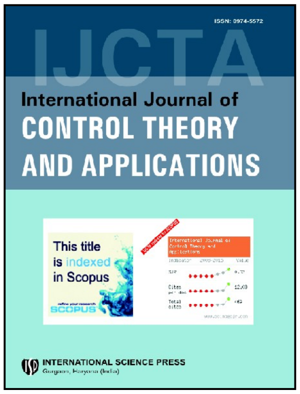

International Journal of Control Theory and Applications

ISSN : 0974-5572

Volume 10 • Number 10 • 2017

Energy Efficient Cluster-Based Routing Protocol in Wireless Sensor Network using Flower Pollination Algorithm

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Abstract: Main ambition of wireless sensor networks (WSN) is to exploit network lifetime and stability periods. Flower Pollination Algorithm (FPA) is uses to elect the cluster head (CH) in set up phase of WSN such that the intra cluster average distance between the member nodes and their respective CHs is minimized and the sum of ratio of residual energy of alive nodes in cluster or energy level of CH is also minimized via maximized. In the research, a Flower Pollination Algorithm based Energy Efficient Routing Protocol (EERPFPA) has been proposed to apply FPA the problem of electing the CH in the cluster set-up phase based on minimizing the intra cluster average distance between the member nodes and their CHs and minimizing the sum of ratio of remaining power/energy of active sensor nodes in cluster to energy/power intensity of CH. It efficiently maximizes the network life time and improves the stability period. In this paper, the simulation results are showed by using MATLAB. The results showed that the proposed algorithm is more energy efficient and more reliable in clustering process as compared to WSN with Harmony search algorithm (HSA) for heterogeneous networks.

Keywords: Energy Efficient Routing Protocol on Flower Pollination Algorithm (EERPFPA, Wireless Sensor Networks (WSN) Cluster Head (CH), Harmony search algorithm (HSA), Flower Pollination Algorithm (FPA).

I. INTRODUCTION

A WSN is a collection of sensor nodes, which produce a network using radio communication in an autonomous and distributed manner. In this network each sensor is to collect the data, messages and information transferring it to the Base Station (BS). When all the nodes transfer their information, data and messages directly send the BS and then their all energy will be quickly reduced. The major problem in networks is the restriction of the storing capacity and energy and low power to execute a routing. In WSN, clustering is the most important method to extend network lifetime. Clustering is the main purpose of reducing complete transmitting capacity accumulates above nodes to choose way or balancing weight between nodes to enlarge the network. In cluster- based routing protocol is to arrange the sensor nodes in to grouping are called cluster. Then choose the CHs or collect the information from other nodes and send to the BS. The main example of cluster- based routing protocol is Low-Energy Adaptive Clustering Hierarchy (LEACH). The LEACH operation is classified in to two rounds. The first round is set-up phase and second is data transmission phase. In set-up phase, all the nodes producing themselves in to groups is called cluster. In this phase only clusters are formed and one node elected as a CH. In data transmission phase, when clusters are formed, sensor nodes send information and messages to the CH. All the CH aggregates information to nearby nodes or send to the BS. In these networks the optimization and energy consumption is one of the challenges have been raised. FPA is mainly inspired from the pollination plants. It is widely used for optimization of multi-objective real-world design problems. This algorithm was developed by Xin- She Yang in 2012 mainly nature based Evolutionary. It is typically associated with FPA such as Bats, birds, insects and other animals. In a very specialist flower- pollinator partnership has co-evolved with some flowers and insects.

In this paper, Section II is defining models and performance parameters. Section III Proposed Energy Efficient Routing Protocol Based on FPA. Section IV provides the experimental results and Section V. Conclusion and Future work.

II. WIRELESS SENSOR NETWORK MODEL

The model of a WSN which is used in the proposed work is an arrangement with diverse nodes which can also be said heterogeneous and these are diverse in their preliminary quantity of power. Suppose "M" be the proportion of the whole count of sensor nodes N, which are set with additional power by a factor of á time than the other sensors. These dominant sensors are referred as advanced nodes or superior nodes, and the rest $(1 - M) \times N$ as usual nodes or normal nodes. Two such networks are shown in figure 1 and 2 with values of M as 10% and 20% respectively.

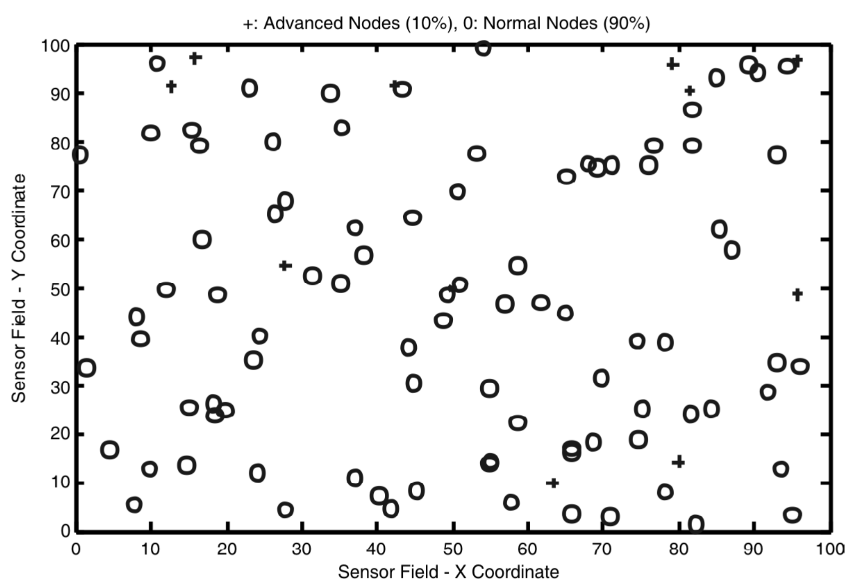

Figure 1: WSN Field with 10% Advanced Nodes

So as per these assumptions, assume that E_0 is the preliminary power of every usual node. The power of every superior node is then $E_0 \times (1 + \beta)$. The entire (preliminary) power of the diverse arrangement can be calculated as:

$$N \times (1 - M) \times E_0 + N \times E_o \times (1 + \alpha) = N \times E_o \times (1 + \alpha \times \mathrm{M}) \quad (1)$$

Accordingly the overall power of system is enlarged by an amount of $(1 + \beta \times M)$ than energy of a homogeneous network having all N nodes same energy E_0 i.e. $N \times E_o$ [15].

