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COMPUTATIONAL ANALYSIS OF ROUTING ALGORITHM FOR WIRELESS SENSOR NETWORK

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Abstract - *Wireless Sensor Network (WSN) are emerging because of the developments in wireless communication technology and miniaturization of the hardware. WSN consists of a large number of low-cost, low-power, multifunctional sensor nodes to monitor physical conditions, such as temperature, sound, vibration, pressure, motion, etc. As the energy available in the sensor nodes used in WSN is limited, the primary focus of WSN applications is to maximize the network life time by using the energy efficiently. Hence making a good use of energy is important in WSN applications. There are techniques to utilize the energy in an efficient way. One such technique is to place the sink node in an optimal position. The widely used technique for finding optimal location for sink node is Particle Swarm Optimization (PSO).*

Recent significant research on wireless sensor network (WSN) has led to the widespread adoption of wireless sensor network (WSN), which can be reconfigured even after deployment. In this project, we propose an energy-efficient routing algorithm for WSN. In this algorithm, to make the network to be functional, control nodes are selected to assign different tasks dynamically. The selection of control nodes is formulated as an NP-hard problem, taking into consideration of the residual energy of the nodes and the transmission distance. To tackle the NP-hard problem, an efficient particle swarm optimization (PSO) algorithm is proposed. Simulation results show that the proposed algorithm performs well over other similar algorithms under various scenarios such as life of node, throughput.

Key Words: wireless sensor Network (WSN), LEACH, PSO.

1. INTRODUCTION

In recent years, researchers have been attracted by wireless sensor network (WSN) due to their potential use in a wide variety of applications. A WSN contains different types of autonomous sensor nodes that are used to sense and transfer the data wirelessly to the Base Station (BS) or the next receiver node. Typically hundreds or thousands of low cost sensors are used in Wireless sensor network [1]. Routing is an issue for these sensor nodes where the resources are limited. These wireless sensor nodes have limited energy, processing capabilities, and sensing abilities. Initially WSNs were used only in the battlefields for military purposes but now their use is extended for monitoring and controlling the different processes in many other civilian areas. A wide range of sensors are available to monitor the different ambient conditions such as temperature, pressure, humidity, movement, and lightening conditions [2]. The sensed information and aggregated data delivery is necessary for efficient communication between sensor nodes. In a healthcare system, the implant and wearable sensors connected with a human body send the data to the coordinator node, which transfer these data towards the communication tier 2 devices. The tier 2 devices then route these data to the central database server for further processing [3].

The information is routed from the root node to the Base station either directly or through other sensor nodes. The BS is either a fixed or a mobile node which is capable of connecting the network to the internet where user can access and process the data. Routing in WSN is very challenging due to the inherent characteristics that distinguish this network from other wireless networks or cellular networks. The most important constraint on WSN is the limited battery power or sensor nodes. The required lower energy consumption restricts the sensor to use the limited resources such as less memory capacity, low transmit power, and less processing computations.

The emergence of big data and cloud technology has driven a fast development of wireless sensor network (WSN). A sensor node is normally comprised of one or more sensor units, data transmission unit, a data processing unit, a power supply unit and data storage,[1]. Wireless sensor networks hold the promise of revolutionizing the way we observe and interact with the physical world in a wide range of application domains such as environmental sensing, habitat monitoring and tracking, military defense, etc. A wireless sensor network is a collection of wireless nodes with limited energy that may be mobile or stationary and are located randomly in a dynamically changing environment.

The characteristics of low-cost, low-power, and multifunctional sensor have attracted a great deal of research attention, in that sensor nodes can perform intelligent cooperative tasks under stringent constrains in terms of energy and computational resources. However, most previous research work only considers the scenario where a WSN is dedicated to a single sensing task, and such application-specific WSN is prone to high deployment costs, low service reutilization and difficult hardware recycling [2]. Network operators run software programs on the controller to automatically manage data plan devices and optimize network resource usage [1]. This architecture enables up-to-date control schemes to be developed and deployed so as to enable new smart sensing services, making simplified network management in WSNs, which makes the future of SDWSNs bright [3]. However, to realize the aforementioned advantages of SDWSNs is not without challenges. In a sensor network, each node acts as both a sensor and router, with limited computing and communications capabilities, and storage capacity. Thus, in many scenarios, wireless nodes must operate without battery replacement for a long period of time. Consequently, the energy constraint is vital for the design of WSNs and SDWSNs. However, in many WSN applications, the deployment of sensor nodes is performed in harsh environments, which makes sensor replacement difficult and expensive [4]. In an SDWSN, although different virtual networks can work together on top of the same physical infrastructure, the centralized control plane may lead to high energy costs due to information collection to reach a global view, and multiple virtual networks may compete for common physical network resources. Therefore, resource utilization of the SDWSN also needs to be carefully designed. In this paper, we consider the SDWSN as illustrated in Fig. 1.1, which consists of a sensor control server and a set of software-defined sensor nodes. The large scales of deployed nodes that are equipped with multi-functions are able to execute multi-tasks simultaneously.

Traditional routing protocols in WSNs consume more energy for multi-tasking sensor networks because of the inflexibility. Therefore, based on the below architecture, we propose a new energy-efficient routing algorithm for software defined wireless sensor networks. Initially routing protocols in WSNs consume more energy for multi-tasking sensor networks because of the inflexibility.

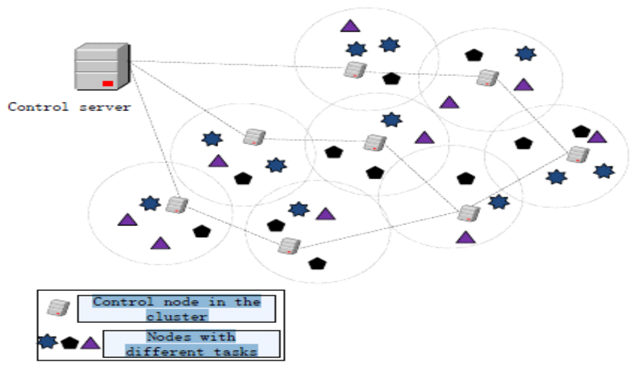

Fig. 1.1 An Example of the Software-Defined Sensor Network with Multi-Tasks.

The control server selects the control nodes of each cluster, and the control nodes instruct the intra-cluster nodes to complete different tasks. In this project, we are motivated to investigate how to minimize the energy consumption if reprogramming by considering the control nodes' selection and multicasting routing [1]. Our main contributions are summarized as follows:

- We propose an energy-efficient routing algorithm for the multi-tasking wireless sensor network. The selection of control nodes is formulated as an NP-hard problem, taking into account the residual energy of the nodes and the transmission distance; and To tackle the NP-hard problem, we propose an efficient particle swarm optimization (PSO) algorithm to solve it.

2. LITERATURE SURVEY

Wang *et al* (2009) proposed a refined protocol named LEACH-H (hybrid cluster-head selection LEACH) in order to prolong the WSN's lifetime. In the first round of LEACH-H, the base-station selected a CH set through adopting Simulated Annealing (SA) algorithm; in the rounds, the 46 CHs subsequently would select new CHs in their own cluster. This will not only solve the problem that the CHs were unevenly distributed in LEACH, but also maintain the characteristics of distribution. The energy consumption of the network is cut down and the live time of WSN is extended in LEACH-H [5].

