Energy Efficient Clustering Protocol for Wireless Sensor Networks Using Particle Swarm Optimization Approach

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Abstract - *WSN comprises of a considerable amount of small and limited power sensor elements that are arbitrarily or physically conveyed over an unattended target region. WSNs have potential applications in atmosphere observing, calamity cautioning frameworks, medicinal services, security surveillance, and reconnaissance frameworks. The main drawback of the wireless sensor network is the restricted power sources of the sensing elements. Expanding the lifetime of the Wireless Sensor systems, energy preservation measures are vital for enhancing the execution of WSNs. This paper proposes LEACH-P which is a novel approach to improve existing LEACH protocol using PSO based clustering. The proposed algorithm is simulated broadly and the results are compared with the existing algorithm to determine its supremacy in terms of network lifetime, stability period and number of data transmitted to the base station.*

Key Words: Wireless Sensor Networks (WSN), gateways, Cluster Head (CH), Particle Swarm Optimization.

1. INTRODUCTION

1.1 Background

Wireless Sensor Networks are having large network in which huge amount of sensor nodes are present that are forming a network with their self-organizing property. The variety of applications includes health care, military, critical infrastructure protection (Akyildiz,Su, Sankarasubramaniam, & Cayirci, 2002), and non-military personnel (e.g., disaster management). In WSN the small sensor nodes are categorized by restricted processing power sources. In this manner, energy preservation of the sensors is the most demanding concern for the long run process of WSNs. Numerous issues have been contemplated for this reason that include low-power radio communication equipment (Calhoun, 2005), power aware medium access control (MAC) layer conventions (Ahmad, 2012) (Aykut, 2011) and so on. Therefore, energy efficient clustering and routing procedures (Abbasi & Mohamad, 2007) (Kemal & Younis, 2005) are the most encouraging regions that have been contemplated widely in such manner.

In a two-level WSN, sensing elements are partitioned into a few groups which are known as clusters. Every group has a pioneer called cluster head (CH). Every one of the sensing element sense neighborhood information and transmit it to their relating CH. At that point, the cluster heads combine the local information and then transmit it to the base station (BS) specifically or by means of different CHs. A cluster based model of wireless sensor network is appeared in Fig. 1. Clustering sensors has various advantages which are as follows: (1) It empowers information total at CH to dispose of the repetitive and uncorrelated information; consequently, it saves power of the sensing elements. (2) Routing can be all the more effectively achieved on the grounds that only CHs need to keep up the nearby path set up of different CHs and subsequently require little steering data; this in turn enhances the adaptability of the system essentially. (3) It preserves correspondence transfer speed as the sensor nodes communicate with their CHs only and therefore stay away from trade of excess information among them.

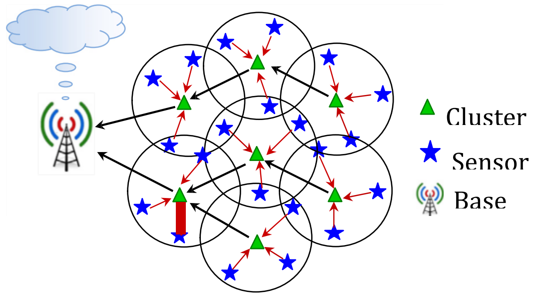

Fig-1: A Wireless Sensor Network Model

Though, CHs tolerate some additional work load contributed by their cluster members as they collect the detected information from their group member sensors, combines them and convey it to the BS. In addition, in numerous WSNs, the CHs are typically chosen among the ordinary sensor nodes which can expire rapidly for this additional work load. In this remarkable circumstance, numerous scholars (Gupta & Younis, 2003) (Low, 2008) (Kuila & Jana, Improved load balanced clustering algorithm for wireless sensor networks., 2012) (Kuila, Gupta, & Jana, A novel evolutionary approach for load balanced clustering problem for wireless sensor networks., 2013) (Bari, Wazed, Jaekal, & Bandyopadhyay, 2009) have proposed the usage of some extraordinary sensing elements called gateways, which are provisioned with additional power. These gateways demonstrates like cluster heads and are in charge of a similar function of the CHs. Along these lines, gateways and CHs are utilized reciprocally in the rest of the paper.

