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An Energy Efficient and Stable Algorithm for Clustering Protocol inWSNs

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***Abstract*- A large number of multi-functional sensor nodes having low cost, low power and small size are usedfor the formation of wireless sensor networks .For the design of wireless networking protocols, Minimizing the energy utilization and maximizing the network lifetime are the key requirements .Routing is the core technology in thefield of WSN.So,a number of routing protocols are proposed for WSN having different objectives. In this paper, the main objective isconcerned withimprovement of stability period of network.The technique of clustering in which aggregation of data is being taken place at the cluster head (CH)rises pecific expressive factors to enlarge lifetimeof the network. In this paper, a harmony search algorithm (HSA)is used for optimal selection of CHs. The simulation results demonstrate that the schemed algorithm outperforms as compared to existing algorithms in terms ofstability period of the network and energy dissipation.**

Keywords— Wireless Sensor Network, Harmony Search Algorithm, clustering, Network Lifetime, Residual energy, stability period.

I. INTRODUCTION

A large number of sensor nodes which are densely deployedover a large geographical region and networked throughwireless links are used for the making of wireless sensornet works.Each sensor node in WSN has capability to communicate with each other and base station is used for the data integration and circulation .In WSN each and every node can become transmitter and receiver.A key feature for these networks is that their nodes are unattended .For these networksan important design consideration is energy efficiency and routing is a core technology for WSN Communication.

MANETS i.e. Mobile Ad Hoc Networks are different from thetraditional wireless communication networks in which thenodes move independently from each other.In MANET anynode can be source or destination and each node can work as arouter which is used for forwarding data to its peers. For routing in wireless sensor networks, so many routing protocols are proposed like data centric routing protocols, hierarchical routing protocols and location based protocols [1].

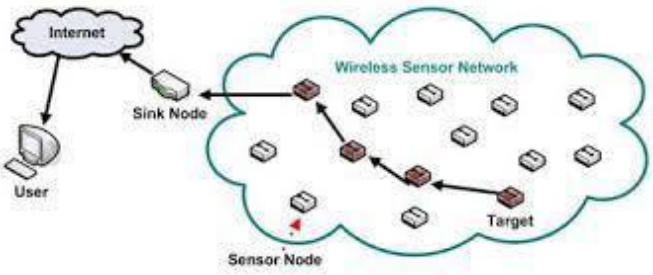

Fig. 1 Wireless Sensor Network

A routing is a core technology in the field of Wireless SensorNetworks.So number of challenges and design issues areoccurred in WSN.Without being effected by advancement intechnology,sensor nodes still have some restrictions likelimited battery,bandwidth constraint,limited computing powerand memory.So these restrictions made need for routingprotocols to be highly adaptiveand resource aware.Some of therouting challenges in WSN are as follows:

1. Energy Efficiency
2. Network Lifetime
3. Limited storage and computation
4. Low bandwidth and high error rates
5. Node failure tolerance of the network
6. Scalability to a large number of sensor nodes
7. To reduce redundant data should support dataaggregation
8. Survivability in harsh environment [2].

Clustering technique effectively reduces the energy consumption and increase the network lifetime [3]. In this nodes are arranged into cluster and there is one leader node known as cluster head (CH). The non-CH nodes sense the

sensing area and collect the information and transmitted this information to CH. CH is responsible for further transmitting the information to BS. The numbers of clustering algorithms are developed in order to reduce energy consumption problem in different scenarios of the network.

In this paper, HSA based clustering algorithm is developed in order to improve the stability period of network. It is tailored to meet the following conflicting goals: maximal stability period, besides this minimizing energy consumption throughout the network lifetime.

The remaining partof the paper is formulated as follows: Section II provides concise explication of the significant papers. The presumptionsrespecting the radio model is described in section III. The proposed HSA based CH election schema is evaluated in section IV and design of fitness function is also analyzed in this section. Next sectionaccommodates the performance evaluation based on simulation results.In next section conclusion and future scope is discussed.

II. RELATED WORK

LEACH [2] is first routing protocols based on clustering where, sensor nodes organized into cluster and CH node is chosen in every cluster. The sensing information is forward to BS through CH. The CH performs the function of aggregation to compress the size of data packet. The aggregated data is sent by CHs to the BS. The decision for election of CH is taken on basis of threshold given in equation 1. The sensor nodes randomly pick the random number between 0 and 1. To become a CH for a particular round, the number chosen by node should be less than below stated threshold value. This threshold is given by:

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

where, r represents the current round, desired percentage of selection of CHs is denoted by P and ($P \leq 5\%$), the group of nodes which have not elected as CHs in last $\frac{1}{p}$ rounds are represents by G.After the CH selection phase,schedule phase comes, in this phase the CHs allocates the time schedule for data transmission to its member nodes. According to that time schedule leaf nodes must sends the sensed information.