Y. He, Y. Zhang *et al* (2010) proposed to tackle the strict limitation of energy supplication in large scale hierarchical structure of WSN. The proposed selection approach in CH selection mechanism considers detected signal strength, a node's residual energy and distance between cluster-head and sink node. An adaptive method based on task requirement in cluster member selection was suggested regarding cluster range setting. This method constrains cluster size and energy consumption of intra-cluster communication is reduced. Simulation showed that the new protocol conserved energy and prolonged WSN life specially when sink node is far from the network. Considering the character of communication scope of node in cluster, there exists areas of redundant place between joined clusters. To give a precise number of CH, efficient coverage is used, instead of full coverage of cluster to calculate the optimal number of CH per round, according to characters of one and two order partial derivative functions [6].

Yoon & Chang (2011) proposed a new cluster-based routing protocol using message success rate. To resolve the node concentration problem and design a new CH selection algorithm based on node connectivity and devise cluster maintenance algorithms. Moreover, to guarantee reliability of data communication, message success rate is a popular measure for data communication reliability, is used in order to select a routing path. Finally, to reduce data communication overhead, only information of neighboring nodes during both cluster-head selection and cluster construction phases were used. Through the performance analysis, it showed that proposed protocol outperformed the existing schemes in terms of communication reliability and energy efficiency [13].

A LEACH algorithm based energy effective routing protocol to meet key QoS requirements was proposed by Peng *et al* (2011). Energy efficiency is an important WSN issue. Network layer routing technology is critical to reduce WSN energy consumption. But, reliability and data aggression must also be analyzed. The new protocol focused on traditional LEACH defects and improved energy efficiency and QoS parameters by excluding nodes with improper geographic location to be CHs. Optimum measuring range of head nodes is designed to be a CH selection criterion and every CHs can be selected according to node density threshold in measuring area, confirmed by node distribution situation and communication needs. Simulations evaluated the new protocol in comparison with traditional LEACH algorithm. The performance of new protocol was verified to reduce energy consumption and guarantee communication quality especially in uneven distribution situations[14].

Kuila & Jana (2012) presented a distributed clustering and routing algorithm for WSN called Cost-based Energy Balanced Clustering and Routing Algorithm (CEBCRA). The algorithm comprised of three phases, namely CH selection, cluster setup and data routing. The CHs were selected in a distributed manner based on residual energy and the neighbour cardinality. In the setup phase, each non-CH sensor node joined a CH within its communication range based on the cost value of the CHs. In data routing phase, CEBCRA first used single-hop communication within each cluster and then performed multi-hop communication between the clusters. For intercluster routing, a CH measured the cost of each path from itself towards base station while selecting other CH as a relay node for data forwarding on those paths. The experimental results showed efficiency of the proposed algorithm in terms of energy consumption and number of live sensor nodes. The results were compared with two existing techniques to show the efficacy of the algorithm[12].

Zhang *et al* (2012) proposed the position of CH as an important factor for the network lifetime. Based on this observation, a non-random CH selection scheme based on the concept of the center of mass in physics was proposed. The problem of power consumption in sensor data collection in a WSN was considered. Since sensor nodes operate on batteries, power efficiency is a crucial issue in designing the network. The geographic deployment of sensor nodes is random, with an irregular network topology. In the existing clustering-based protocols for the WSN, the CHs are usually selected at random, which may result in higher power consumption and shorter network lifetime. The purpose of proposed scheme was to use minimal power in the process of data collection. It was shown that proposed scheme could save up to 50% of power consumption [11].

Jain & Trivedi (2012) proposed an algorithm for energy efficient clustering and multi-hop routing in WSN. The sensor network is constructed in the form of a circular area with the base station. An adaptive cluster selection strategy which selects the Cluster Heads (CHs) not only on the basis of residual energy, but also on the distance from the base station. A key point of the algorithm is that CH selection is done after each round and multiple times within the same round. This is done since the CH near the BS is involved in most of the communications and hence it may get exhausted early [10].

Wang et al (2013) proposed a Fuzzy-based system for CH selection and controlling sensor speed in WSNs. In WSN, cluster formation and CH selection were critical issues. They could drastically affect the network's performance in different environments with different characteristics. The 42 proposed system was constructed by two Fuzzy Logic Controllers (FLC). Using four input linguistic parameters for evaluating CH decision probability in FLC1, the output of FLC1 was used and two other linguistic parameters as input parameters of FLC2 to control sensor speed. FLC2 was evaluated by simulations and showed that it achieved good performance [8].

Izadi et al (2013) was proposed a type-2 fuzzy based Self-Configurable Cluster Head (SCCH) selection approach to consider CH selection criterion which presented a cluster backup approach. So, when cluster failed, the system worked efficiently. This protocol's novelty is the ability to handle communication uncertainty, an inherent operational aspect in sensor networks. Results revealed that SCCH performed better than other developed methods [9].

3. SYSTEM DEVELOPMENT

3.1 Wireless Sensor Network

Wireless Sensor Network (WSN) can be defined as a self-configured and infrastructure less wireless networks to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location or sink where the data can be observed and analyzed. A sink or base station acts like an interface between users and network. One can retrieve required information from the network by solving queries and gathering results from the sink. Typically a wireless sensor network contains hundreds of thousands of sensor nodes. The sensor nodes can communicate among themselves using radio signals. A wireless sensor node is equipped with sensing and computing devices, radio transceivers and power components. The individual nodes in a wireless sensor network (WSN) have limited processing speed, storage capacity, and communication bandwidth. After the sensor nodes are deployed, they are responsible for self-organizing an appropriate network infrastructure often with multi-hop communication with them. Then the onboard sensors start collecting information of interest. Wireless sensor devices also respond to queries sent from a "control site" to perform specific instructions or provide sensing samples. Wireless sensor devices can be equipped with actuators to "act" upon certain conditions. These networks are sometimes more specifically referred as Wireless Sensor and Actuator Networks as described in (Akkaya et al., 2005).

The working mode of the sensor nodes may be either continuous or event driven. Global Positioning System (GPS) and local positioning algorithms can be used to obtain location and positioning information of object. Wireless sensor network (WSN) enable new applications and require non-conventional paradigms for protocol design due to several constraints. Owing to the requirement for low device complexity together with low energy consumption (i.e. long network lifetime), a proper balance between communication and signal/data processing capabilities must be found. This motivates a huge effort in research activities, standardization process, and industrial investments on this field since the last decade (Chiara et. al. 2009). At present time, most of the research on WSNs has concentrated on the design of energy- and computationally efficient algorithms and protocols, and the application domain has been restricted to simple data-oriented monitoring and reporting applications (Labrador et. al. 2009). The authors in (Chen et al., 2011) propose a Cable Mode Transition (CMT) algorithm, which determines the minimal number of active sensors to maintain K-coverage of a terrain as well as K-connectivity of the network. Specifically, it allocates periods of inactivity for cable sensors without affecting the coverage and connectivity requirements of the network based only on local information. In (Cheng et al., 2011), a delay-aware data collectionnetwork structure for wireless sensor networks is proposed. The objective of the proposed network structure is to minimize delays in the data collection processes of wireless sensor networks which extends the lifetime of the network. In (Matin et al., 2011), the authors have considered relay nodes to mitigate the network geometric deficiencies and used Particle Swarm Optimization (PSO) based algorithms to locate the optimal sink location with respect to those relay nodes to overcome the lifetime challenge. Energy efficient communication has also been addressed in (Paul et al., 2011; Fabbri et al. 2009). In (Paul et al., 2011), the authors proposed a geometrical solution for locating the optimum sink placement for maximizing the network lifetime. Most of the time, the research on wireless sensor networks have considered homogeneous sensor nodes. But nowadays researchers have focused on heterogeneous sensor networks where the sensor nodes are unlike to each other in terms of their energy. In (Han et al., 2010), the authors addresses the problem of deploying relay nodes to provide fault tolerance with higher network connectivity in heterogeneous wireless sensor networks, where sensor nodes possess different transmission radii. New network architectures with heterogeneous devices and the recent advancement in this technology eliminate the current limitations and expand the spectrum of possible applications for WSN considerably and all these are changing very rapidly.