Tragically, the gateways are likewise battery-worked and consequently energy constrained. Lifetime of the gateways is exceptionally vital for the long run operation of the system. The transmission energy (E) related with distance (d) on the basis of following formula, i.e. $E \propto d^{\lambda}$,where λ is the path loss exponent and $2 \leq \lambda \leq 4$ (Habib & Sajal, 2008) . In this way, minimization of transmission separation can decrease the energy utilization. In any case, a few applications are extremely time-basic in nature. Subsequently, they ought to fulfill strict delay constraints so that the BS can get the detected information within a predetermined time bound. In any case, the delay is relative to the quantity of forwards on the dissemination path between a source and the sink. With a specific end goal to limit the delay, it is important to limit the quantity of forwards, which can be accomplished by boosting the separation between continuous forwards. Along these lines, while outlining routing procedures we have to fuse an exchange off between transmission separation and quantity of forwards as they stance two clashing destinations. Moreover, load balancing is another critical issue for WSN clustering. Especially, this is a problem that needs to be addressed when the sensor nodes are not disseminated consistently. In this paper we address the accompanying issues:

- Energy proficient routing with an exchange off between transmission distance and number of information forwards.
- Energy proficient load balanced grouping with energy preservation of the WSN.

Keeping in mind the end goal to acquire a quicker and proficient arrangement of the clustering and routing issue with the above issues, a metaheuristic approach, for example, particle swarm improvement (PSO) is extremely attractive. The primary goal of this paper is to enhance existing LEACH with an effective PSO-based clustering for WSNs with the thought of energy utilization of the sensor hubs for extending system life time.

1.2 Authors' Contribution

In this paper, an energy efficient protocol for WSN is proposed using particle swarm optimization. The proposed research work will execute the PSO with leach protocol. The PSO in clustering for optimal selection of cluster head is applied to enhance the advancement in the residual energy of node by sending a data packet to the cluster head which is located very nearest to the Base station. The proposed LEACH (LEACH-P) discovers a path from all the gateways to the base station which has comparably lower overall distance with less number of data forwards.

The proposed LEACH takes care of energy consumption of the normal sensor nodes as well as the gateways. We perform extensive simulation on the proposed methods and evaluate them with several performance metrics including network life-time, stability, energy consumption and total number of data transmitted. The results are compared with LEACH (Heinzelman, Chandrakasan, & Balakrishnan, 2002) which is a widespread cluster-based routing procedure. Our key contributions can be brief as follows:

- Sensor nodes are deployed arbitrarily along with a few gateways.
- The PSO in clustering for optimal election of cluster head is applied for the advancement in the residual energy of node by sending a data packet to the cluster head.
- Simulation of the proposed procedure to determine supremacy over existing procedure.

The rest of the paper is organized as follows. The related work is discussed in Section 2. LEACH is defined in Section 3. An outline of particle swarm optimization is given in Section 4. The system model is presented in Section 5 which comprises energy model and network model. The proposed algorithm i.e. LEACH-P is described in Section 6. The experimental Setup and the simulation results are described in Sections 7 and 8 respectively and we conclude in Section 9.

2. RELATED WORK

(Heinzelman, Chandrakasan, & Balakrishnan, 2002) have been proposed a mainstream cluster-based steering technique LEACH which is able to control the cluster head work load among the sensing elements that is profitable for balancing the load. However, the fundamental weakness of this method is that a sensing element with low power might be chosen as a CH which may die hastily. Furthermore, the CHs communicate with a base station by means of one-hop which is unrealistic for WSNs with extensive scope region. Therefore, a lot of procedures have been established to advance LEACH which can be found in (Tyagi & Kumar, 2013)], (Al-Refai, 2011). (Kuila & Jana, An energy balanced distributed clustering and routing algorithm for wireless sensor networks, 2012) have been proposed a cost- based disseminated energy stable clustering and routing procedure for selection of cluster head and cluster creation. But, the procedure experiences the network issue of the chose CHs.

