vi) else moves to step (xii).
(xii) Print $Gbest^{i}$.

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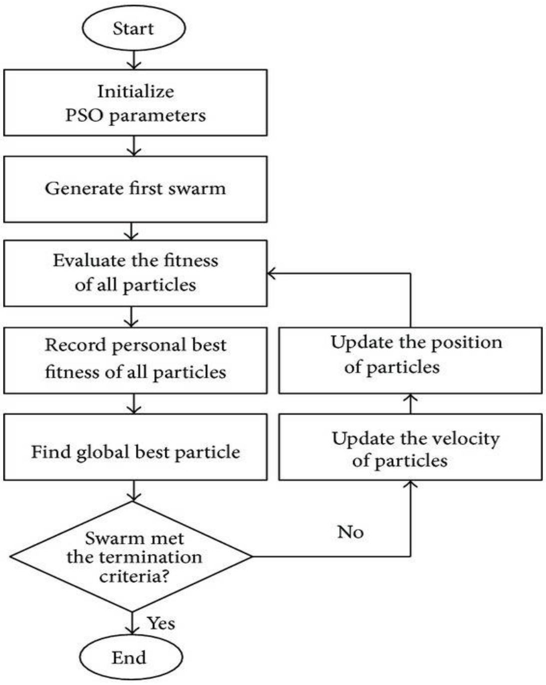

Figure 3.1 Flowchart of Particle Swarm Optimization Algorithm

IV. SIMULATION RESULT

The simulation is done using MATLAB. Let us assume the homogeneous 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

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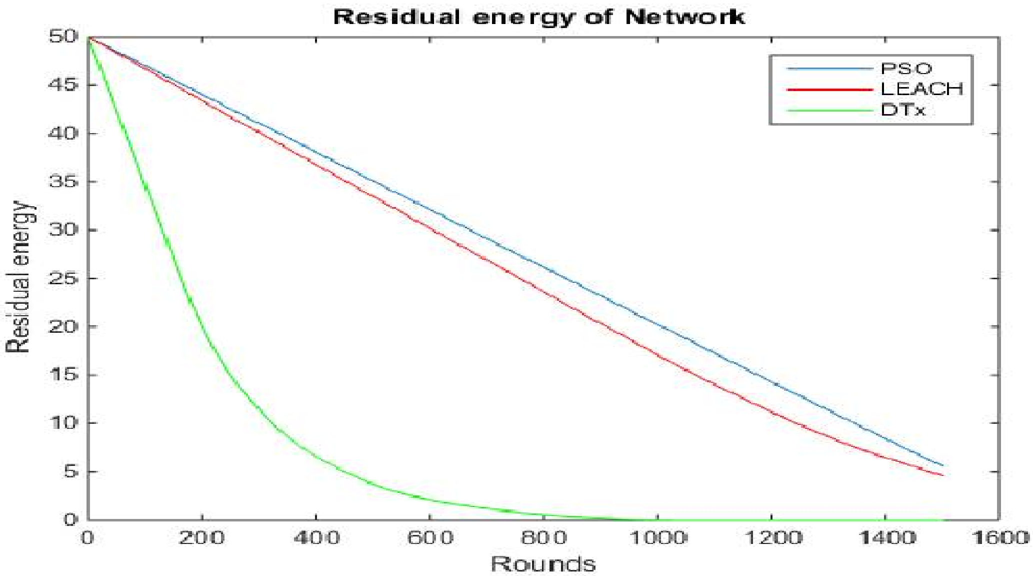

Figure 5.1 Residual Energy of the network

Fig 5.1: 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. Particle Swarm Optimization (PSO) compares the alive nodes with LEACH and Direct Transmission (DTx) .

It is observed that nodes life time was increased by using the Particle Swarm Optimization Algorithm when it is compared with LEACH and DTx less energy was consumed .