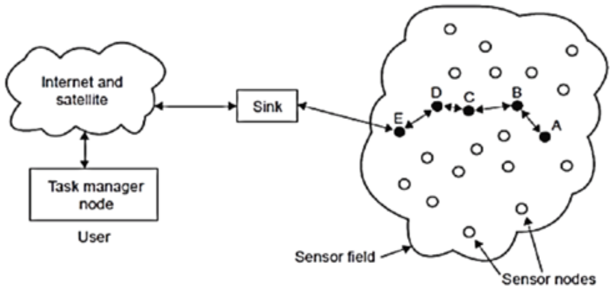

Fig. 3.1. A Typical Wireless Sensor Network

Wireless Sensor Networks are wireless networks that usually consist of a large number of far distributed devices that are equipped with sensors (instruments that measure quantities in our environment to monitor physical or environmental phenomenon's. These devices work autonomous and are logically linked by self-organizing means. Some of the challenges for these systems are:

• **Reliability:** WSNs are wireless networks and are therefore fenceless to problems like packet loss. Nevertheless, they are used in areas such as chemical attack detection, in which these problems could easily lead to serious catastrophes.
• **Power Consumption:** The nodes of Wireless Sensor Networks are usually battery powered because of their small in size . This limits the lifetime of a sensor node and raises the topic of energy-efficiency in all aspects.
• **Node Size:** Perquisite is the keyword in many studies about WSNs. Developing smaller nodes, with the same or even more efficiency than their bigger brothers is still a challenge in wireless sensor network, even if present sensor nodes, are hardly as big as a coin.
• **Mobility:** Many applications used for the factor mobility into WSN challenges. For example, commercial applications, like vehicle tracking, need networks that are able to constantly change its routing paths and infrastructure.
• **Privacy and Security:** Unlike wired channels, wireless channels are accessible to both, legitimate and illegitimate users. Therefore, several methods, like encoding the traffic, have to be discussed in below.

Wireless Sensor Networks is a class of special wireless ad hoc networks. A wireless ad hoc network is a collection of wireless nodes, that communicate directly over a common wireless channel. There is no additional infrastructure or requirements are needed for ad hoc networks. Therefore, every node is equipped with a wireless transceiver and has to be able to act as a router, to process packets to their destinations. Strength of these networks is their ability to self-organize the infrastructure of the routing, after they were deployed the main difference between common ad hoc networks and Wireless Sensor Networks is their different area of application. For WSN, monitoring and collecting data are to the fore, while common ad hoc networks focus more on the communication aspects.

3.2 Routing Algorithm Based on Particle Swarm Optimization

Particle swarm optimization is originally proposed by Kennedy, Eberhart and Shi and was first intended for simulating social behaviour, as a stylized representation of the movement of organisms in a bird flock or fish school. The algorithm was simplified and it was observed to be performing optimization. The book by Kennedy and Eberhart describes many philosophical aspects of PSO and swarm intelligence. An extensive survey of PSO applications is made by Poli. Recently, a comprehensive review on theoretical and experimental works on PSO has been published by Bonyadi and Michalewicz.

PSO is a metaheuristic as it makes few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions. However, metaheuristics such as PSO do not guarantee an optimal solution is ever found. Also, PSO does not use the gradient of the problem being optimized, which means PSO does not require that the optimization problem be differentiable as is required by classic optimization methods such as gradient descent and quasi-newton methods.

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling. Particle swarm optimization shares many similarities with evolutionary computation techniques such as Genetic Algorithms (GA). The system is initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. The detailed information will be given in following sections. Compared to Genetic Algorithm, the advantages of PSO are that PSO is easy to implement and there are few parameters to adjust. PSO has been successfully applied in many areas: function optimization, artificial neural network training, fuzzy system control, and other areas where Genetic Algorithm can be applied [12].

3.3 Particle Swarm Optimization Algorithm

When the search space is too large to search exhaustively, population based searches may be a good alternative, however, population based search techniques cannot guarantee you the optimal (best) solution.

I will discuss a population based search technique, Particle Swarm Optimization (PSO). The PSO Algorithm shares similar characteristics to Genetic Algorithm, however, the manner in which the two algorithms traverse the search space is fundamentally different.

Both Genetic Algorithms and Paticle Swarm Optimizers share common elements:

1. Both initialize a population in a similar manner.
2. Both use an evaluation function to determine how fit (good) a potential solution is.
3. Both are generational, that is both repeat the same set of processes for a predetermined amount of time.

Algorithm 1 Population Based Searches

```
procedure PBS
    Initialize the population
    repeat
        for i = 1 to number of individuals do
            G(x_i)                          ▷ G() evaluates goodness
        end for
        for i = 1 to number of individuals do
            P(x_i, θ)                       ▷ Modify each individual using parameters θ
        end for
    until stopping criteria
end procedure
```

3.4 Concepts of Particle Swarm Optimization with Flowchart

Particle Swarm has two primary operators first is velocity update and second is position update. During each generation each particle is accelerated toward the particles previous best position and the global best position. At every iteration a new velocity value for each particle is calculated based on its current velocity, the distance from its previous best position and the distance from the global best position. The new velocity value is then used to calculate the next position of the particle in the search space. This process is then iterated a set number of times or until a minimum error is achieved.

Algorithm 2 Particle Swarm algorithm

```
procedure PSO
  repeat
    for i = 1 to number of individuals do
      if G(x⃗_i) > G(p⃗_i) then                     ▷ G() evaluates goodness
        for d = 1 to dimensions do
          p_id = x_id                              ▷ p_id is the best state found so far
        end for
      end if

      g = i                                        ▷ arbitrary
      for j = indexes of neighbors do
        if G(p⃗_j) > G(p⃗_g) then
          g = j    ▷ g is the index of the best performer in the neighborhood
        end if
      end for

      for d = 1 to number of dimensions do
        v_id(t) = f(x_id(t−1), v_id(t−1), p_id, p_gd)   ▷ update velocity
        v_id ∈ (−V_max, +V_max)
        x_id(t) = f(v_id(t), x_id(t−1))                 ▷ update position
      end for
    end for
  until stopping criteria
end procedure
```

Particle Swarm Optimization begins with a group of random particles (random solutions), aiming at finding out the optimum solution through an iterative process based on the velocity and position of particle. Each particle has a fitness value, which will be evaluated by the fitness function to be optimized in each iteration[1]. During the search process, each particle in the population consists of dimensional vector including the velocity vector vi = [vi1; vi2; :::; vid], the current position vector (pBest) xi = [xi1; xi2; :::; xid], and the previous best position vector pi = [pi1; pi2; :::; pid], where d is the dimensionality of the search space. What's more, the whole population maintains a global best-so-far population vector pg = [Pg1; pg2; :::; pgd] [3]. The flowchart of PSO is shown in Fig. 3.2.