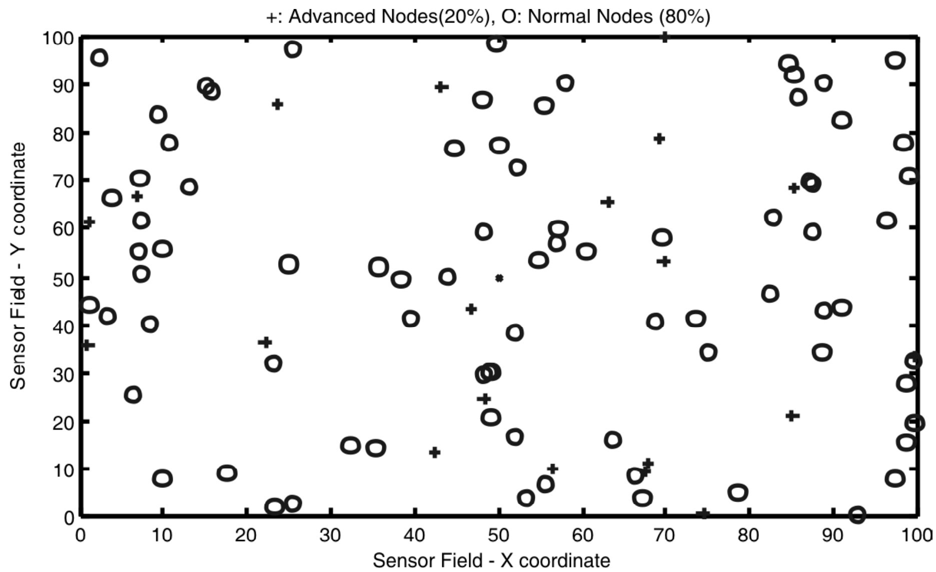

Figure 2: WSN Field with 20% Advanced Nodes

Radio Model

In order to calculate the power consumption by radio and achieve and satisfactory SNR (signal to noise ratio) for sending N bit information to a receiver s distant given by:

$$E_{TX}(l,d)=\begin{cases} L\cdot E_{elec}+L\cdot\in_{fs}.d^2 & if\ d\le d_0 \\ L\cdot E_{elec}+L\cdot\in_{mp}.d^4 & if\ d>d_0 \end{cases} \quad (2)$$

Where E_{elec} the energy is dissipated per bit to run the transmitter or the receiver circuit and d is the distance between the sender and the receiver. From above the equations are [15].

The communication distances between both the free space $\in_{fs}$ and multipath fading channel $\in_{mp}$ models are used for spreader amplifier. And short distance is defined as.

$$d_0=\sqrt{\frac{\in_{fs}}{\in_{mp}}}. \quad (3)$$

To collect an L bit message the radio expends

$$E_{Rx}=L\ .\ E_{elec} \quad (4)$$

Moreover the process of data aggregation uses the power as E_{DA}[15].

Optimal Clustering

Clustering/grouping techniques fragment an arrangement into non overlapping groups comprising a CH each. Non-CH or member sensors send sensed information to CHs, where the sensed information can be combined as this information can be adequately interrelated due to the sensors' spatial closeness, and sent to BS. So the energy expended of any CH node is always more than normal nodes. And if there is more number of CHs in a network then its lifetime is reduced. So the best possible count of groups should be selected in an arrangement. Prior research has considered moreover by simulation or logically the optimal possibility of a sensor being selected as a CH sensor. This grouping is best in the way that power expenditure is well spread over all nodes and the whole power expenditure is least. Such best grouping extremely depends on the energy representation is used. The optimal number of clusters K_{opt} to be constructed can be found as [15].

$$k_{opt} = \sqrt{\frac{N}{2\pi}} \frac{2}{0.765} \tag{5}$$

Where N is entire number of sensor nodes in network.

Performance Parameters

Before discussing the proposed technique, we need to take a look at the various parameters to be considered while simulating the proposed technique on the computer software. The basic parameters are listed below as followings

Network Lifetime: The time gap from the beginning the operation (of sensor network) until the dead of the very last active node.

Stability Period: The time gap from the beginning the operation (of sensor network) until the dead of the first node.

Instability Period: The time gap from the dead of the first node until the dead of the last node.

First Node Dead (FND): Round number at which the first node dead. It also represents stability period of network i.e. bigger the FND is, longer is the stability period of network.

Half Node Dead (HND): Round number at which the 50% of sensors are dead.

Last Node Dead (LND): Round number at which whole sensors are dead.

Number of Alive Nodes per Round: The total amount of Sensor nodes that has not expended their full energy in a round.

Throughput: Rate of data transmitted over the network together with the rate of data transmitted from CHs to the base station as well as the rate of data transmitted from the sensor nodes to their CHs.

III. PROPOSED ENERGY EFFICIENT ROUTING PROTOCOL BASED ON FPA

In the proposed work a technique named EERPFPA is projected to apply FPA to the problem of electing the CH in the cluster set-up phase based on minimizing the intra cluster average distance between the member of sensor nodes and their respective CH and minimizing the amount of ratio of remaining energy of alive nodes in cluster to energy level of CH. It efficiently maximizes the network lifetime and improves the stability period. The operation of the EERPFPA protocol is set up into rounds, where each round begins with a set-up phase, when the BS find the locations of CHs and assigns members nodes of each CH, followed by a steady-state phase, when the sensed data are transfer to CHs and collect in frames; then these frames are transfer to the BS.