(Bari, Wazed, Jaekal, & Bandyopadhyay, 2009) proposed a GA-based methodology for information directing between gateways in a two-tire wireless sensor network. The relay sensing elements may shape a system among them to route information towards the base station. In this design, the lifespan of a system is determined mainly by the lifespan of these relay sensors. An energy-aware communication strategy can greatly extend the lifetime of such networks. However, integer linear program (ILP) formulations for optimal, energy-aware routing rapidly become computationally intractable and are not suitable for concrete systems.

(Kennedy & Eberhart, 1995) proposed a system for development of reliable nonlinear limits. The system was found through re-enactment of an enhanced social model; thusly the social analogy is discussed, however the calculation stays without metaphorical support. The paper portrays the particle swarm improvement idea as far as its forerunners, rapidly investigating into the phases of its advancement from social rebuilding to analyzer. The improvement of a couple of perfect models is laid out, and an execution of one of the guidelines is inspected. The relationship between particle swarm development and both manufactured life and hereditary controls are depicted.

(Singh & Lobiyal, 2012) proposed an Energy-efficient cluster head selection using Particle Swarm Optimization approach and examination of Packet Retransmissions in WSN. Particle Swarm Optimization (PSO) method is useful for creating vitality mindful clusters with an ideal choice of the group head. The PSO eventually diminishes the cost of discovering ideal position for the cluster head hubs. The execution of PSO approach is achieved inside the cluster instead of the sink where a user is able to extract data, which makes it a semi-distributed method. The choice criteria of the target capacity depend on the lasting vitality, least normal distance from the member hubs and head count of the likely head hubs. (Singh & Lobiyal, 2012)] and (Abdul, 2007) have utilized the PSO for CH choice among the typical sensor hubs and don't deal with the group development. PSO and ant colony optimization (ACO) are utilized as a part of WSNs for other optimization issues likewise and they can be found in (Saleem, 2011), (Kulkarni, 2011), (Zungeru, 2012).

(Kuila & Jana, 2014) have proposed Energy effective clustering and routing which are two surely understood advancement issues which have been studied broadly to increase lifespan of wireless sensor networks (WSNs) and describes Linear/ Nonlinear Programming (LP/NLP) definitions of these issues taken after by two proposed procedures for the same in view of particle swarm optimization (PSO). The routing procedure is established with a well-organized particle encoding scheme and multi-objective fitness function. The clustering algorithm is described by considering power maintenance of the nodes through load balancing.

(singh, 2016) have proposed a Multi-Hop LEACH which is vitality efficient routing convention for wireless sensor network; a strategy of routing is recommended in view of both particle swarm optimization technique and V-LEACH protocol and multi-hop system design. Multi hop communication has been applied to limit vitality dissipation in the transmission from cluster head to the sink.

3. LEACH: LOW-ENERGY ADAPTIVE CLUSTERING HIERARCHY

LEACH is a self-organizing, adaptive clustering procedure that uses randomization to circulate the energy load uniformly among the sensors in the system. In LEACH, the sensors sort out themselves into nearby formed clusters, with one element acting as the local base station (BS) or *cluster-head*. LEACH comprises arbitrary circulation of the high-powered cluster-head position such that it circulates among the numerous sensors in order not to drain the battery of a single senor. Moreover, LEACH achieves neighborhood information aggregation to “compress” the volume of information being transmit from the cluster heads to the base station, further decreasing energy dissipation and improving system lifetime.

The procedure of LEACH is fragmented up into *rounds*, where every round begins with a set-up phase, when the clusters are structured, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase.

3.1 Setup phase

In this phase clusters are framed and a cluster head (CH) is decided for every cluster. Each node produces an arbitrary number in the range of 0 and 1, and if that arbitrary number is not as much as threshold value T (n), then it will become a cluster head. In each round, T (n) is set to 0, for the sensing element which previously functioned as CH in past rounds, so that this node will not be chosen once more. The possibility of being chosen is T (n) for the sensing elements that have not been chosen once. If only single sensor node left then T (n) is set to 1, implies this node will be surely chosen as CH (Heinzelman, Chandrakasan, & Balakrishnan, 2002).