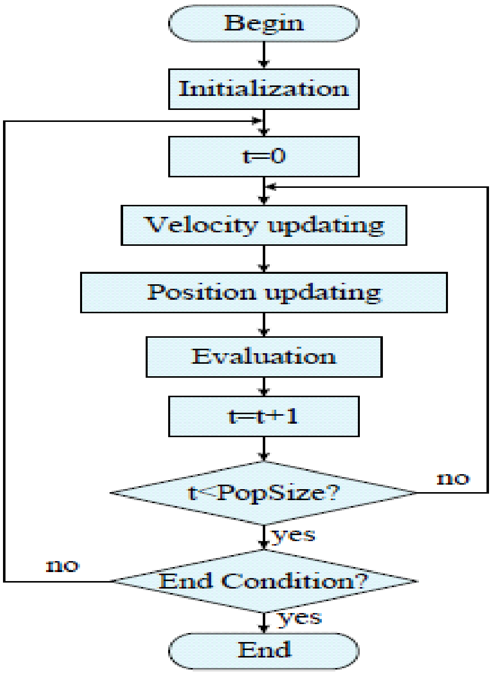

Fig. 3.2. Flowchart of the PSO Algorithms

As can be seen from the figure, during each iteration of the evolutionary process in PSO, each particle learns from its own search experience pBest and the swarm's search experience gBest to update its velocity vi and position xi [12, 13]. During the iterations, the velocity of the particle is updated according to the following

$v_{id}(t+1) = wv_{id}(t)+c1(p_{id} - x_{id}(t))+c2(pgd - x_{id}(t))$ ……(5)

The position of the particle is updated as follows

$x_{id}(t + 1) = x_{id}(t) + v_{ij}(t)$ …..(6)

where the representation of v_{id} is similar to that of x_{id}; P_{id} and Pgd are the d^{th} dimension of the i^{th} particle's velocity. Coefficients _ and _ are two randomly generated values within the range of [0; 1] for the d^{th} dimension. c1 and c2 are two acceleration parameters which are commonly set to 2.0 or adaptively controlled according to the evolutionary states. Factor w is the inertial weight, which plays the role of controlling the impact of the previous velocity of a particle on the current one so as to balance between global search (large inertial weight) and local search (small inertial weight). However, PSO exhibits poor local search ability and often leads to premature convergence, especially in complex multipeak search problems. To tackle this issue, this paper proposes a method which adapts itself nonlinearly as follows

$w = (w_{max} - w_{min} \square d_1)^* e^{1/1+d_2*t/K}$ ……(7)

where w_{max} and w_{min} represent the maximum and minimum inertial weights and are always set to 0.9 and 0.4, respectively. K is the maximum number of allowed iterations while t represents the current iteration. d1 and d2 are two control factors which control the value of w between w_{min}

and w_{max}. The execution of the algorithm is comprised of two phases, i.e., the control nodes' selection phase and the data transmission phase. The two phases are performed in each round of the network operation and repeated periodically. We elaborate on how to use the non-linear weight particle swarm optimization algorithm (NWPSO) to select the control nodes in the next section.

3.5 LEACH PROTOCOL

Low energy adaptive clustering hierarchy is hierarchical protocol which allows the nodes to transmit data to the cluster heads of the cluster to which they belong. The cluster heads aggregate the data received from the non-cluster head nodes or cluster member & forward it to the Base Station (Sink). It is a cluster based routing protocol whose main aim is to increase the lifetime of the wireless sensor network. It is a very good example of self-adaptive & self-organised protocol. Its overall operation is based on rounds & each round consists of two stages- set up stage & steady state stage.

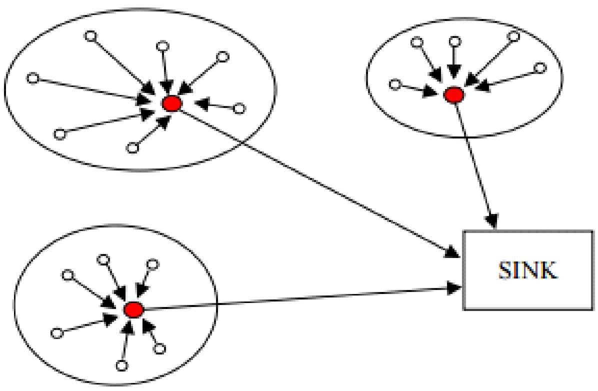

Fig.3.3. Architecture of LEACH Protocol

The core idea of LEACH protocol lies in dividing the whole network into various clusters. In each cluster, a cluster head is selected in hierarchical manner & this role is rotated among the nodes in the cluster in order to homogeneously distribute the power load in every round. This protocol allows scalability & robustness in the network & also helps in compressing the size of information to be sent to the Base Station. The basic architecture is depicted in figure no. 3.3.

LEACH Protocol is a well representative of hierarchical routing protocols. It is self-adaptive and self-organized. LEACH protocol uses round as unit, each round is made up of cluster set-up stage and steady-state stage[8], for the purpose of reducing unnecessary energy costs, the steady state stage must be much longer than the set-up stage. The process of it is shown in Figure 3.4.

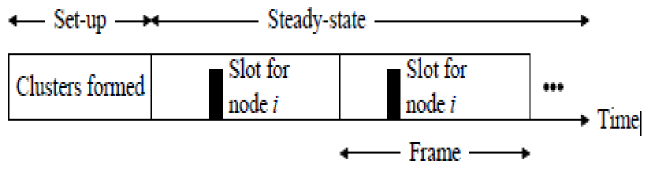

Fig. 3.4 LEACH Protocol Process.

At the stage of cluster forming, a node randomly picks a number between 0 to 1, compared this number to the threshold values $t(n)$, if the number is less than $t(n)$, the it become cluster head in this round, else it become common node. Threshold $t(n)$ is determined by the following.

$$t(n)=\begin{cases}\dfrac{p}{1-p*(r \bmod \frac{1}{p})} & if\ n \in G\\ 0 & if\ n \notin G\end{cases}$$

Where p is the percentage o
f the cluster heads nodes in all nodes, r is the number of the round, G is the collections of the nodes that have not yet been head nodes in the first 1/P rounds. Using this threshold, al l nodes will be able to be head nodes after 1/P rounds. The analysis is as follows: Each node becomes a cluster head with probability p when the round begins, the nodes which have been head nodes in this round will not be head nodes in the next 1/P rounds, because the number of the nodes which is capable of head node will gradually reduce so for these remain nodes, the probability of being head nodes must be increased. After 1/P-1 round, all nodes which have not been head nodes will be selected as head nodes with probability 1, when 1/P rounds finished, all nodes will return to the same starting line. When clusters have formed the nodes start to transmit the inspection data. Cluster heads receive data sent from the other nodes, the received data was sent to the gateway after fused. This is a frame data transmission. In order to reduce unnecessary energy cost, steady stage is composed of multiple frames and the steady stage is much longer than the set-up stage.

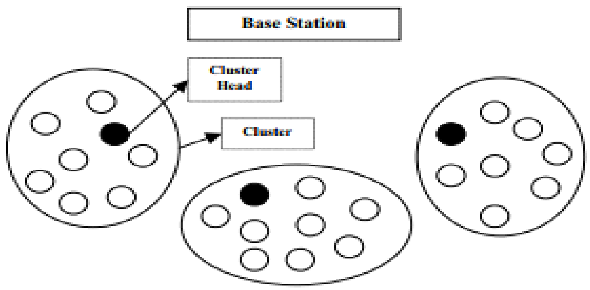

Fig. 3.5. Cluster Formation in LEACH

A. Cluster Head Selection Formation Algorithm

Step-1: Create Sensor Network Model.
Step-2: Assign initial energy to sensor nodes.
Step-3: Sort the nodes based on the distance from Base station using Bubble Sort in increasing order. To calculate node-distance from Base-Station the given formula is used

Node_distance (i)
$\sqrt{(S(i).xd-(sink.x))x^2+(S(i).yd-(sink.y))x^2)}$

Step-4: For round=1 assign cluster heads based on minimum distance from the base-station No of Cluster Heads for round-1= (p*n). Decrease the energy of the nodes chosen as cluster head by the formula as mentioned below by checking the conditions