Cluster Set-up Phase of WSN

In set-up phase, the CHs are decided by BS using FPA out of the existing alive sensors nodes having residual energy more than a threshold energy level, and associated cluster members are established and thus groups are built as showing in figure 3. A threshold energy level is average energy level of all active sensor nodes. Initially, at the beginning BS send a small communication to wake up and to demand the Identifications, locations and power intensity and type of the node (advanced or normal) of every sensor nodes in the sensor network..

Depending on the responded data from sensor nodes, the BS utilizes FPA to elect CHs based on minimization of fitness function given by equation 8. The whole process to minimize the fitness function and CH selection is illustrated in figure 4. Also, the BS allocates the associated sensor nodes of every CH on the bases of minimum Euclidean distance. When CHs are chosen and associate members of CH are assigned, the BS sends a small message to notify sensor network about CH and associated members.

When a small message is received from the BS, every CH generates the TDMA schedule by conveying period to its associated member sensors and notifies these sensors by this schedule. The TDMA schedule is utilized to avoid from intra-cluster collisions and reduce energy consumption between data communications in the cluster and facilitates every member of the radio equipment shut down when it is not in utilization. Furthermore, to decrease inter-cluster intrusion each CH chooses a unique Code Division Multiplexing Access (CDMA) code and notifies all associated member sensors within the cluster to send their information using this scattering code.

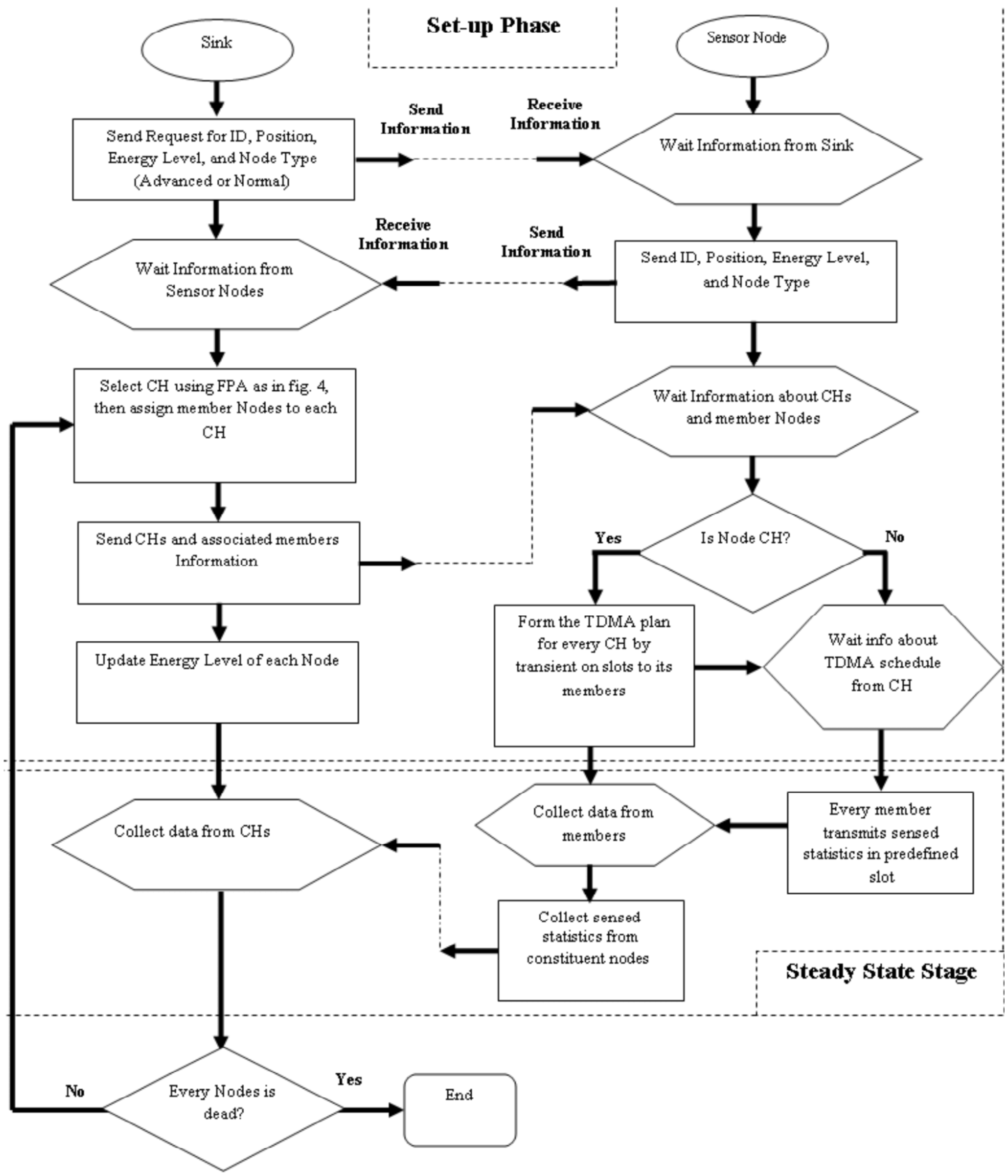

Figure 3: Operation of Proposed EERPFPA Protocol

Steady State phase of WSN

Through the steady state phase, the sensor nodes get up and begin sensing information/parameters to be sensed. After that every sensor transmits the sensed data to its CHs as per the TDMA time table as exposed in figure 3. The CH sensor node must remain its receiver on to obtain whole information from the sensor nodes in the group. While whole information has been obtained, the CH sensor node perform signal processing function to collected the data into a single signal. This collected signal is transmitted to the BS. After a specified instance, which is resolute a priori, the network once again goes back into the cluster setup phase and fresh CHs are resolute by means of FPA by the BS for next round.