T (n) is characterized as below:

$$T(n) = \begin{cases} \dfrac{P}{1 - P * \left(r \bmod \frac{1}{P}\right)} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Where,
p= percentage of number of CH in the number of nodes in network,
r = present round number,
G= set of sensing elements that have not been chosen in the previous 1/p rounds of CH selection.
When any of the sensing elements is chosen as CH, it advises different nodes. The nodes which are non-cluster heads pick their CH in the view of received signal quality for this round. The CH element sets up a TDMA schedule and transfers this schedule to every one of the nodes in its cluster.

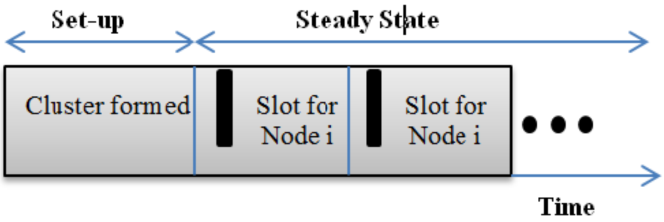

Fig.-2 Interval Period of LEACH

3.2 Steady-state phase

In this phase, the non-CH nodes begin detecting information and send it to their CH as per the TDMA schedule. The CH node aggregates the acknowledged information and sends it to the sink. Communication is done via direct-sequence spread spectrum and every cluster utilizes a unique spreading code to decrease inter-cluster interference. After certain timeframe, the system again goes into the setup phase and enters another round of choosing cluster heads (CHs).

3.3 Limitations of LEACH Protocol

A few of these assumptions are as per the following:

- All nodes can convey with sufficient power to reach the base station if necessary.
- Nodes dependably have information to send.
- Nodes found near each other have connected information. It is not evident how many predetermined CHs are going to be uniformly disseminated throughout the system. Therefore, there is a possibility that the chosen CHs will be focused in one part of the system. Subsequently, some nodes will not have any cluster head closer to them.
- CHs are chosen arbitrarily in LEACH, hence nodes with less vitality might be picked up, and which could lead to these nodes die too quick.

4. OVERVIEW OF PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization (PSO) is encouraged by natural lifecycles, like bird flocking, fish schooling and arbitrary search techniques of evolutionary procedure (Kennedy & Eberhart, 1995) (Wei & Nor, 2014). It can be seen from the nature that creatures, especially winged animals, fishes, etc. always travel together in a random search for food in a cluster without colliding. It is because every member tracks the cluster by modifying its position and speed utilizing the cluster information. Thus it decreases individual's exertion for looking of nourishment, shelter and so on.

PSO comprises of a swarm of a predefined size (say N_P) of particles. Each element gives a complete answer to the multidimensional optimization issue. The dimension D of the considerable number of particles is equal. A particle P_i, $1 \le i \le N_P$ has position X_{id}, $1 \le d \le D$ and velocity V_{id} in the d^{th} dimension of the hyperspace. The notation for demonstrating the ith particle P_i of the inhabitants as follows:

$$P_i = [X_{i,1}, X_{i,2}, X_{i,3} \ldots\ldots, X_{i,D}]$$

Every particle is estimated by a fitness function to judge the superiority of the solution to the problem. To achieve the global best position, the particle P_i monitors its individual best, i.e., personal best called $Pbest_i$ and global best called Gbest to update its individual position and velocity. In every repetition, its position X_{id} and velocity V_{id} and in the dth dimension is modified utilizing the accompanying conditions.

$$V_{i,d}(t) = w * V_{i,d}(t-1) + c_1 r_1 * (Xpbest_{i,d} - X_{i,d}(t-1)) + c_2 r_2 (Xgbest_d - X_{i,d}(t-1))$$

$$X_{i,d}(t) = X_{i,d}(t-1) + V_{i,d}(t)$$

where
w = inertial weight
c_1 and c_2 = non-negative constants called acceleration factor
r_1 and r_2 = two different consistently disseminated arbitrary numbers in the range [0,1].
The modified procedure is iteratively repeated until either an acceptable Gbest is attained or a fixed number of iterations t_{max} is achieved.