If (Node_distance (i) > do)
S(i).E=S(i).E-((E_{TX}+E_{DA})*(4000)+ Emp*4000* (node_distance(i)*node_distance(i)*node_distance(i)*node_distance(i)));
Else
S(i).E=S(i).E-((E_{TX}+E_{DA})*(4000)+E_{fs}*4000*(node_distance(i)*node_distance(i)));
Step-5: For the next round
r =1:1: rmax
If (S(i).E ≥ E_{avg}) then
i = nominee_clusterhead //nominated for cluster-head selection
Calculate node-degree of the chosen nominee for cluster heads
If (Node_degree ≥ avg_degree)
i=cluster head //cluster-head selected
Step-6: Dead node
if (S(i).E = 0) then
Dead=I //ith node dies
n=n-dead //n: decrease no of alive nodes
Step-7: Goto step-5
Step-8: End

Setup Phase

In LEACH protocol, clusters are formed by making use of a distributed algorithm and there is no communication with the Base Station required. Each node uses a stochastic algorithm at each round to determine whether it will become a cluster head in that round or not. The algorithm for cluster formation in the LEACH protocol carries out the task of cluster formation, cluster head node selection & notification to non-cluster head nodes. This phase can be further sub-divided into three parts
i. Advertisement
ii. Cluster set-up
iii. Transmission schedule creation

The algorithm is designed in such a way that the same node should not get chosen as cluster head node every time. The cluster head node is selected on the basis of random number between 0 and 1. This random number is chosen by the sensor node whose value lies between 0 & 1. Let a threshold value, T(n), is considered & it is calculated as

$$T(n) = \frac{p}{1-p(r \bmod p-1)} \quad \text{if } (n \in G)$$
$$0 \quad \text{otherwise}$$

where p is the cluster head probability, r is the current round & G is the set of nodes that have not been cluster heads in the last 1/p rounds.

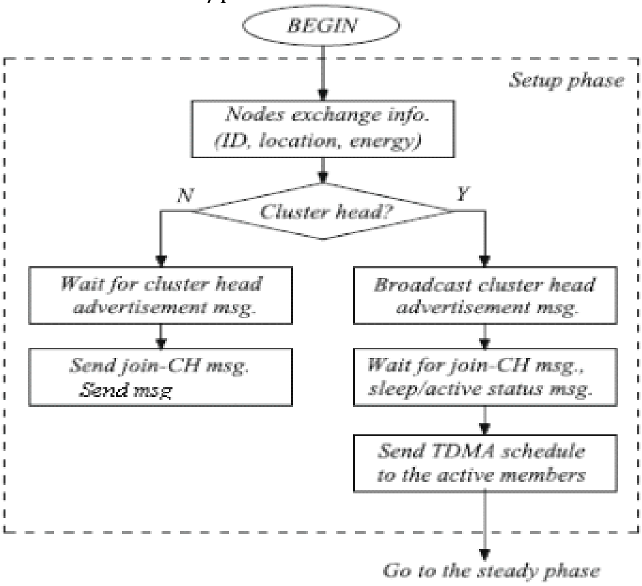

Fig.3.6. Flowchart of LEACH Protocol in Set-up Phase

Steady State Phase

After cluster heads selection and TDMA slots allocation, the steady state phase starts. Based on TDMA protocol, the communication starts between the cluster head and their respective cluster heads in their allocated time slots. The cluster node can only communicate with its cluster head of respective cluster in a predefined time slot. Initially all cluster nodes are in sleep mode during unallocated time slots. This leads to better energy efficiency of the protocol. Non-cluster head nodes transmit their data to their associated cluster head. Then this cluster head forwards the aggregated data to base station. In Steady phase during which the cluster nodes send their data to the cluster head. The member sensors in each cluster communicate only with the cluster head via a single hop transmission. The cluster head then aggregates all the collected data and forwards this data to the base station either directly or via other cluster head along with the static route defined in the source code as shown in Fig. 3[7]. After completion of steady state the certain predefined time, which is decided beforehand, the network again goes back to the Set-up phase.

Steady State Phase In Steady State Phase, the actual transmission of data takes place. On the basis of functionalities performed in this stage the Steady State Phase can be sub-divided into three parts

- Data transmission to cluster head
- Data fusion (Signal Processing)
- Data transmission to base station

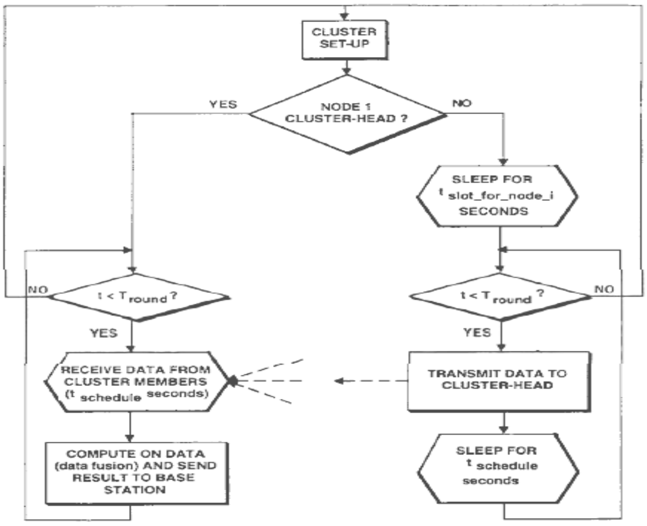

Fig.3.7. Flowchart of LEACH Protocol in Steady State Phase

Within each cluster the cluster head node creates a TDMA schedule, randomly picks a CSMA schedule & broadcasts it to the non-cluster head nodes in steady state. After this step i.e steady state, the member nodes start sending their respective data to the cluster head node during their allotted TDMA slot. The radio of all the other nodes except the active member node is turned off which minimizes their energy dissipation. But the cluster head node has to keep its radio on in order to receive the messages from the member nodes. After that all nodes send data to their respective cluster, it aggregates the collected data, called data fusion, and transmits the fused data to the Base Station (Sink). The process of aggregation is required so that the amount of data transmitted to the Base Station can be as compressed as possible. Apart from being energy-efficient it also makes fair utilization of bandwidth communication bandwidth is fixed.

To minimize the energy cost, the steady state phase is composed of multiple frames. So the steady state phase is longer than the set-up phase. After a certain period of time, the overall system goes back into the set-up phase again & another round gets started & a new cluster head node is chosen. Each cluster communicates with a different CDMA code to minimize the interference among different clusters

Energy Calculation in LEACH Protocol

For calculation of energy in LEACH Protocol, we will consider first order radio model. For this, some assumptions have to be made:

- Sensors, communicating with each other as well as with the Base Station, lie within the communication range. Base Station placed at the center of the network.
- Energy dissipation is neglected
- All the sensors are of same capability

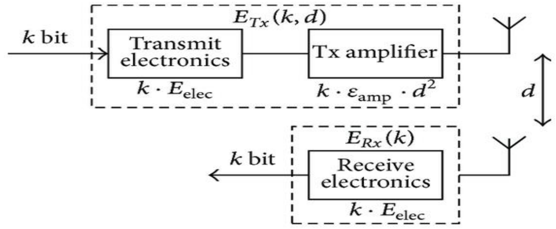

Fig.3.8. First Order Radio Energy Model

Thus, energy required to transmit k-bit message in a distance d is given by-

$E_{Tx}(k,d) = k * E_{elec} + k * E_{fs} * d^{2,}\ d < 0$

$k * E_{elec} + k * E_{amp} * d^4\ , d \geq 0$

New Improved Algorithm Based on LEACH Protocol

In LEACH protocol, due to the randomly clusters forming, the energy of each cluster head is very different, so do is the distances between cluster heads and base station. Function of cluster head is collect the data from their respective cluster head and send to the base station. In the process of data collection and transmission, the energy consumed by data transmission is greater than that of data fusion [4]. If the current energy of a cluster head is less or the distance to base station is much far, then the cluster head will be died quickly because of a heavy energy burden. To address these issues, this article proposes a new improved algorithm based on particle swarm optimization how to balance the energy loads of these cluster heads.