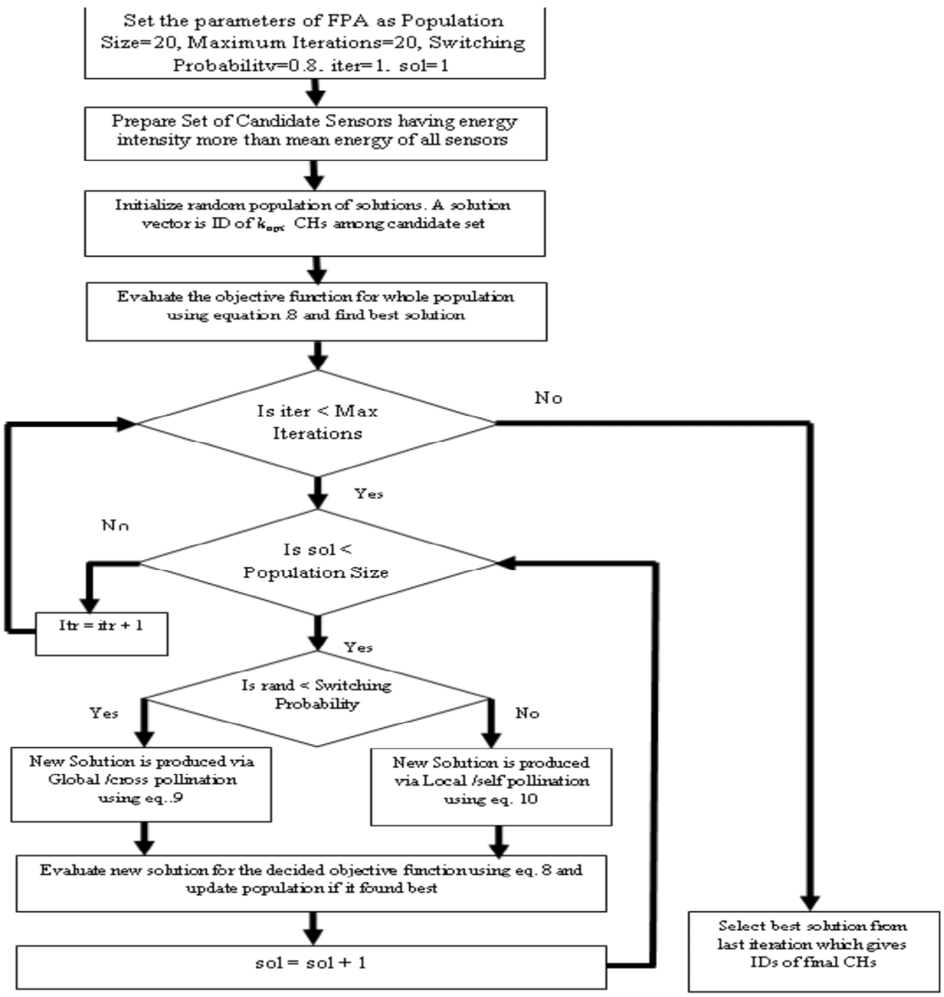

Figure 4: Flow chart of (CH) Election Algorithm using FPA in projected research

The facts of the projected EERPFPA procedure and how FPA is employed to elect the CHs as follows:

Fitness Function The problem of improving the clustering solution and to elect CHs can be invented as an optimization problem and mathematically expressed as a combination of two functions as described below

$$f_1 = \max_{i\epsilon(1,\, k_{opt})} \left\{ \frac{\Sigma \forall n \epsilon c_i d(n, CHi)}{|Cj|} \right\} \tag{6}$$

where k_{opt} symbolizes the CHs count, Ci is the ith cluster distinguished with cluster-head CHi, and any member node, n, belong to the cluster Ci that satisfy the shortest space between n and CHi. This function represents the highest of the sum of the Euclidean distance of associated sensor nodes to their CHi moreover $|Cj|$ is the count of sensor nodes that belong to group C_i [16].

By reducing this function, it tend to reduce the intra-cluster average distance between these member nodes and their individual CHs. 2nd function is given by [16]

$$f_2 = \Sigma_{i=1}^{k_{opt}} \left\{ \frac{\Sigma \forall n \epsilon c_i E_n^{res}}{E_{CHi}^{res}} \right\} \tag{7}$$

It represents the addition of fraction of remaining power of all sensor nodes in a cluster to the energy level of CH of that cluster.

The objective (i.e. fitness) function is to minimize the following function.

$$\text{Fitness} = \alpha \times f_1 + (1 - \alpha) \times f_2 \tag{8}$$

From above all these equations are given by [16]. By reducing the fitness function, it is projected that the cluster development and the CH election of the WSN can be optimized for growing the efficiency of energy consumption within the network.

The constant α denotes the donation of f_1 and f_2 in the fitness function. To avoid the election of the sensor nodes having small energy intensity to be the CH, the CH sensor nodes are elected from the cluster of applicants. Merely the sensor nodes having energy intensity more than the mean energy intensity of the entire sensor nodes in the set-up can be the CH candidate.

WSN CH Election Problem Mapping with FPA

Flower Pollination algorithm is developed based on the characteristics of the flower pollination.

STEP 1: Initialize optimization problem and set parameters

To direct the CH selection, EERPFPA utilizes population of solutions that progress toward optimizing the required fitness function i.e. to reduce the intra cluster spaces and optimize the energy consumption in network. For this purpose a fitness function is formed using eq. 8. Other parameters of the algorithm like Population Size, Maximum Iteration, and Switching Probability (Ps) is set.

