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A novel Energy Efficient Cluster Head Selection Method for Wireless Sensor Networks

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Abstract

Wireless Sensor Networks are becoming a worldwide sensational topic with recent advances in wireless communications and digital electronics. It serves as the backbone for controlling real-life applications. It consists of group of sensor nodes that sense the information from an event area and passes it to the base station which reacts according to the environment. There are number of cluster based routing protocols, in which a region is divided into number of clusters and within each cluster, a cluster head is elected based on some parameter. So, a novel selection method for the cluster head having efficiency in energy is based on Flower Pollination Algorithm (FPA) is proposed in this paper. The performance of our proposed scheme is being analyzed and is compared with the already existing protocols like LEACH, C-LEACH and K-Means in terms of energy efficiency, number of alive nodes, packet drop ratio and energy dissipation etc

Index Terms: Wireless Sensor Networks, LEACH, k-Means algorithm, Flower Pollination Algorithm, Energy-efficiency, Cluster Head**.**

1. Introduction

Wireless Sensor Networks (WSNs) is vital technology to provide large-scale monitoring and sensor measurements at high temporal and spatial resolution. WSN includes hundreds or thousands of tiny battery powered sensor nodes that are randomly deployed in an environment [1, 2]. Sensor networks have a unique capability called *self organizing* capability through which nodes adjust themselves in a region of interest. These

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nodes sense the region for occurrence of event at different locations and passes this sensed information to the base station or command node so that it can react according to the condition. Before transmission, sensor nodes process the raw data with the help of built-in processor included in nodes itself. WSNs have sensing, computation and communication capabilities which are highly used in large number of different applications. The idea of WSNs came into origin from battlefield surveillance where military applications are performed and now this idea is used in various number of areas like in industries, healthcare applications and home network etc[3]. The sensor networks comprise of microphones as audio sensors, cameras as vision sensors and those that measure large number of physical phenomenon (like infra-red, ultrasound, noise, temperature, strain, vibration, fluid levels, generators to manufacturing lines, humidity, pumps, acidity, building maintenance, aviation and so on) in various areas of agriculture and forestry, military applications, structural engineering and health care.

Data sensed by the sensor nodes is transmitted in a multi-hop or single hop fashion by sending the data to base station directly but this direct communication cannot be implemented practically if number of sensor nodes is large in number. According to [4,5], sensor nodes are dynamic in nature also and are limited in the communication range and computing power. Energy of sensor nodes gets reduced while communicating with other nodes or the base station. These nodes get converted into dead nodes from the alive nodes, which can make the network less energy efficient. Making clusters of the sensors is one of the possible solutions to deal with this issue as this can make the network with the best energy efficiency and scalability. In cluster based routing, a network is divided into number of clusters and within each cluster, a cluster head is elected based on some pre-decided parameter. CH nodes in clusters have larger energy as compared to non-cluster head nodes. So, to balance energy level of network, we propose Flower Pollination Algorithm (FPA) which gives more energy efficient network as compared to existing approaches.

2. Related Work

In this section, we discuss the existing routing protocols such as LEACH, LEACH-C, k-Means algorithm and cluster head selection approach which is followed in these routing algorithms [6-15].

2.1 LEACH

Low-Energy Adaptive Clustering Hierarchy (LEACH) is a protocol that is used for dynamic clustering in WSNs. This protocol randomly select the cluster heads in a network so that energy can be distributed evenly among the among the sensor nodes[6]. Data collected by cluster heads from sensor nodes is transmitted to the base station. This is needed because a sensor node is not of any use if its battery dies. Each time when an updation process of cluster restructuring is initiated, then it is known as a *round* and further each round is sub-divided into two stages: *set-up phase* and *steady phase* as shown in Fig. 1.

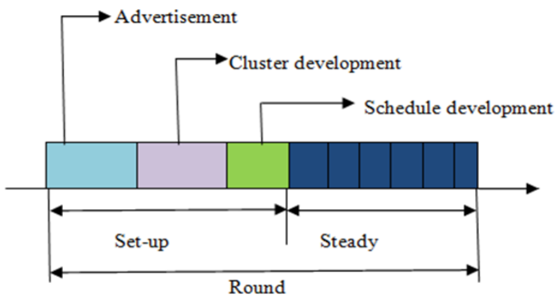

Fig.1. Formation for cluster round in LEACH protocol.