The Idea of Improved Algorithm

LEACH (LEACH Protocol with particle swarm optimization) is optimized based on LEACH Protocol, the methods of cluster-head selection and clusters forming are same as LEACH protocol. If a cluster head's current energy is less than the average energy, that is $Ecur \leq Eave$, where $Eave = \sum_1^N E(i)cur$ is the average energy of all nodes in the network, or the distance between the cluster head and base station is longer than the average distance, that is $d \geq dave$, where $davg = \sum_1^N di$ is the average distance of all nodes distance to base station, then the common node with maximum energy in this cluster will be selected as the secondary cluster head. If $Ecur \leq Eave$ and $d \geq dave$, it is unnecessary to select a secondary cluster head.

In a cluster which has secondary cluster head, the secondary cluster head is responsible for receiving and fusing data collected from the member nodes and sending them to its cluster head, the cluster head is only responsible for sending data to base station. In a cluster without secondary cluster head, the cluster head is responsible for collecting data from the cluster member node and sending data to base station after the data was fused. It is clear from the first order energy transfer model (Figure 3.8) that the

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energy consumption of data receiving and data fusion are less than that for data transferring [5]especially for long distance data transferring, so the life of clusters with secondary cluster heads will not be extended a lot so as to bring new energy imbalance of energy consumption of entire network. The network topology of the optimized algorithm is shown in Figure 3.9.

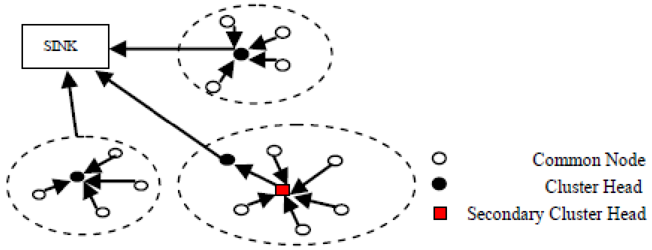

Fig.3.9 Network Topology of LEACH

First-Order Wireless Transmission Model

This article uses first-order wireless communication model, it is shown in Figure 3.10

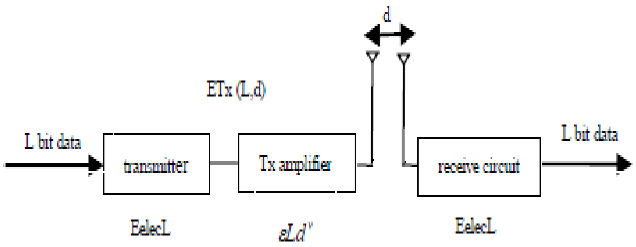

Fig. 3.10 The wireless communication model

The total energy consumed in Figure 3.10 is calculated by formula (2) and (3) [6],

$$E_{Tx}(L,d)=\begin{cases} LEelec + LEfsd^2, d \le do \\ LEelec + LEfsd^4, d > do \end{cases} \quad (2)$$

$$E_{Rx}(L) = LEelec \quad (3)$$

Where *Eelec* represents the energy consumed to transmit or receive 1 bit message *Efs* is the amplification coefficient of free-space signal and *Emp* is the multi-path fading signal amplification coefficient, their value depend on the circuit amplifier model, d represents the distance between transmitter and receiver, L is the bit amount of sending information.

The Optimal Number of Cluster Heads

In LEACH Protocol, all nodes are divided into n clusters randomly, if the value of n is too small, each cluster head burdens so heavily that some clusters will die earlier due to energy loss this will affect the network lifetime. If the value of n is too large, this also results in some unnecessary overhead because clusters need to send broadcast messages to all nodes. Suppose N nodes are randomly distributed within the square area of length M, assuming that the base station locates in the center of region and the distance of each node or cluster head to the base station is less than or equal to *d0* ,where

$$d0 = \sqrt{\frac{Efs}{Emp}}$$

we know by references [6] that the optimal number of cluster heads should be

$$nopt = \sqrt{\frac{N}{2\pi}}\frac{M}{dto\ BS} \quad (4)$$

If some nodes' distance to base station is greater than *d0* , we can also get formula (5) by the same method which was used in references [6] and [7].

$$nopt = \sqrt{\frac{N}{2\pi}}\sqrt{\frac{Efs}{Emp}}\frac{M}{dto\ BS} \quad (5)$$

So the optimal probability for nodes to become cluster heads is

$$Popt = \frac{nopt}{N} \quad (6)$$

By the formula (4) and (5) we know that the optimal number of cluster heads only relates to the number of network nodes N, the regional side length M, as well as the location of the base station. We can set these parameters initially in the network. In this paper, the optimal probability for nodes to become cluster heads is chosen as 7% according to formula (6) and all parameters are set . The parameters need to be used in description of algorithm are as following: Threshold value, as shown in formula (1) Average energy of all nodes is $Eave = \sum_1^N E(i)$ Average distance; between nodes and base station is $dave=\sum_1^N d(i)$.

The Stage of Cluster Forming

First, a node choose a number between 0 to 1, if the number is less than *T*(*n*) then the node becomes cluster head otherwise it becomes normal nodes. Cluster heads broadcast their own information to other nodes , the other nodes will listen to the broadcasting messages which is broadcast by node. All normal nodes determine which cluster they should join in this round based on the signal strength they received. After determining which cluster they should belong, CSMA Protocol will be used to send a confirmation message to their cluster heads. At this point the clusters forming stage is finished.

The Selecting of Secondary Cluster Head

Each cluster head decides whether to set a secondary cluster head according to the current energy itself and the distance to the base station, if $E(i)ave < E$ or $d(i)ave > d$, then these kinds of cluster heads should choose the node with maximum energy as secondary cluster head in its cluster, otherwise, the secondary cluster head is not required in the cluster.

To Create a Transport Schedule

All clusters are divided into two categories, in clusters with secondary cluster heads, the secondary cluster head broadcasts message to cluster nodes and builds a schedule (uses TDMA access channel, a time slot is assigned to each node), informs the schedule to the other nodes. In clusters without secondary cluster head, the cluster heads distribute sending time slot to the others after get the join information of normal nodes. The stable stage begins when each node have gotten its sending time slot.

Data Transferring

When clusters have formed and the TDMA schedule is determined, the nodes start to transfer the monitoring data. The secondary cluster heads receive data from the other nodes and fuse these data, these fused data was sent to the cluster heads, then cluster heads send these data to base station by single-hop method. In those clusters without secondary cluster head, cluster head collect data from cluster member and it send to base station.

Simulation of Optimized Algorithm

This paper uses Matlab10.0 as simulation platform to emulate LEACH protocol and the optimized protocol (LEACH-optimize), the improved algorithm aims at balancing the total energy consumption of nodes and extending the network's time. So we measure the optimized protocol performance from two aspects: the lifetime and the total energy consumption of the network. The lifetime of network means the time from the beginning of simulation to the time when the last node died. As the energy of wireless sensor network is limited, so the energy consumption in its lifetime is a meaningful indicator to measure the performance of it.