Many routing protocols are introduced in order to increase the performance of LEACH. Centralized version of LEACH is proposed which is opposite of LEACH. In LEACH, the nodes are organized into clustersthemselves without any central control but in case of LEACH-C, the nodes are categorized into cluster by BS.

In paper [4], author compared his proposed LEACH Heterogeneous system with Leach-Homogeneous system. In his paper, he analyzes the basic clustering routing protocol (distributed) LEACH which is the Low Energy Adaptive Clustering Hierarchy protocol (homogeneous system) & then proposed a new routing protocol (heterogeneous system) using which the sensor nodes form the cluster and the cluster-head is elected based on the residual energy of the individual node calculation.Simulation results show that the nodes remain alive for a longer time (rounds) in proposed LEACH-Heterogeneous system than Leach-Homogeneous system. Also first node dies (FND) and Half of the nodes alive (HNA) in the proposed Leach heterogeneous system is compared with Leach- Homogeneous system in terms of network lifetime. In the Leach-Heterogeneous system the energy efficiency is increased near to 40% than Leach-Homogeneous system and lifetime of the networks also increased.

In paper [5] author proposed a distributed cluster head CH selection algorithm LEACH-DT that actually takes the distances from sensors to the base station that optimally balances the consumption of energy among the sensors. Instead of using a heuristic method, he propose a distributed LEACH based CH selection algorithm in which based on the distances to the BS, nodes are automatically self-selected to become CHs with different probabilities, in such a way that the network can be balanced by balancing the energy consumption among the nodes. His simulation results shows that LEACH-DT outperforms the original LEACH by improving the network lifetime over 10%.

In paper [6] author proposed an energy efficient clustering algorithm for WSNs based on the LEACH algorithm. The proposed algorithm solves the extra transmissions problem that can occurs in LEACH algorithm. In order to solve the extra transmission problem, he make a change in the setup phase of the LEACH algorithm. In this phase, once the cluster heads are selected, the other sensor nodes do not necessarily select the closest node.

Among the cluster heads that, in comparison to themselves, have a shorter distance to the BS, these nodes select the closest cluster head and inform it that it will become a member of the cluster. If such a cluster head does not exist, it will not be the member of any clusters and will send its data directly to the BS. Using three metrics, First Node Dies (FND), Half of the Nodes Alive (HNA) and Last Node Dies (LND), he compare LEACH with his proposed algorithm in terms of the network lifetime. The simulation results show that the proposed algorithm can decrease the energy consumption of the network and dramatically increase the network lifetime for LND (Last NodeDies) metric in the case of the BS is located relatively close to the sensor nodes [7].

In paper [8] author gives a fuzzy logic based energy-aware dynamic clustering technique is proposed, which increases the network lifetime in terms of LND. Here, two inputs are given in the fuzzy inference system and a node is selected as a cluster head according to the fuzzy cost (output). Residual energy and node centrality are the two inputs of this FIS. Here, node centrality is the value to indicate that how central the node is among its neighbors. It is calculated by

adding all distances from a node to its neighbors. Hence, the lower value of the node centrality indicates that the corresponding node requires lower energy as a CH. The main advantage of this protocol is that the optimum number of cluster is formed in every round, which is almost impossible in low-energy adaptive clustering hierarchy. Moreover, this protocol has less computational load and complexity.

In paper [9] author proposed a new technique for the selection of the sensors cluster-heads based on the amount of energy remaining after each round. Election of a cluster-head in each round is based on an energy value greater than ten percent of the residual value at each sensor. As the minimum percentage of energy for the selected leader is determined in advance and consequently limiting its performance and nonstop coordination task, the new hierarchical routing protocol is based on an energy limit value threshold preventing the creation of a group leader, to ensure reliable performance of the whole network.

In paper [10] author proposed a Cross Layer-Low Energy Adaptive Clustering Hierarchy model (CLLEACH), an efficient routing protocol to increase the lifetime of the battery. CL-LEACH considers residual energy and for cluster head selection and provides an energy efficient transmission schemes for WSN.

Stable election protocol (SEP) was introduced for clustered heterogeneous WSNs [3]. This protocol helps to improve the stability period of hierarchical clustering process. In this,initial energy consider while election of CHs..The energy of advanced nodes is greateras compared to normal nodes and has greater probability to become CHs.

A new evolutionary based routing protocol (ERP) is introduced by Bara *et al.*for clustered heterogeneous WSNs [8]. Bio-inspired algorithms extend the network lifetime but reduce the stability period.It deals with problem of routing in clustered based network by designing new fitness function which considers parameters like ratio of intra- cluster distance to and inter- cluster distance and CH count. This protocol helps in increasing network lifetime as well as stability in heterogeneous WSNs.