The set-up stage includes three sub-stages called *advertisement stage, cluster development* and *schedule development*. In first phase, CH of each cluster broadcast its identity to the sensor nodes whereas in steady phase CH gets all the information given by sensor nodes. CH consumes large amount of energy as compared to cluster member nodes in communication. Therefore, to cop up with this issue, LEACH proposed that every member of cluster should get equal chance to become CH [7] so, that energy dissipation can be balanced in a network.

In this, random value between 0 and 1 is assigned to each node in each round. That particular node become the CH if its value is less than the threshold value. Therefore, by this method energy consumption in a network can be balanced by giving all nodes a fair chance to elect as CH. But this approach does not provide information about node location during the selection of CHs. As a result, this protocol may lead to the unbalanced energy in the network.

2.2 C-LEACH

To deal with the issue related to LEACH protocol, C-LEACH is developed that uses the information regarding the location of sensor nodes [8]. This C-LEACH protocol with its routing steps is described in Fig. 2. It is shown that BS gets all the information regarding the current location and energy level of the sensor nodes (marked as 1 in Fig. 2). After this, average energy of all the sensor nodes is determined in the present round and further division of network is done into different number of clusters. This information is then transmitted to the closest CH after the selection of CH in every cluster (Step 2 in Fig. 2). Therefore, after determining the routing path, set-up phase is finished.

Advantage of this protocol is that, there is a reduction in the energy consumption and dissipation of a sensor network with the use of this location information about member nodes. However, better routing is not always provided by this protocol because the gathering and transmitting this information also consumes energy.

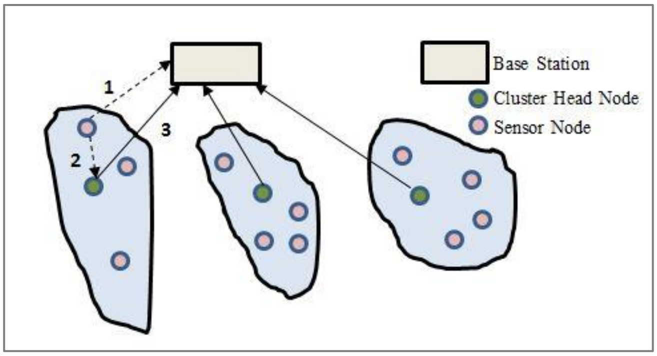

Fig.2. Routing methodology in LEACH-C protocol

2.3 K-MEANS

In this, randomly clusters are formed in the network and sensor nodes arrange themselves to be in one of the clusters. After each node gets the cluster, the centroid of each and every cluster for 'n' nodes can be determined as follow in two-dimensional space.

$$Centroid(X,Y) = \frac{1}{n}\sum_{i=1}^{n} X_i , \frac{1}{n}\sum_{i=1}^{n} Y_i \quad (1)$$

Here where X_i and Y_i denote the position of CH. Here, centroid acts as a virtual node which locates at the center of each cluster. The CH closer to the centroid is chosen as the new CH in the cluster[9].

3. The proposed scheme (FPA)

Flower pollination is an intriguing process in the natural world. Its evolutionary characteristics can be used to design new optimization algorithms. Flower Pollination Algorithm is principally used to solve constrained and unconstrained optimization problems. Researchers are attracted towards this algorithm for its processing speed, ease to modify based on the requirement and robustness. In the proposed Cluster Head Selection method, we use Flower Pollination Algorithm (FPA) in which clusters of objects are developed using the Euclidean distances between them. The underlying network model is given as:

3.1 Network Model

In FPA, WSN have the following features:

- Each sensor node is provided with a unique identity.
- All sensor nodes are static in nature.
- All nodes send their sensed data to the base station.
- Initial energy is same for all nodes.
- Sensor nodes are deployed randomly in an event area.

3.2 Energy Consumption Model

This model is used for evaluating the performance of the FPA. This model includes transmitter and receiver as depicted in Fig. 3.

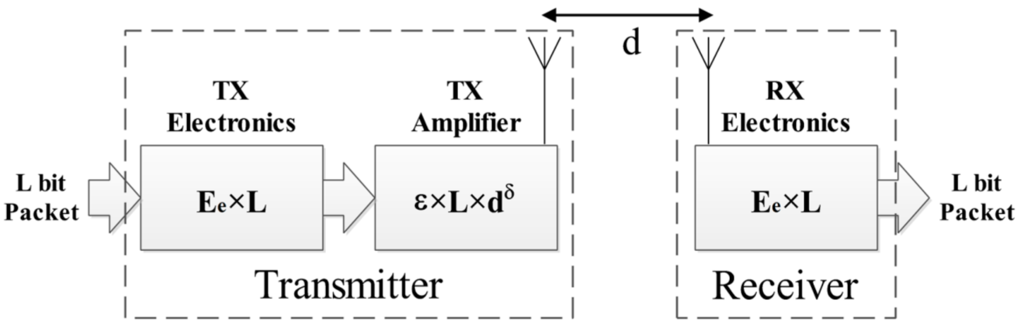

Fig.3. Energy Consumption Model of proposed FPA

During the duration of transmitted packet and received packet, energy is dissipated and this energy can be estimated by free space (fs) and multipath (mp). The energy consumption for transmission is given by equation (2).