Simulation Parameters

Simulation scenarios in this article are:
1. Sensor nodes are randomly distributed in a square region i.e. 100 x 100;
2. Sensor nodes are homogeneous and have a unique ID number throughout the network, nodes energy is limited all node have same energy. The node's location is fixed after deployed;
3. The base station is in the center of region with fixed location i.e. 50 x 50;
4. Nodes communicate with base station via single-hop or multi-hop;
5. The wireless transmitter power is adjustable. Specific parameters are shown in table and receiver electronic circuitry *E*(*elec*) is 50nJ/bit and for acceptable SNR required energy for transmitter amplifier for free space propagation *Efs* is 100pJ/bit/m2 and for two ray ground *Emp* is 0.0013pJ/bit/m4. The crossover distance *do* is assumed to be 87m. All parameters are specified in Table 1

Sr No.	Simulation Parameter	Value Used
1	Number of sensor node (N)	100
2	Network area (M×M)	100×100
3	Eelec (Transmission & reception energy per bit)	50nJ
4	Efs (Transmit amplifier energy dissipation of free space model)	100pJ/bit/m^2
5	Emp (Transmit amplifier energy dissipation of two model)	0.0013pJ/bit/m^4
6	E0(Initial energy of deployed node)	0.25J,0.5J,1J
7	Eda (Data aggregation energy per bit)	5nJ
8	K (Number of bits in a packet)	4000 byte
9	d0 (Cross over distance)	87m
10	Location of data sink	(50,50)
11	Popt	0.1
12	Massage size	4000 bits
13	Number of iteration	4000

Analysis of Simulation Results

100 nodes randomly distribute within the square area of the 100m*100m, the base station is located in the center of the region, the base station coordinates is (100,100). It can be seen from the figure 3.11 that the nodes' distribution are randomly.

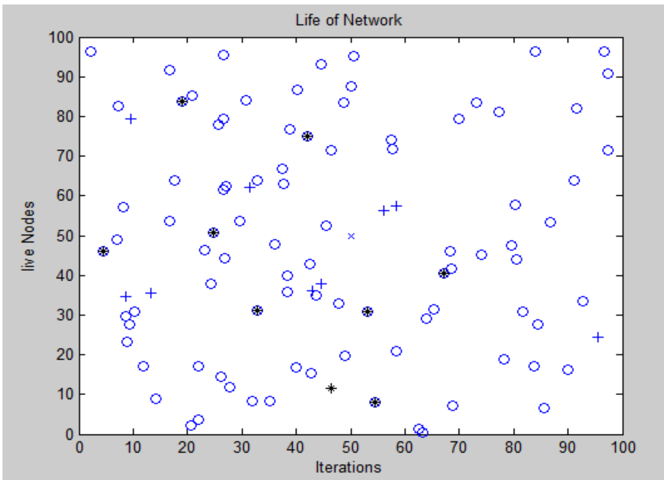

Fig.3.11. Randomly Distributed Nodes

The Network Lifetime

The network lifetime in this paper is defined as the time from the beginning of the simulation to the time when the last node died. In wireless sensor network the network life is divided into stable and unstable period [6]. Stable period usually means the time from the beginning of the simulation to the time when the first node dies, the unstable period refers to the time from the death of first node to the end of simulation or until all rounds are not completed. If it happened that some nodes begin to die, the network operation may become unstable and unreliable data transferring will occur. Therefore, the longer the stable period is, the better the performance of the network. In Low energy adaptive clustering hierarchy protocol, cluster heads are responsible not only for communicating with the base station, but for the data fusing. Randomly distributing the nodes and randomly selecting the cluster heads causes some cluster heads die earlier because of the low energy or the long distance to base station. Secondary cluster heads are set for these clusters to be responsible for the communication with common nodes and data fusing, this balances the energy load of cluster heads and avoids premature death of these cluster heads, so the stable period of network lifetime will be maximize. Figure 3.12 is network lifetime in simulation, simulation results indicates that the network lifetime of the improved.

First node died in LEACH Protocol in round 557, the first node died in the optimized Protocol in round 857. When 90% nodes died, the network reliability is extremely reduced and the running is almost meaningless. We may as well to define the time from the simulation beginning to the time 90% nodes died as effective lifecycle, analyzing from figure 3.14, we know that the effective lifecycle of the optimzed algorithm is longer 50% than that of LEACH protocol. The percentage of stable period of lifecycle in LEACH Protocol is 28%, the one in the improved protocol is 44%, The percentage of stable period of lifecycle in optimized algorithm increases by 15%. This indicates that the running performance of optimized protocol is much better than that of LEACH Protocol. The analysis of simulation results is consistent with the theoretical analysis.

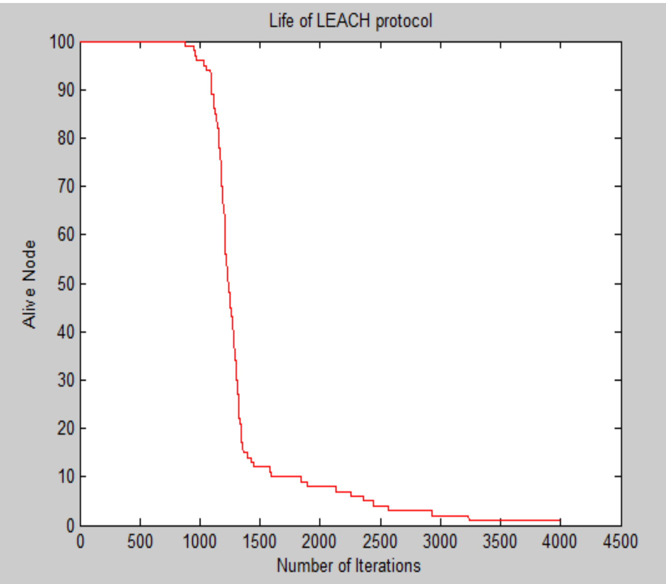

Fig. 3.12 The Network Lifetime

4. RESULTS AND ANALYSIS

4.1 SIMULATION RESULT

We compare Optimize-LEACH with LEACH and optimize-LEACH based on two performance metrics: total energy consumption and lifetime. Optimize-LEACH protocol has more residual energy than LEACH and optimize-LEACH. The simulation of LEACH and optimize-LEACH has 100 sensor nodes, which are randomly distributed in an area of 100m × 100m. BS is put at the location with $x = 50$, $y = 50$. The bandwidth of data channel is set to 1 Mbps, the length of data messages is 4000 bytes and packet header for each type of packet was 25 bytes. The number round is set to 4000s. When a node uses energy down to its energy threshold, it can no longer send data and is considered as a dead node.

Comparison of Node life with Different Energy

Given below table shows the life of network with different energy also it shows when the first node is dead and when the last node is dead with 3 different energy ie 0.25J, 0.5J and 1J.

Table 2. Lifetimes Using Different Amounts of Initial Energy for the Sensors.

Energy(J/node)	Protocol	Round First Node Dies	Round First Node Dies
0.25J	LEACH	585	1474
	LEACHopt	1170	3552
0.5J	LEACH	1291	3081
	LEACHopt	1333	3166
1J	LEACH	1175	3299
	LEACHopt	2492	6310

The simulation results from Fig. 4.1 to Fig. 4.4, demonstrate relative behavior of LEACH, Optimize-LEACH and discussed algorithms with parameters values n =100, p= 0.1, Eo = 0.25 J, 0.5J and 1J. The simulation result showing relative behavior of LEACH, and optimize-LEACH discussed algorithms with parameters values n =100, p= 0.1, Eo = 0.25 J, 0.5J and 1J

MATLAB tool is used to get the simulation results. As mentioned earlier, optimize-LEACH works in rounds. The total number of rounds used for our experiments is 4000. Simulations of Optimize-LEACH in comparison with LEACH [7], are performed to observe the frequency of dead and alive nodes per round, number of Cluster Head (CH) nodes per round, network lifetime, and overall throughput.

Simulation Result of First Dead Node

Figure 4.1 shows that the first node of normal LEACH is dead after 585 round where as in optimize LEACH protocol the first node dead after 1170 rounds so we can clearly say that the lifetime of first node is increase by 2 times than normal LEACH.