STEP 2: Prepare Candidate Set

To stay away from the election of the sensor nodes having small energy intensity to be the CH, the CH sensor nodes are elected from the group of candidates. Merely the sensors having energy intensity more than the mean energy intensity of the entire sensors in the set-up can be the group of CH candidates.

STEP 3: Initialization Population

A population is generated having solutions equal to Population Size. Each resolution vector is represented as Identification of CHs randomly selected amongst group of candidates. And generated population is evaluated using fitness function represented by equation 8. And find the best solution among the initial population.

STEP 4: Generation of new solution

For every member of the population generate a new solution either using global (cross) pollination or using local (self) pollination depending upon the switching probability Ps.

To generate a new solution via global pollination a step vector L is drawn which obeys levy flights and mathematically new solution can be described as

$$X_i(t+1) = X_i(t) + L*(X_i(t) - gbest) \quad (9)$$

Where $X_i(t+1)$ is new solution, $X_i(t)$ is solution/pollen in current population, gbest is current best solution among population at current generation/iteration.

To generate a new solution via local pollination below mathematically equation is used

$$X_i(t+1) = X_i(t) + epsilon*(X_j(t) – X_k(t)) \quad (10)$$

Where $X_i(t+1)$ is new solution, $X_i(t)$ is solution/pollen in current population, epsilon is random number, Xj(t) and $X_k(t)$ are two randomly selected solutions from current population at current generation/iteration.

STEP 5: Update Population

The recently produced solution vector is examined in terms of the fitness function value. If the fitness function value for the recent produced solution is improved than the previous best solution, then new solution is included in the population in place of the previous best solution. The resolution vector with the minimum fitness assessment can be measured the best resolution of the problem in the present iteration.

STEP 6: Termination

Go to the step 4 until maximum iterations are attained. The present fit resolution is chosen from population after execution criteria is met. This is the resolution for the optimization problem formulated. The Identification (IDs) in this solution represents the elected CHs.

IV. RESULTS AND DISCUSSIONS

Both algorithms are realized in MATLAB Environment. The simulation is carried out using Custom Built Iterative Based Simulator in MATLAB R2010b which simulates the sending, receiving, dropping and data forwarding etc. The simulations are carried out on various sensor node networks with different heterogeneous situations, every collected of 100 sensors arranged random in a ground of 100m×100m sensor field. It concludes that the both coordinates of every node are randomly chosen between 0 and the 100 which is highest value of the measurement. Experiments were performed considering 10% and 20% advanced nodes. BS is located at the midpoint of the field. For reasonable in similarity, the features of the networks and radio models exercised for the capable protocol simulations are considered the same. The initial energy of a usual sensor is set to $E_0 = 0.5J$, $\epsilon_{fs} = \frac{\frac{10pJ}{bit}}{m2}$, $\epsilon_{mp} = \frac{0.0013pJ}{bit}/m4$, and $EDA = \frac{\frac{5nJ}{bit}}{report}$. The message packet size that nodes transmit to their CHs as well as combined message packet size that a CH transmits to the BS is set to 4000 bits. Results for every simulation are given both quantitatively and qualitatively. The switching probability in FPA was fixed at 0.8. The various parameters used in HSA were HMCR and PAR, 0.95 and 0.7 correspondingly. The population' size was considered 20 and allowable to develop for 20 generations for both algorithms. And same fitness function was minimized using these algorithms to elect CH.

Assessments

To confine the performance analysis of the projected FPA in the network test occurrences and to study its performance against HSA algorithm, figure 5 statistically qualify them with 10% of node heterogeneity. The figure describes the active nodes count versus protocol rounds.

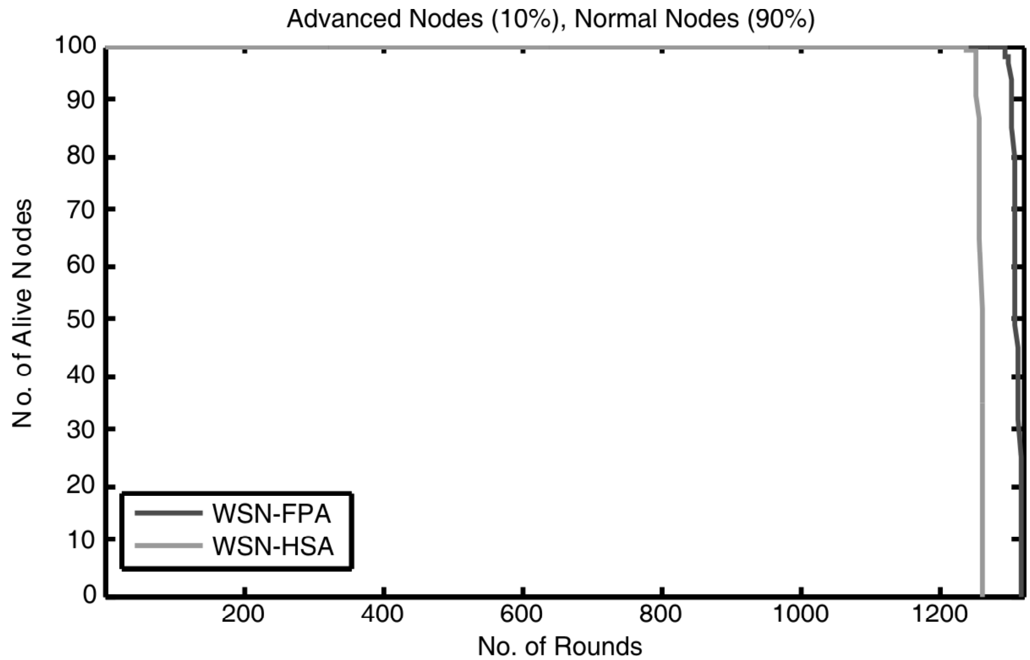

Figure 5: Active nodes count in the system versus rounds for 10% heterogeneity

Table 1
Percentage of dead nodes over rounds of WSNs (with 10% advanced nodes)

% dead nodes	*HSA*	*FPA*
10	1253	1302
20	1255	1305
30	1257	1307
40	1258	1308
50	1259	1309
60	1259	1311
70	1260	1313
80	1261	1314
90	1261	1315
100	1262	1316

In Table 1 the percentage of dead nodes over rounds of WSNs with 10% of advanced nodes of network lifetime. The results in Table 1 confirm the round count where a particular percentage of sensors expire for the compared algorithm. Outcomes in the table evidently demonstrate the optimistic impact of the projected FPA for decreasing died nodes count while the algorithm rounds continue, and consequently, increasing the network lifetime. In Table 1, the increase network lifetime was 4.3% as compared with HSA, respectively.