$$E_{Tx}(k,d) = \begin{cases} E_e * L + \epsilon_{fs} * d^2, d < d_0 \\ E_e * L + \epsilon_{mp} * d^4 * L, d \geq d_0 \end{cases} \quad (2)$$

Here E_e denotes the amount of energy needed to process 1-bit data. ϵ_{fs} and ϵ_{mp} are the energies required for the transmission of 1-bit data so that acceptable bit error rate can be achieved through fs and mp models, respectively. This depends upon the transmission distance of data. Here, energy dissipation of fs is directly proportional to $d^2$and that of multipath is proportional to d^4. The threshold, $d_o$can be calculated as follows:

$$d_o = \frac{\sqrt{s}}{\sqrt{n}} \quad (3)$$

Energy required on reception of k-bit message is calculated by equation (4).

$$E_{Rx} = E_e * L \quad (4)$$

3.3 Proposed Scheme

In this scheme, we use Flower Pollination Algorithm (FPA) in which clusters of objects are developed using the Euclidean distances between them. In FPA, CH selection method includes four steps as described below:

Step 1: *Initial clustering*

The idea of FPA is initiated with the target of cluster formation in WSN. We assume that the sensor network consist of *n* number of nodes and is sub-divided in *k* number of clusters. From the total *n* nodes, randomly *k* nodes are selected as CHs in the network. Remaining nodes decide their CH which is closest to them based on the Euclidean distance.

Step 2: *Re-clustering*

As all the nodes in the network are assigned with their CHs, the re-clustering of all the nodes is performed with the LEACH algorithm which selects the cluster head as follow:

$$T(n) = \begin{cases} \frac{P}{1-P\left(r \bmod \frac{1}{P}\right)} & : n \in G \\ 0: & otherwise \end{cases} \quad (5)$$

In equation (5), *P* refers to the percentage of number of CHs in a network, *r* belongs to the present round number, and *G* belongs to the set of sensor nodes which are not being selected as CH in the past *1/P* rounds. A random value between 0 and 1 is given to each node in each round. If value is lower than the threshold value *T(n)*, then that node is elected as the CH.

Step 3: *Choosing the CH*

After the formation of clusters, each node is assigned with an ID number according to the Euclidean distance. The order of the CH selection is chosen according to the ID number of a node. Hence, the identity of each node is an important part for the selecting a CH node.

Step 4: *Change the cluster*

Cluster is changed by using flower pollination in which, each plant has multiple flowers and each flower releases millions of pollen gametes, that is, millions of sensor nodes are present in a network. The solution x_i is equal to pollen gamete or a flower, which means the new position of CH. Pollinators or insects carry flower pollens from one location to another over a large distance. By this, pollination and reproduction of the fittest is ensured and is represented as 'g'. In sensor network, it means that CH of a network changes and the fittest CH is chosen over a large range and this flower constancy rule is given as:

$$X_i^{r+1} = X_i^r + Th\,(X_i^r - g) \tag{6}$$

Where X_i^r belongs to the position i or solution vector X_i of round r, and g belongs to the current best possible solution created between all other solutions in the present round. The parameter '*Th*' is the threshold value denoting the CH energy, which is essentially a step size.

The local CH selection (Rule 2) can be represented as

$$X_i^{r+1} = X_i^r + \in (X_j^r - X_k^r) \tag{7}$$

Where X_j^r and X_k^r are CHs from different clusters of the same network. Mathematically, if these two values arise from the similar CH, then this becomes a local random walk when we draw ϵ from threshold in [0,1].The whole algorithm is shown in Fig. 4.