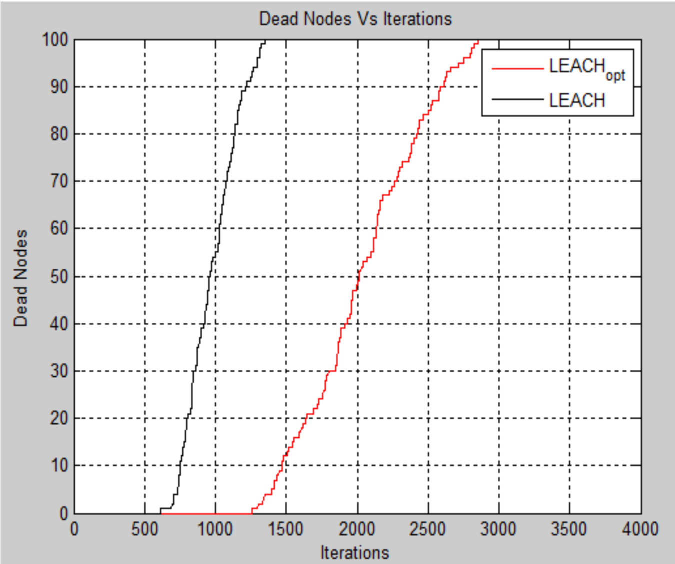

Fig. 4.1. Plot of Dead Nodes Vs. Number of Iteration

Simulation Result of Network Life

Figure 4.2 shows that the last node of normal LEACH is dead after 1474 round where as in optimize LEACH protocol the last node dead after 3552 rounds so we can clearly say that the lifetime of last node is increase by 3 times than normal LEACH.

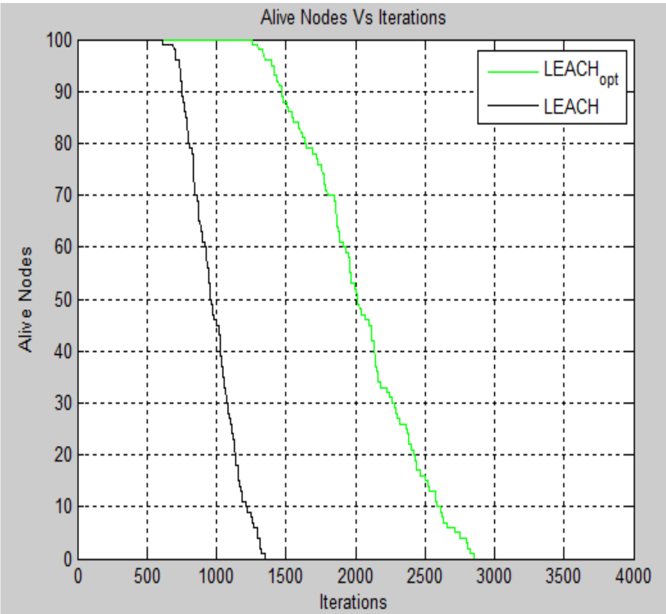

Fig. 4.2. Plot of Alive Nodes Vs. Number of Iteration

Simulation Result of Throughput

Figure 4.3 shows the throughput of optimize-LEACH and LEACH .The throughput of Optimize-LEACH is 119.66 Mbps and the throughput of LEACH is 68.51Mbps so we can say that optimize-LEACH improved 90% throughput than LEACH

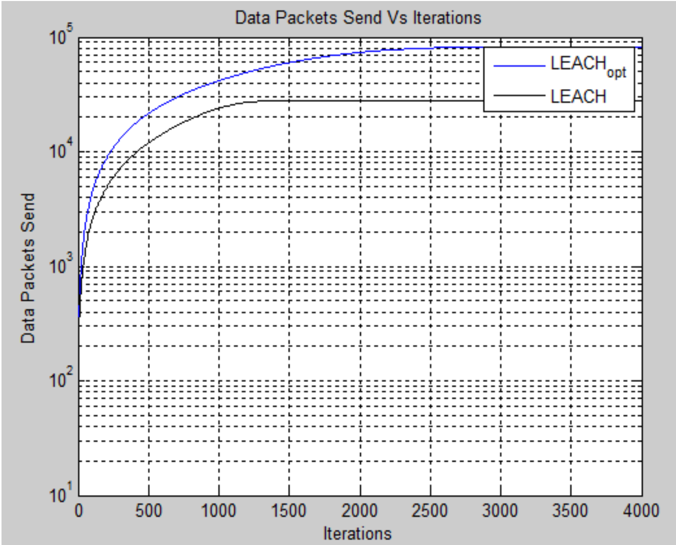

Fig.4.3 Plot of Throughput Vs Number of Iterations for LEACH and Optimized LEACH

Selection of Cluster Head in Each Round

Optimize-LEACH has an efficient number of cluster heads due to static clustering. Optimized-LEACH [7] and normal LEACH select the number of cluster heads using distributed algorithms whereas a fixed number of cluster heads is selected during each round in optimize-LEACH. There is uncertainty in the selection of cluster heads in normal LEACH. The numbers of cluster heads selected in each round by using these protocols are shown in fig 4.4.

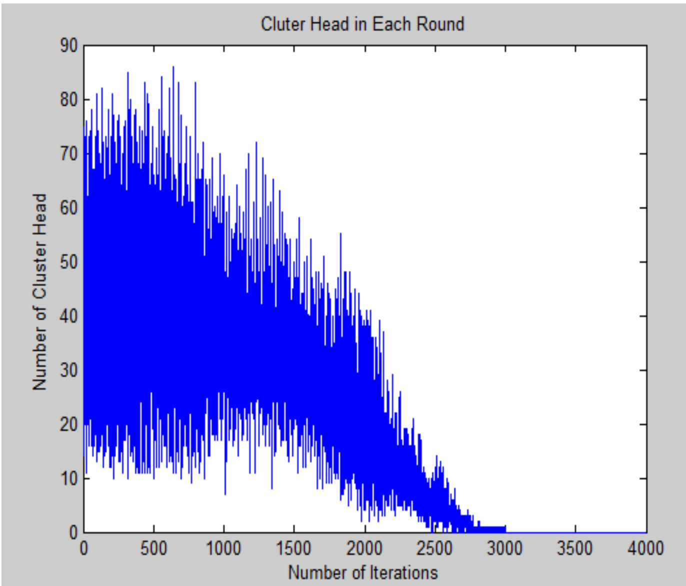

Fig.4.4 Plot of Number of Cluster Heads Vs. Number of Iterations in Each Round.

A lower number of selected cluster heads means each cluster head needs to forward more member nodes data, which results in the early depletion of the cluster head battery. function of cluster head is collecting data from their respective cluster member and sending data to the base station (sink node) After becoming a cluster head, the node needs to perform the additional functions of cluster heads. A higher number of cluster heads causes more network energy consumption.

5. CONCLUSION

In this paper, we proposed an optimized routing scheme for wireless sensor networks. The main focus was to enhance cluster head selection process and enhance the lifespan of the network. Static clustering is used in our proposed scheme. In optimize-LEACH, cluster heads are selected in each cluster on the basis of residual node energy. The formation of rectangular clusters, selection of advanced clusters, and creation of zones make the WSN communication more energy efficient. In our proposed strategy, the stability period of network and network life-time and throughput have been optimized. Simulation results show that there is significant improvement in all these parameters when compared optimize-LEACH with existing routing protocols LEACH. We perform MATLAB simulations to observe the network stability, throughput, energy consumption, network lifetime and the number of cluster heads. Our proposed routing protocol outperforms in large areas in comparison with the optimized-LEACH and LEACH.

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