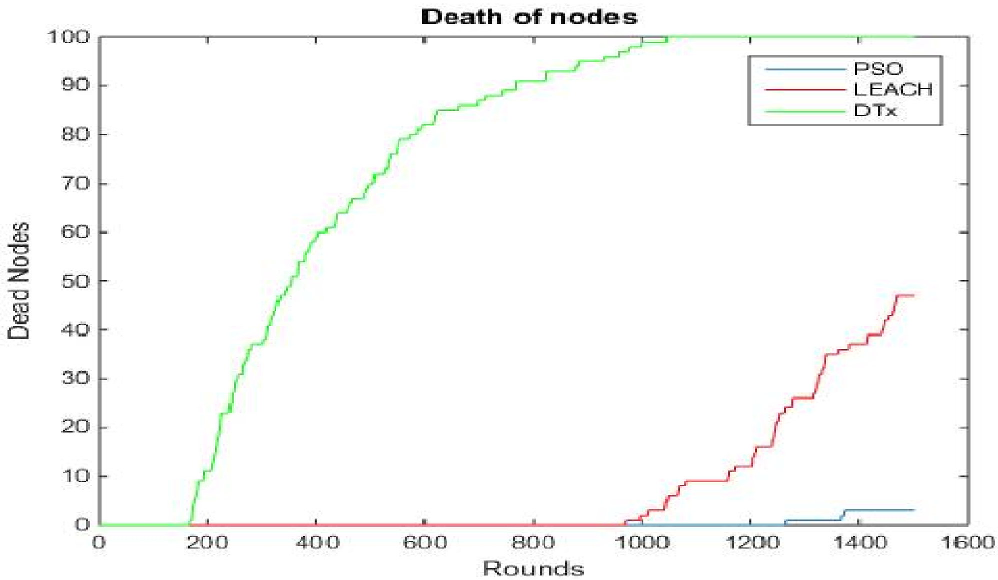

Figure 5.2 Dead nodes of the network

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Fig 5.2 :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 Particle Swarm Optimization (PSO) LEACH and Direct Transimission (DTx).

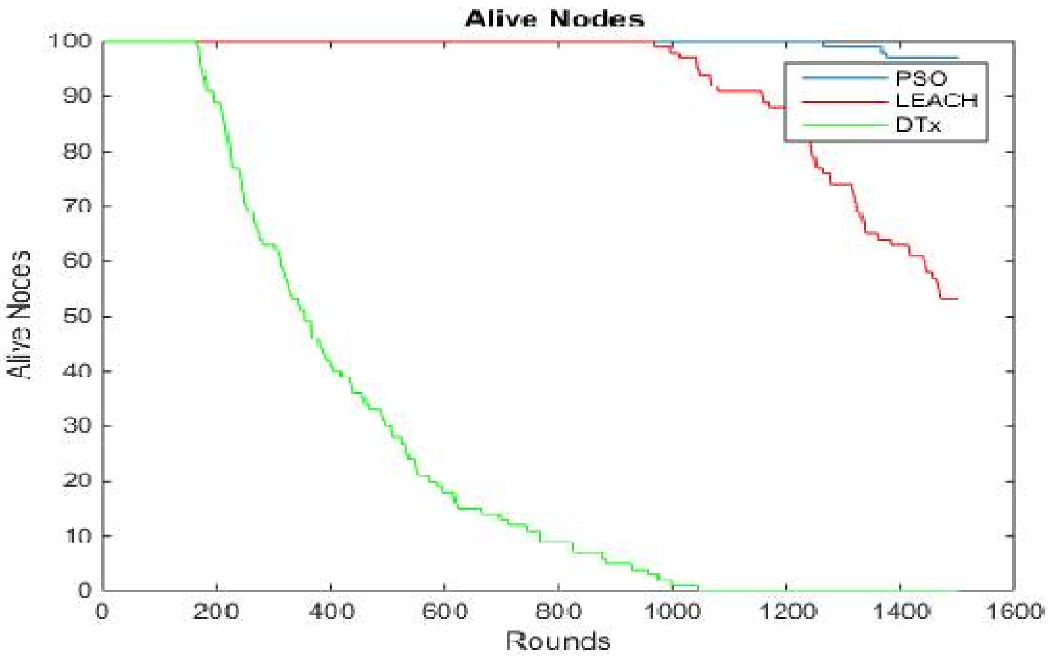

Figure 5.3 Alive nodes of the network

Fig 5.3:A Snapshot which shows the Number of Alive Nodes with respect to the Rounds. Particle Swarm Optimization (PSO) compares the alive nodes with LEACH and.Direct Transmission It is observed that nodes life time was increased in Particle Swarm Optimization (PSO)., when it is compared with LEACH and Direct Transmission (DTx).

V. CONCLUSION

In this paper, we have proposed the PSO algorithm which is best for solving the path problem. The parameters can be chosen self-adaptively in PSO which enhances the performance of network. In future work, we can implement some other optimization technique on cluster head selection and also work on WSN 3D environment.

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