Algorithm: Flower Pollination Algorithm (FPA)

Objective minimize energy f(x), x = $(x_1, x_2, \ldots\ldots, x_d)$
Deploy n sensor nodes with randomly selected CHs.
Find the best CH represented by 'g' in the initial step of CH selection.
Define a threshold $Th \in [0,1]$
while $(r < MaxRounds)$
  for $i = 1 : n$ (all *n sensors* in the network)
    if $CH\_\epsilon < Th + t_i$, t_i is the threshold value while running
      $X_i^{r+1} = X_i^r + Th\,(X_i^r - g)$
    else
      Draw ϵ from threshold in [0,1]
      Randomly choose j and k among all the solutions
    Do local CH selection via
      $X_i^{r+1} = X_i^r + \in (X_j^r - X_k^r)$
    end if
    Search new *CHs.*
    if new CHs are better, then update them in the network.
  end for
  Find the current best solution or CH as $\boldsymbol{g}$**.**
end while

Fig.4. Pseducode of FPA for cluster head selection

The flowchart of the overall process with the proposed method is shown in Fig 5. After this, computer simulation gives the performance of the FPA.

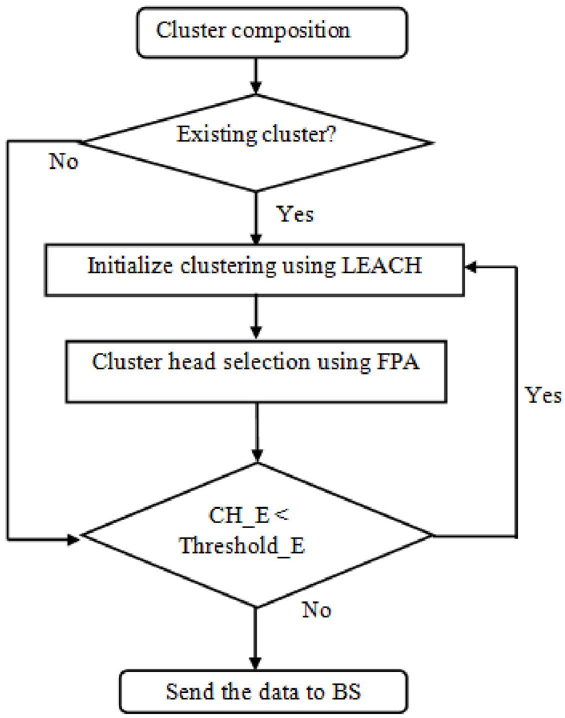

Fig.5. Flow chart of FPA

4. Performance Evaluation

With the help of simulated environment, evaluation of C-LEACH, k-Means based approach and proposed FPA based Cluster Head selection protocols are done in this section. A network of 100 sensor nodes which are deployed randomly in an area of 200m × 200m is considered. In this, initial energy is taken as 2J and data packet size is 500 bytes. Table 1 represents the simulation parameters used for performance evaluation.

Table 1. Simulation Parameters

Parameters	**Values**
Size of network	(0,0) ~ (200, 200)
Location of BS	(0,0)
Number of nodes	100
Initial energy	2J
Size of data packet	500 byte
Energy taken for aggregation (E_{DA})	50nJ/bit/signal
Initial energy of a node (E_{elec})	50nJ/bit

In this experiment, the number of clusters is calculated so that energy efficient network can be operated. Our proposed FPA based cluster head selection scheme is compared with the protocols like C- LEACH and K-Means based clustering approach in terms of packet drop ratio, network lifetime and energy efficiency. When the energy of all nodes becomes zero, then the number of rounds at that time is known as network lifetime. Fig. 6 shows the random deployment of sensor nodes in an event area.

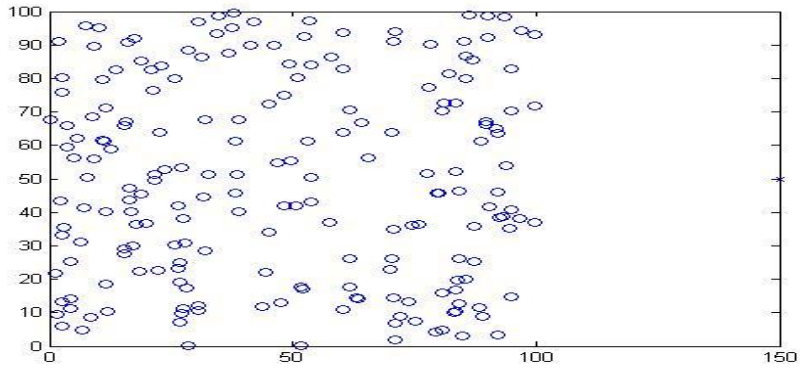

Fig.6. Sensor nodes deployment in an event area.