5. RESEARCH METHODOLOGY

5.1. Energy model

The radio model for energy which is used in this paper is similar as discussed by W.B. et al. (Heinzelman, Chandrakasan & Balakrishnan, 2002). In this model, both the free space and multi-path blurring channels are utilized relying upon the distance between the sender and receiver. If the distance is not as much as threshold value d_0, then the free space (f_s) model is applied, otherwise, the multipath (m_p) model is applied. Let E_{elec}, ε_{fs} and ε_{mp} be the energy essential by the hardware circuit and by the amplifier in free space and multipath respectively. Then the vitality required by the radio to transmit an l-bit message over a distance d is given as per the following:

$$E_T(l,d) = \begin{cases} lE_{elec} + l\varepsilon_{fs} d^2 & \text{for } d < d0 \\ lE_{elec} + l\varepsilon_{mp} d^4 & \text{for } d \ge d0 \end{cases}$$

The energy essential by the radio to accept an l-bit message is given by

$$E_R(l) = lE_{elec}$$

The E_{elec} relies on few variables such as advanced coding, modulation, filtering, and spreading of the signal, whereas the amplifier energy, $\varepsilon_{fs} d^2 / \varepsilon_{mp} d^4$, relies on the distance between the transmitter and the receiver and also on the acceptable bit-error rate. It ought to be observed that this is an improved model. In general, radio wave propagation is highly variable hard to demonstrate.

5.2. Network model and assumptions

In this paper, the proposed work simulates the WSN model where all the sensing elements are deployed arbitrarily along with a few high powered gateways and once they are deployed, they become stationary for one round and vary from round to round. The process of Gateways formation per round is same as the cluster head formation process in LEACH. The assumptions made are following:

- All the chosen sensing elements are assumed as static after deployment.
- Every one of the nodes can use power control for various distances from the transmitter to the receiver.
- Every one of the nodes is location unaware (i.e. they are not armed with the GPS-gadgets).
- Sensor nodes are allocated with a unique identification (ID) and similar preliminary power.
- The cluster-heads are dominant for performing computations to the base station for long range transmissions
- The base station utilizes the external energy supply and the power will not be drained.

6. PROPOSED WORK

The proposed research work will perform the PSO with leach protocol. Sensing elements are deployed arbitrarily along with a few gateways. The proposed procedure is done mainly in the following steps.

Step1: Apply PSO approach in clustering for optimal selection of cluster head to improve the progression in the remaining energy of node by sending a data packet to the cluster head which is situated closest to the Base station. The cluster head is nominated using PSO approach, based on the distance from the cluster member node to base station and the remaining energy of that node.

Step2: Compute the distance between transmitter and receiver based upon the distance between the transmitter and receiver. If the distance is less than a threshold value d_0, then the free space (f_s) model is applied, otherwise, the multipath (m_p) model is applied.

Step3: A sensing element can be allocated to any gateway if it is within the communication range of that sensing element. Therefore, there are some pre-specified gateways on to which an individual sensor node can be allocated.
The numerous steps of a PSO are represented in the flowchart as shown in Fig. 3.

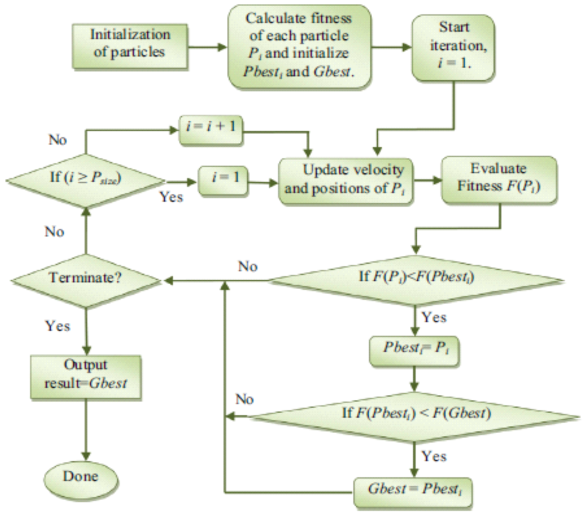

Fig.-3: Flowchart of PSO (Kuila & Jana, 2014)

The proposed algorithm:

Set-Up Phase
1. CH $\Longrightarrow$ N: id_{CH} ,crc ,adv
2. n_i $\longrightarrow$ CH: id_{ni} , id_{CH} ,crc, join_req
3. CH $\Longrightarrow$ N: id_{CH} ,(… ,(id_{ni} , T_{ni})…) , crc ,sched
4. GW==> N: $id_{gw, crc, adv}$

Steady State Phase
5. n_i $\longrightarrow$ CH : id_{CH} , crc
6. n_{i} -------> GW : id_{gw}, crc
7. CH $\longrightarrow$ BS: id_{CH} , id_{BS} , GW ----- > BS: $id_{gw,}$ id_{BS}
8. Base Station get information from all the cluster heads and Gateways.