Fig. 6 confines the performance analysis of the projected FPA in the network test occurrences and to study its performance against HSA algorithm. The figure describes the active nodes count versus protocol rounds statistically qualify them with 20% of node heterogeneity.

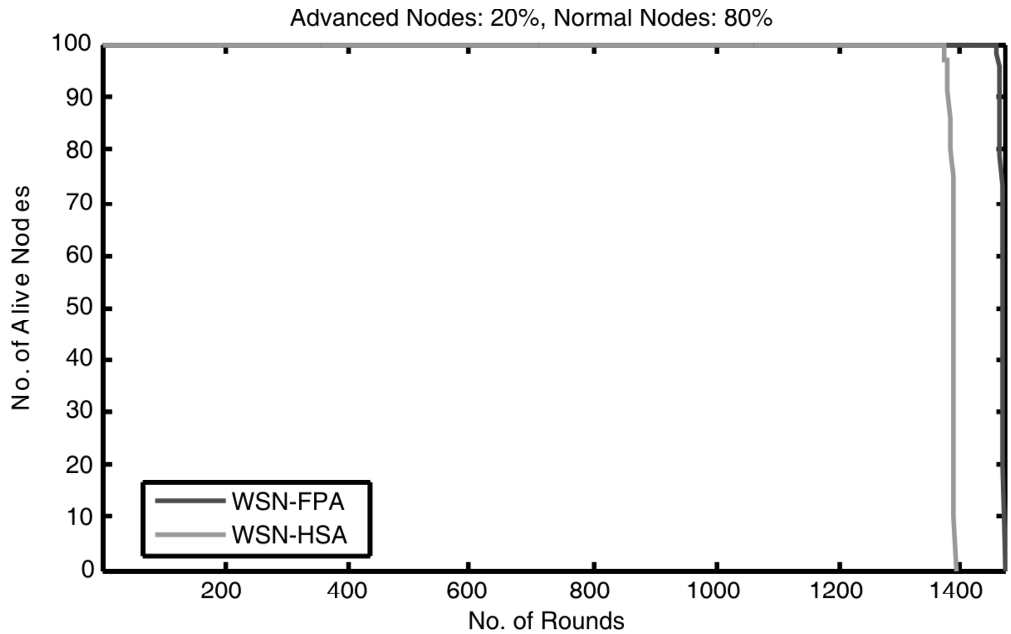

Figure 6: **Active nodes count in the system versus rounds for 20% heterogeneity**

Table 2
Percentage of dead nodes over rounds of WSNs (with 20% advanced nodes)

% dead nodes	*HSA*	*FPA*
10	1381	1461
20	1383	1464
30	1385	1466
40	1386	1467
50	1387	1468
60	1388	1468
70	1388	1469
80	1389	1469
90	1389	1470
100	1390	1470

In Table 2, the percentage of dead nodes over rounds of WSNs with 20% advanced nodes of network lifetime. The results in Table 2 confirm the round count where a particular percentage of sensors died for the compared algorithm. Outcomes in the tables evidently demonstrate the optimistic impact of the projected FPA for decreasing died nodes count while the algorithm rounds continue, and consequently, increasing the network lifetime. Also, in Table 2, the gain was 5.8% as compared with HSA correspondingly.

Supplementary comment can be made from the tables, which intimate the performance of FPA in opposition to HSA. FPA outperforms HSA in keeping the active sensors bigger than that of these algorithms throughout the network life time. This scrutiny can be quantitatively offered in Tables 1 and 2 for both types of WSNs.

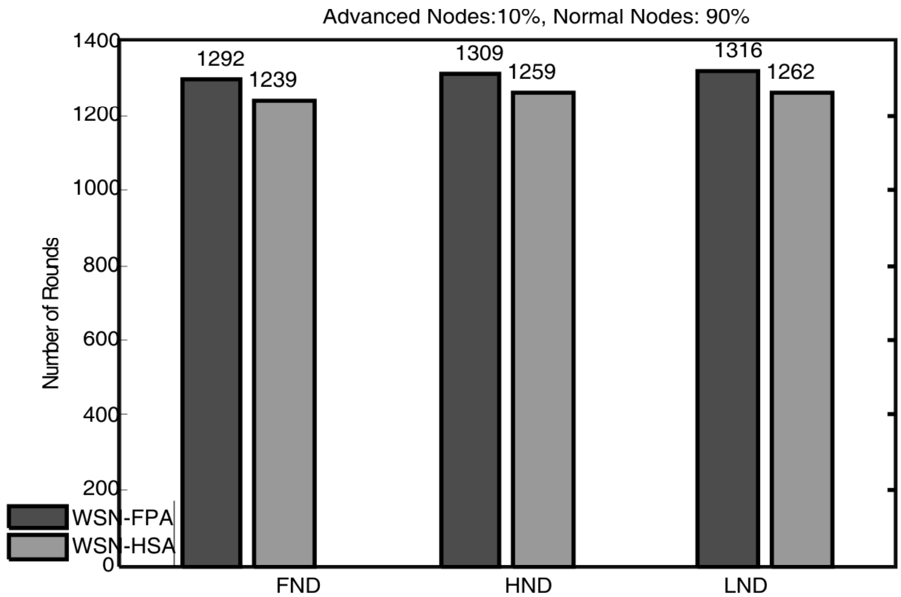

Figure 7: Number of rounds at FND, HND, LND (10% Heterogeneity)

Fig 7 illustrates the rounds count at FND, HND and LND for both the techniques. From these statistics it can be clarified that FPA algorithm in both cases outperforms the HSA in terms of stability period as well as network lifetime. The FPA algorithm extends the stability period by 53 in comparison to HSA in case of 10% heterogeneity.