Test Case 1: Analysis of C-LEACH in terms of energy and dead nodes

The simulation results of C-LEACH protocol in terms of energy consumption are given as follows. Fig. 7 shows the change in average energy of each node as the number of rounds increase. As it is evident from the result, that average energy level goes on decreasing exponentially as the number of rounds is increasing.

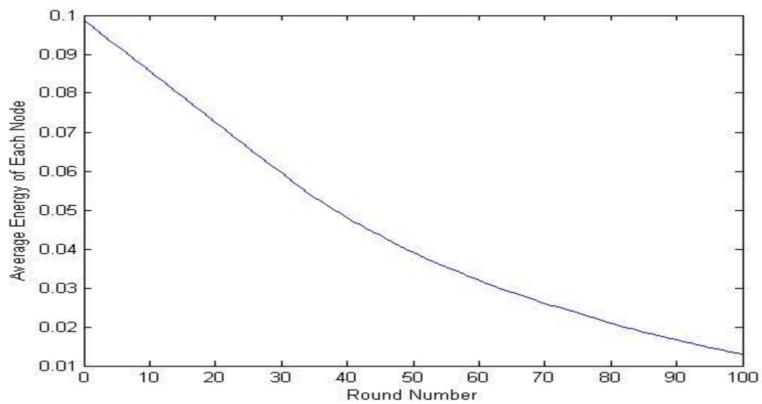

Fig.7. Average Energy Vs Number of rounds in C-LEACH.

Fig. 8 shows the increase in number of dead nodes with the increase in number of rounds. We observe that the number of dead nodes is more than 100 after 100 rounds.

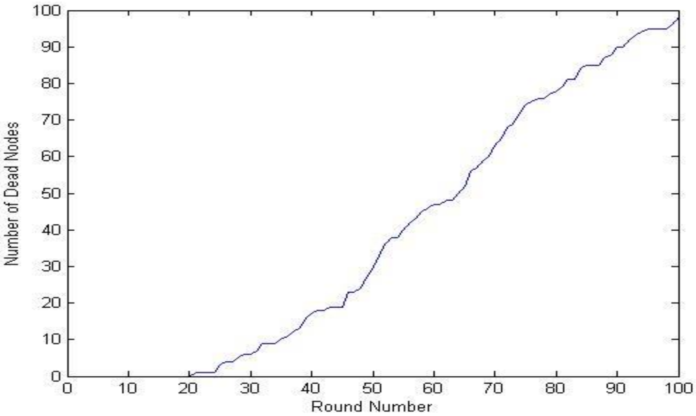

Fig.8. Number of Dead Nodes Vs Number of rounds in C-LEACH.

4.1 Results of K-Means based approach

Simulation results of K-Means protocol are given as follows. Fig. 9 shows the average energy with the increase in number of rounds.

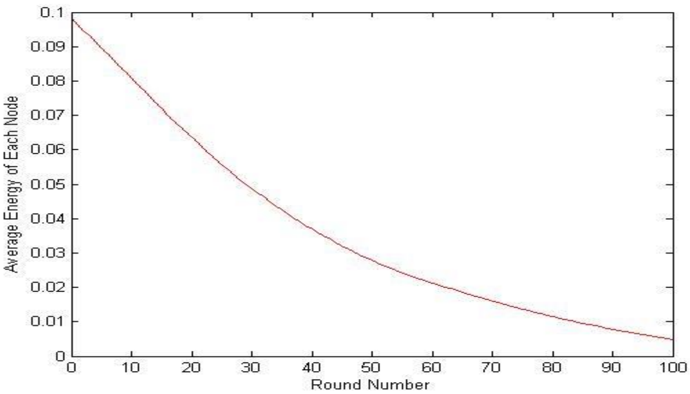

Fig.9: Average energy Vs number of rounds in K-Means.

Fig. 10 shows the change in number of dead nodes with the change in number of rounds.

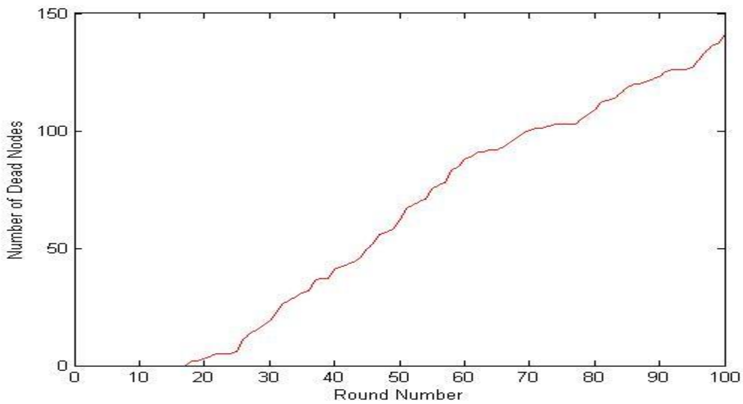

Fig.10. Number of dead nodes Vs Number of rounds in K-Means.