The symbol used in proposed algorithm signifies:
CH, n_i, BS: Cluster Head, ordinary node, base station
N: Set of all nodes in the network
Adv,join_req,sched : String identifiers for message sorts
Crc : Cyclic redundancy check
id_{ni} , id_{CH} , id_{BS} : Nodes n_i ,CH, BS id's respectively
<y, T_y> : A node id y & its active slot T_y in the clusters TDMA schedule
$\longrightarrow$, $\Longrightarrow$: Unicast, broadcast transmissions, respectively

7. EXPERIMENTAL SETUP

In this section, the simulation results for LEACH-P using NS-2.34 are presented. WSN comprises of N = 100 and 200 sensors and few gateways which are arbitrarily deployed in a field of measurement 100 m*100 m with a BS situated at (50,175). Each sensing element was supposed to have initial power of 2J and every gateway has 4.5J. The following parameter values shown in Table1 in the simulation run. All sensing elements are either static or micro-mobile are considered and disregard the power loss due to collision and intrusion between signals of dissimilar nodes.

The performance metrics used for the computation of the procedures are: stability period, system lifetime, and number of data transmitted to the BS.

- Stability period: By stability period, we mean how much energy is dissipated in the network till the entire network die or for how much time network is stable.
- System lifetime: By system lifetime, we mean the round number at which whole system die or the number of rounds from network initialization till the death of all nodes.
- Number of Data transmitted to BS: By this metric, we mean the total number of data that are directly transmitted to BS either from CHs or non-CH nodes. The parameters used in simulations are shown in Table 1. Results along with discussions are given in the accompanying subsections.

Table-1: Simulation Parameters

Parameter	Value
NS-2 Version	2.34
Channel Type	Wireless Channel
Area	100*100
Routing Protocol	LEACH
No of nodes	100 and 200
Number of cluster	5
Simulation Time	3600
Node initial energy	2 joules
Gateway initial energy	4.5 joules
Equal energy(startup)	YES
RXThresh	6e-9
CSThresh	1e-9
Round Period	Each 35 seconds

8. SIMULATION RESULTS

In this section simulation results for LEACH and LEACH-P is depicted for 100 and 200 sensor nodes. Proposed algorithm is simulated broadly and depicts the simulation results for both the routing and clustering in a combined way.

8.1 The Performance comparison of LEACH and LEACH-P for 100 sensor nodes

Chart 1 shows the result analysis of total energy dissipation in network for 100 sensor nodes. It is clear from figure that LEACH-P consumes less energy than LEACH. Chart 2 shows the result analysis of number of data transmitted in LEACH-P is more as compared to LEACH as gateways are used in LEACH-P to handle overload of data on sensor nodes. Chart 3 shows that the result analysis of network lifetime. The first one node dies at 370 and 700 rounds for LEACH and LEACH-P respectively and apart from first node, rest of nodes dies at 481 and 817 rounds for LEACH and LEACH-P respectively. The simulation result shows that LEACH-P lifetime is more than LEACH due to cluster head optimization using PSO approach in LEACH-P.

Table-2: Performance comparison of LEACH and LEACH-P for 100 sensor nodes

Performance metrics	LEACH	Proposed LEACH
Total Energy Consumed(Joules)	309.101	433.04
Total Data Transmitted(bits)	47863	85745
First Node Dies	370	700
Lifetime(rounds)	481	817