Table 3
Round counts of FND, and LND for WSN with 10% Heterogeneity

WSN	*HSAFND*	*HASLND*	*FPAFND*	*FPALND*
1	1239	1262	1292	1316

In Table 3 the round count of FND and LND with 10% of heterogeneity WSN. Note that in each table, the most excellent values are described in boldface. In table the demonstrate of the round number of FND and LND

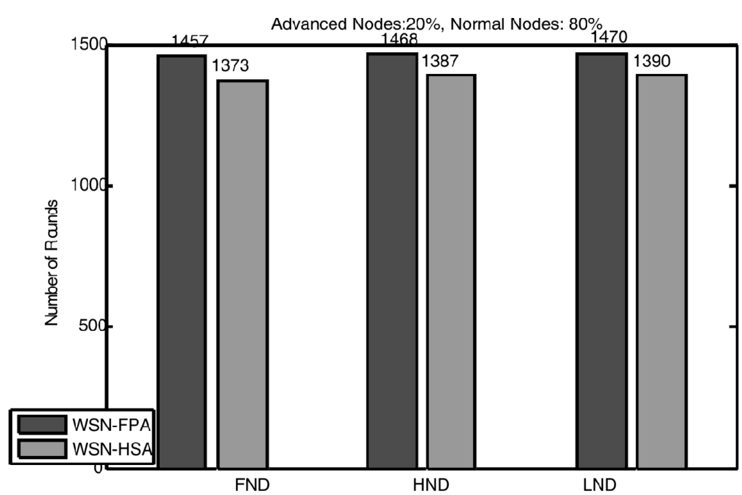

Figure 8: Number of rounds at FND, HND, LND (20% Heterogeneity)

for both types of WSNs. The individual outcomes in this table confirm that FPA can expand the time until LND more than HSA (in all run). On the other hand, the constant phase of FPA until FND is enlarged in comparison to that of HSA by 4.3–6.11%.

Fig 8 illustrates the rounds count at FND, HND and LND for both the techniques. From these statistics it can be clarified that FPA algorithm in both cases outperforms the HSA in terms of stability period as well as network lifetime. The FPA algorithm extends the stability period by 84 as compared to HSA in case of 20% heterogeneity

Table 4
Round counts of FND, and LND for WSN with 20% Heterogeneity

WSN	*HSAFND*	*HSALND*	*FPAFND*	*FPALND*
1	1373	1390	1457	1470

In Table 4 the round counts of FND and LND with 20% of heterogeneity WSN. Note that in each table, the most excellent values are described in boldface. In table the demonstrate of the round number of FND and LND for both types of WSNs.

The individual outcomes in this table confirm that FPA can expand the time until LND more than HSA (in all run). On the other hand, the constant phase of FPA until FND is enlarged in comparison to that of HSA by 4.3–6.11%.

Table 5
Residual energy over protocol rounds for a total of 1316 rounds (with 10% Heterogeneity)

% round	*HSA*	*FPA*
10	48.9815	48.9591
20	42.6848	42.6846
30	36.6905	36.7038
40	30.9193	31.0277
50	25.2613	25.4041
60	19.6713	19.8386
70	14.1536	14.3314
80	8.6010	8.7883
90	3.0854	3.2827
100	^0	0

In Table 5 the remaining energy over protocol rounds for a total of 1316 rounds with 10% of heterogeneity WSN. Note that in each table, the most excellent values are described in boldface. Demonstrate the optimistic impact of FPA for saving additional power in the arrangement at a chosen round space. Both clustering algorithms employ the whole energy. HSA disperses the network power sooner than other. And FPA preserves more energy than HSA algorithm in addition to longer stability period. In the table, ^means that the residual sensors were deceased before the equivalent rounds proportion

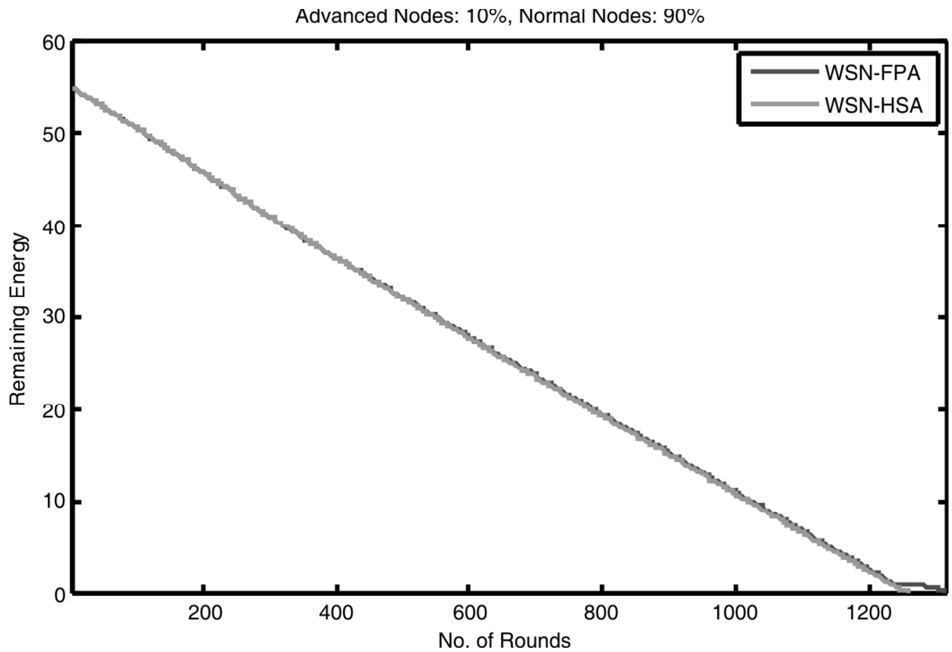

Figure 9: Residual energy of network with rounds (10% Heterogeneity)