4.2 Results of proposed FPA based approach

An event area is shown in fig. 11, where energy of sensor node gets finishing which leads to the formation of dead nodes. Therefore, resulting in the change of CHs

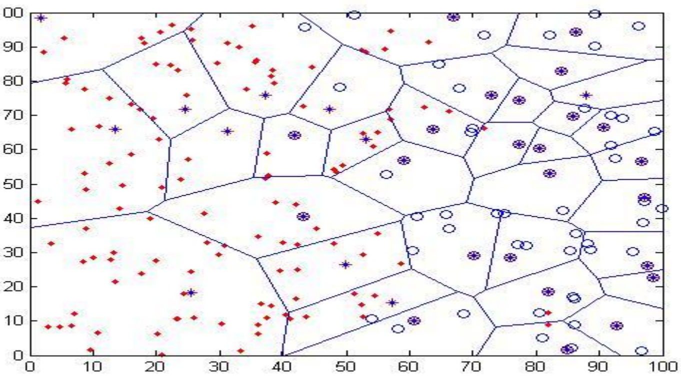

Fig.11. Selection of CH using FPA

As shown in Fig. 12, average energy of each node gets decrease with increase in number of rounds upto 100 but the energy of FPA is higher than that of C-LEACH and K-Means.

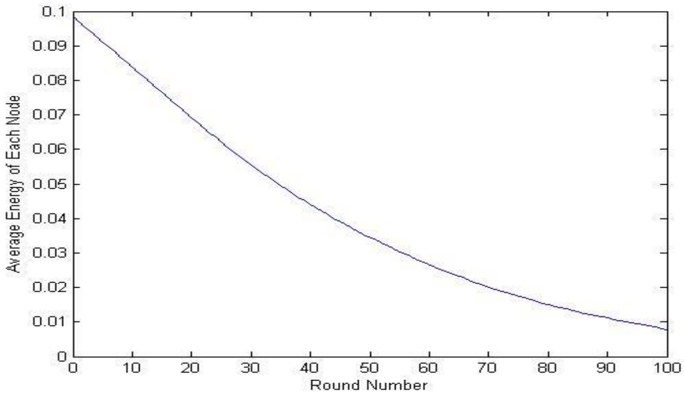

Fig.12. Average Energy Vs Number of rounds in FPA.

From fig. 13, it is clear that number of dead nodes gets increased with the increase in number of rounds but number of dead nodes of FPA is less than other two protocols.

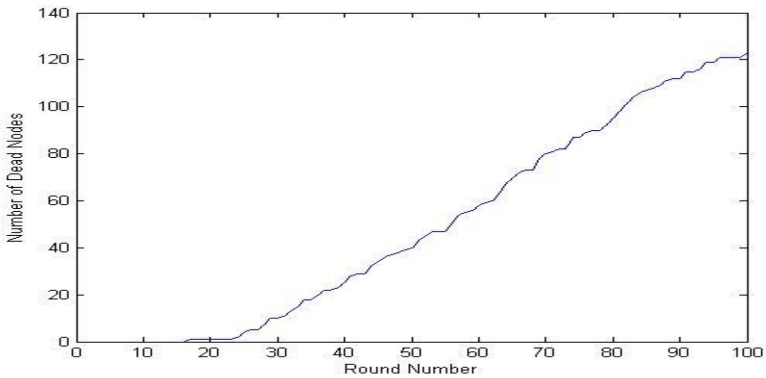

Fig.13. Number of dead nodes Vs number of rounds in FPA

4.3 Comparison of FPA with C-LEACH and K-Means

Comparison of FPA is done with the already existing protocols like C-LEACH and K-Means in terms of energy dissipation, number of dead nodes, energy efficiency and packet drop ratio.

Residual energy

Upon increase in number of rounds, the change in energy is shown in Fig 14. On observing this figure carefully, results related with energy efficiency of FPA are far better than LEACH and K-Means. Small amount of energy is still left behind after completion of 20 rounds as compared with other two existing protocols. However, sensor network still left with the remaining energy after 20 rounds.