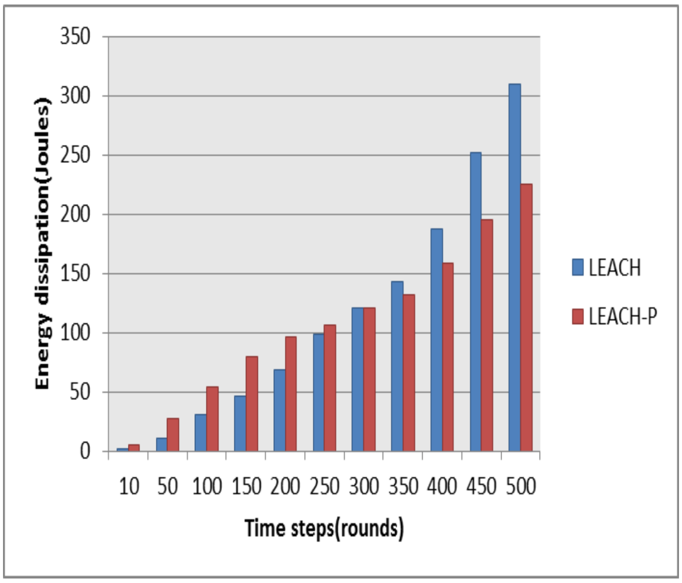

Chart-1: Result analysis of energy dissipation for 100 sensor nodes

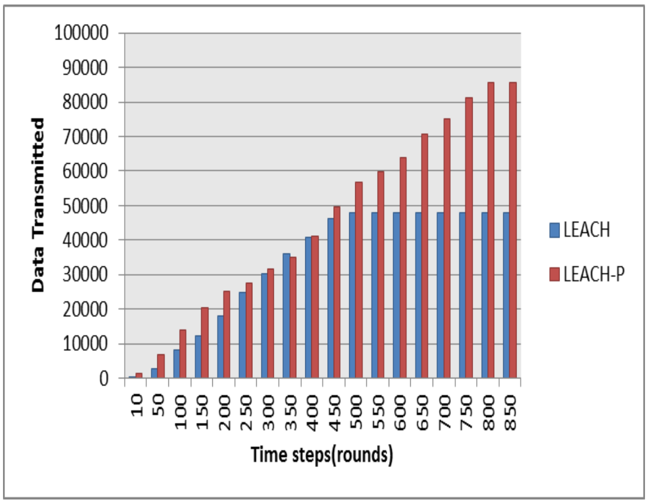

Chart-2: Result analysis of no. of data transmitted for 100 sensor nodes

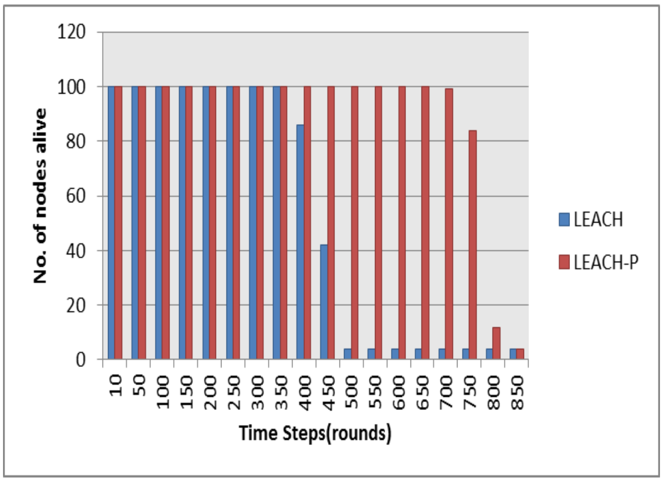

Chart-3: Result analysis of network Lifetime for 100 sensor nodes

8.2 The Performance comparison of LEACH and LEACH-P for 200 sensor nodes.

Chart 4 shows how the energy dissipation in the system varies as the percentage of sensors that are cluster-heads is changed. From this plot, we find that the performance of our approach is superior over LEACH. LEACH-P consumes less energy as compared to LEACH because of using PSO in clustering for optimal selection of cluster head to enhance the advancement in the residual energy of node by sending a data packet to the cluster head which is located very nearest to the Base station. Chart 5 shows that the data transmitted in LEACH-P is more as compared to LEACH. When the routing and clustering is over, sensor nodes those are within gateway communication send their data directly to gateway and those are within cluster head communication send their data directly to their respective cluster head due to which data transmitted is more than the LEACH. Chart 6 depicts the number of nodes alive and dead nodes in system lifetime.