Fig 9 shows the residual energy of the network with rounds 10% heterogeneity of WSN as it proceeds towards final rounds and is very clear that remaining energy reduces with rounds but FPA algorithm outperforms the HSA by having more residual energy at any time of network for both the cases of heterogeneity.

Table 6
Residual energy over protocol rounds for a total of 1470 rounds (with 20% Heterogeneity)

% round	*HSA*	*FPA*
10	53.7233	53.6769
20	47.3002	47.1438
30	40.5580	40.5605
40	33.9745	34.0741
50	27.5986	27.7384
60	21.2846	21.4601
70	15.0463	15.2438
80	8.8350	9.0530
90	2.6296	2.8626
100	^0	0

In Table 6 the remaining energy over protocol rounds for a total of 1470 rounds with 20% of heterogeneity WSN. Note that in each table, the most excellent values are described in boldface. Demonstrate the optimistic impact of FPA for saving additional power in the arrangement at a chosen round space. Both clustering algorithms employ the whole energy. HSA disperses the network power sooner than other. And FPA preserves more energy than HSA algorithm in addition to longer stability period. In the table, ^means that the residual sensors were deceased before the equivalent rounds proportion,

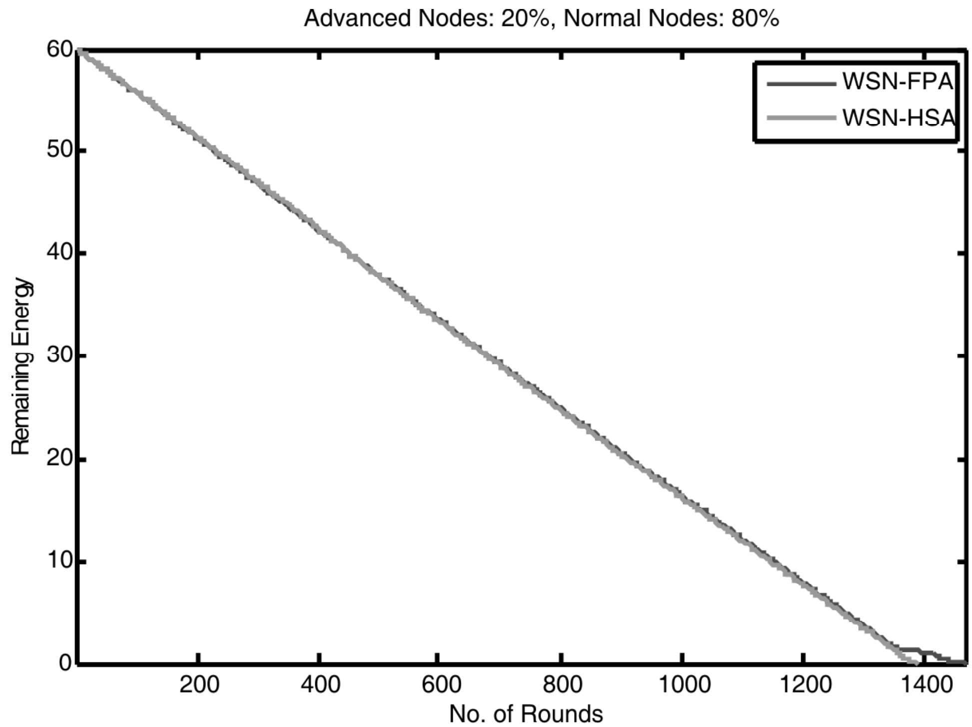

Figure 10: Residual energy of network with rounds (20% Heterogeneity)

Fig 10 shows the residual energy of the network with rounds 20% heterogeneity of WSN as it proceeds towards final rounds and is very clear that remaining energy reduces with rounds but FPA algorithm outperforms the HSA by having more residual energy at any time of network for both the cases of heterogeneity.

V. CONCLUSIONS AND FUTURE WORK

In the last EERPFPA has been proposed to efficiently maximize the network lifetime and stability period of WSN. EERPFPA uses FPA to elect the CHs in the setup phase of WSN such that the intra cluster average distance between the member sensor nodes and their respective CHs is minimized and the addition of fraction of remaining energy of active sensor nodes in cluster to energy level of CH is also minimized via minimization of described fitness function which improves the network survivability as well as stability period of the WSN. MATLAB simulation experimental results demonstrate that the projected EERPFPA protocol is additional energy efficient and more reliable in grouping process in comparison to WSN with HSA for heterogeneous networks. Also, EERPFPA performs better the earlier protocols in terms of throughput, FND, LND, active nodes count per round, and energy dissipation rate. The throughput of EERPFPA is always more than the previous algorithms so it can be said that more data is transferred in the network using the proposed technique in comparison to previous techniques with same or less amount of energy consumption. So Proposed routing protocol EERPFPA performs better almost all aspects of a WSN.

The future work can also include mobility in the network and then check performance of EERPFPA.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to my co-supervisor, Ms. Mamta Arora, Assistant Professor, & ECE Department, Chandigarh University, Gharuan, for her valuable guidance, excellent supervision, care and assistance during the entire period of my research work.

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