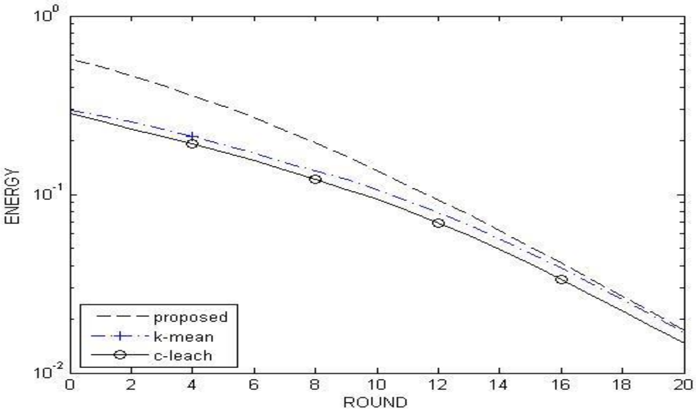

Fig.14. Residual Energy of the network as Number of rounds

Change in number of dead nodes

To know about the sensor network lifetime, number of live sensor nodes is detected at different rounds. As it is clear from the Fig. 15 that after the completion of 20 rounds, not even a single live node is left in LEACH and k-Means protocols, but there is still presence of some live nodes in our FPA scheme. Therefore, we can conclude that the lifetime of the FPA is higher than that of k-Means and LEACH protocols. This all is because the communication overhead of FPA is less than that of two existing protocols that might lead to creation of unbalanced clusters. Note that the FPA leads to the formation of clusters so that the distances from the CHs to the member nodes of the cluster get minimized as much as possible.

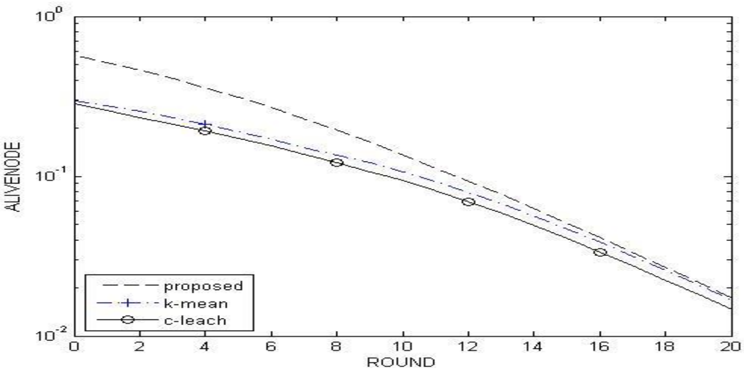

Fig.15. Number of Alive Nodes as Number of Rounds increases

Energy dissipation

Energy of nodes get dissipated when in communication. So, the energy dissipation of CHs of our proposed scheme with LEACH and K-Means protocols is shown in Fig 16. It is clearly visible that energy dissipation of FPA is lower than the existing K-Means and LEACH protocols. Moreover, the pattern of FPA is smoother than the other two protocols. Reason for this is the large number of small distances and the balanced distances between the CHs and their sensor nodes.

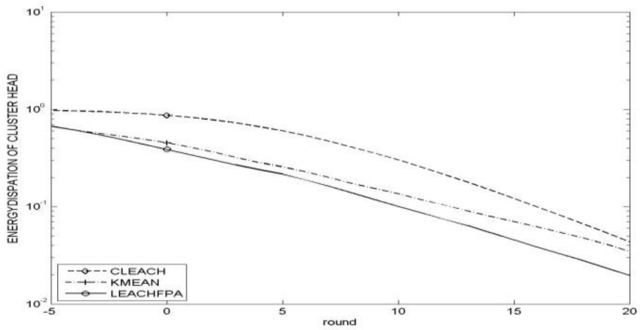

Fig.16. Energy Dissipation of CHs.

Packet Drop Ratio

Packet drop ratio is defined as the ratio of the number of packets that are dropped until a destination compared to the total number of packets that that are sent by the sender. Mathematically, we define it as:

$$PDR = \frac{P1}{P2} \quad (8)$$

Where, P_1 is the number of data packets received by the destination and P_2 is the number of data packets generated by the source. As shown in Fig. 17, it can be seen that packet drop ratio of FPA is less from LEACH and K-Means protocols with the increase in number of rounds.