The firs node for LEACH LEACH-P dies at 805 and 1310 rounds respectively and all nodes die at 1087 and 1858 respectively. It is clear from the figure 9 that LEACH-P is superior to the LEACH.

Table-3: Performance comparison of LEACH and proposed LEACH for 200 sensor nodes

Performance metrics	LEACH	Proposed LEACH
Total Energy Consumed(Joules)	866.1758	1260.719
Total Data Transmitted(bits)	115398	194249
First Node Dies	805	1310
Lifetime(rounds)	1087	1857

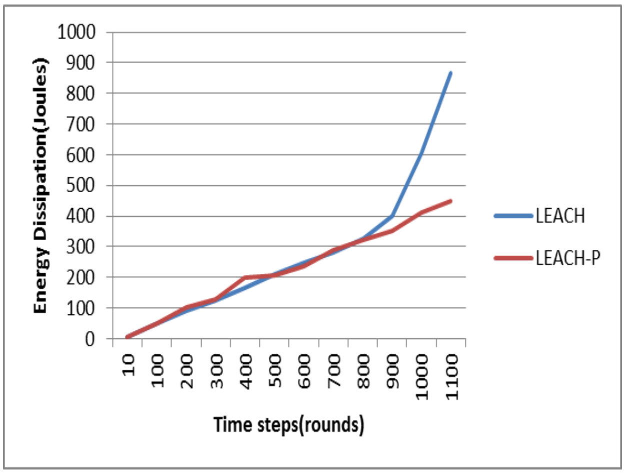

Chart-4 Result analysis of energy dissipation for 100 sensor nodes

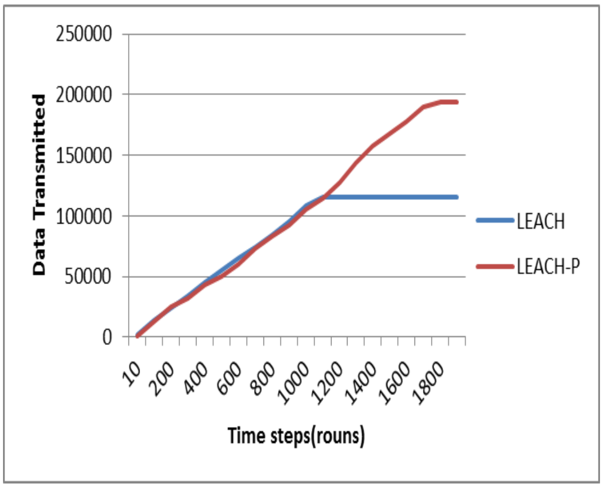

Chart-5 Result analysis of no. of data transmitted for 100 sensor nodes

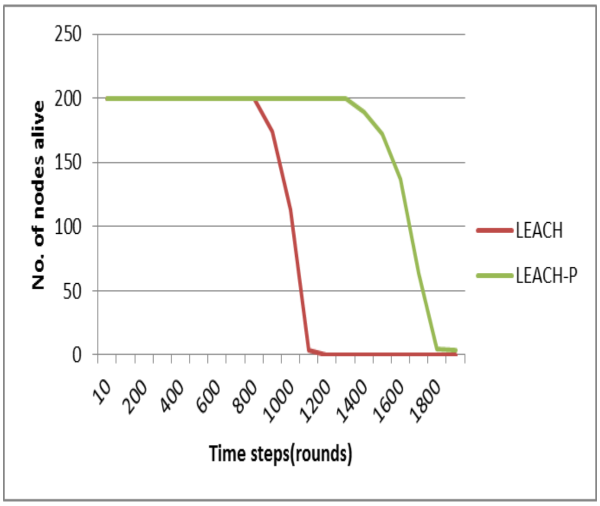

Chart-6 Result analysis of network Lifetime for 100 sensor nodes

9. CONCLUSIONS

In this paper, the LEACH –P which is an enhancement of LEACH is proposed. PSO in clustering is applied for optimal selection of cluster head to improve the progression in the residual vitality of node by transmitting a data packet to the cluster head which is situated very nearest to the Base station. Thus the power consumption of the CHs is considerably balanced and the lifetime of the system is enhanced. The experimental results have shown that the proposed LEACH performs better than the existing LEACH in terms of system lifetime, stability period and the total data transmission.

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