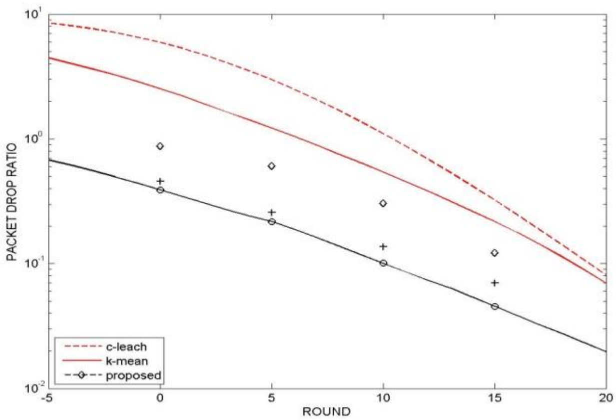

Fig.17. Packet Drop Ratio as the Number of Rounds

5. Conclusion and Future work

LEACH and k-Means are the existing hierarchical routing protocols and they make selection of CHs which results in the reduction of lifetime for the overall network. Our protocol called FPA is proposed in this paper, which selects the CH in an efficient way for a network to be energy efficient. This is based to find the CH having the minimum distance from local and global pollination. According to simulation results, performance of the FPA is much better than that of the LEACH and k-Means algorithm in terms of energy efficiency, number of alive nodes, energy dissipation and the packet drop ratio. The grouping of the sensor nodes into several clusters is done with the help of flower pollination approach. The time taken for clustering process can be optimized further. In future, the network lifetime can be optimized and the clustering time can be further minimized.

References

[1] Akyilidiz I.F., Su W., Sankarasubramaniam Y. and Cayirci E. Wireless sensor networks: A survey. Computer Networks 2002; volume 38, no. 4, pp. 393-422, March 2002.

[2] Xiaofeng M., Min Y., Dilin M. Application overview of wireless sensor networks. Computer application and software 2008; 25(3):179-181.

[3] Zytoune Q., Aroussi M. El., Rziza M., Aboutajdine D. Stochastic Low Energy Adaptive Clustering Hierarchy. Computer Networks and Internet Research Journal 2008, 8(1): 47-51.

[4] Younis O. and Fahamy S. Distributed clustering in ad-hoc sensor networks: A hybrid, energy-efficient approach. in Proc. IEEE INFOCOM 2004, 1: 629-640.

[5] Akkaya K., Younis M. A survey on routing protocols for wireless sensor networks," Ad Hoc Networks 2005, 3(3):325-349.

[6] Heinzelman W.B., Chandrakasan A.P. and Balakrishnan H. Energy-Efficient Communication Protocol for Wireless Microsensor Networks. Proceedings of the Hawaii International Conference on System Sciences, January 2000, 8(8): 8-20.

[7] Guo L.Q., Xie Y., Yang C.H and Jing Z.W. Improvement on LEACH by combining Adaptive Cluster Head Election and Two-hop transmission. Ninth International Conference on Machine Learning and Cybernetics, Qingdao, July 2010; 1678-1683.

[8] Xiangning F., Yulin S. Improvement on LEACH Protocol of Wireless Sensor Network. International Conference on Sensor Technologies and Applications 2007; 260-264.

[9] Park G. Y., Kim H., Jeong H. W. and Youn H. Y. A Novel Cluster Head Selection Method based on K-Means Algorithm for Energy Efficient Wireless Sensor Network. 27th International Conference Adv. Inf. Network Application Work 2013; 910–915.

[10] Singh M. P., Kaur K.. A Study and Analysis of Congestion Control Wireless Sensor Networks. I.J. Wireless and Microwave Technologies 2016, 6(6):14-23.

[11] Kumar V., Singh P., Kumar A., Tyagi N. Performance Analysis of Energy Aware Backbone based Approaches for Data Dissemination in Wireless Sensor Network. I.J. Wireless and Microwave Technologies, 2016; 6(5):72-82.

[12] Hajraoui A., Chakkor S., Baghouri M., Essaâdi A., Bourzek A. The Scalability and Stability Analysis of KLEACH Routing Protocol in Wireless Sensor Networks. I. J. Computer Network and Information Security, 2016; 8(4): 22-29.

[13] Rana S., Bahar A. N., Islam N., Islam J. Fuzzy Based Energy Efficient Multiple Cluster Head Selection Routing Protocol for Wireless Sensor Networks. I. J. Computer Network and Information Security 2015; 7(4):54-61.

[14] Banerjee R. Cluster Based Routing Algorithm with Evenly Load Distribution for Large Scale Networks. in International Conference on Computer Communication and Informatics (ICCCI) 2014; pp. 1–6.

[15] Thein M. C. M. and Thein T. An energy efficient cluster-head selection for wireless sensor networks. in 1st International Conference on Intelligent Systems, Modelling and Simulation 2010; pp. 287–291.

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