Hierarchical cluster based routing (HCR) protocol introduced by Hussain*et al.* [11], where selection of CHs depends upon various factors. Genetic algorithm(GA) is used for the optimization process. As the population contains various chromosomes and best chromosomes is used for generation of next population. At the end of round, best fitness chromosome is evaluated and population is updated accordingly. HCR outperforms as compared to other clustering algorithms.

To design and implementation the real time application of sensor network which is based on the framework in protocol using HSA [12]. HSA is an optimization method of music-based. To optimize the energy distribution in wireless sensor networks in which cluster members minimizes intra-cluster distance with respective cluster-heads. Wireless sensor networks compared with the cluster based protocols by using FCM clustering algorithm or to develop with a LEACH-C. The proposed protocol shows experimental results using harmony search algorithm can be realized in the surveillance applications of building environments and for safety centralized cluster in networks. Using proposed HSA based protocol in the lifetime of network extended in wireless sensor and obtained the experimental test of results, that is comparison the LEACH-C and FCM protocols.

III. ENERGY DISSIPATION RADIO MODEL

This paper analysis the energydissipation mode shown in the following figure 2. For a particular node, due to receiving and transmitting the energy isdissipated. The energy is expanded in transmitter to transmitk-bit message is as follow:

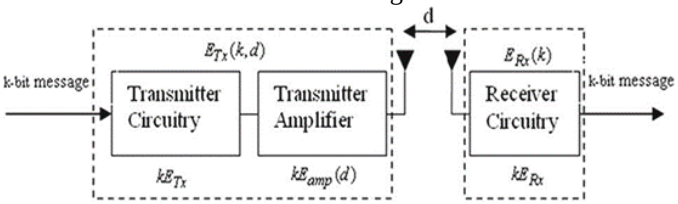

Fig. 2 Energy dissipation model [11]

ET(.k,d) = (Eelec * k) + (Efs*k*d^2) if d<=d0
(Eelec * k) + (Emp*k*d^4) if d>d0
where Eelec - Energy dissipated to run the electronicscircuits
k - packet size
Efs and Emp - Characteristics of the transmitteramplifier
d - Distance between the two communicating ends.

Energy dissipation to receive a k-bit message is given by-
ER(k) = Eelec* k
The values of radio characteristics are
Eelec = 50 nJ/bit
Efs = 10 pJ/bit/m^2
Emp = 0.0013pJ/bit/m^4

IV. PROPOSED PROTOCOL

In the proposed work a technique named stable harmony search algorithm based routing protocol (SHSARP) is proposed to solve the problem of electing the Cluster head (CH) in the group. Set-up phase is based on minimizing the intra cluster average space linking the member sensors and their relevant CHs and minimizing the total of fraction of remaining energy of active sensors in group to energy level of CH. It efficiently maximizes the network lifetime and improves the reliability period. The procedure of the SHSARP protocol is split into rounds, where every round starts with a set-up stage, when the Base Station (sink) locates CHs and assigns associated sensors of every CH, followed by a steady-state stage, when the collected information is sent to CHs and

receive in frames; then these frames are sent to the Base Station (sink).

*Cluster Set-up Phase***:** In set-up phase, the cluster heads are decided by sink using HSA 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 exposed in Figure 4.4. A threshold energy level is mean of energy intensity of all active sensors. Initially, the sink launches 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 in the sensor arrangement. Depending on the responded data from sensors, the sink utilizes HSA to elect CHs based on minimization of fitness function given by equation 4. Also, the sink allocates the associated sensors of every CH on the bases of minimum Euclidean distance. When CHs are elected and associate members of CH are assigned, the sink (BS) launches a small communication to notify sensor network about CH and associated members.

When a small communication is received from the Base Station, every CH generates the TDMA timetable by conveying period to its associated member sensors and notifies these sensors by this timetable. The TDMA timetable is utilized to stay away from intra-group crashes and decrease power expenditure among communications in the group and facilitates every associate of the transmitting apparatus shut down when it is not in utilization. Furthermore, to decrease inter-group intrusion each CH chooses a distinctive CDMA code and notifies all associated member sensors within the group to send their information using this scattering code.

The facts of the proposed SHSARP procedure and how HSA 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 setback and exactly articulated as a combination of two functions as described below

$$f1 = \max_{i \in (1,} k_{opt)} \left\{ \frac{\sum \forall n \in C_i \, d(n, CHi)}{|Cj|} \right\} \quad (2)$$

where k_{opt} symbolizes the CHs (leaders) count, C_i is the ith group renowned with group-head CH_i, and any member node, n, belong to the group C_i that convinces the shortest space between n and CH_i. This function represents the highest of the sum of the Euclidean distance of associated sensors to their cluster heads CH_i moreover $|Cj|$ is the count of sensors that belong to group C_i.

By reducing this function, it seems to reduce the intra-group average space between these member nodes and their individual CHs. 2nd function is given by

$$f2 = \sum_{i=1}^{k_{opt}} \left\{ \frac{\sum \forall n \in C_i \, E_n^{res}}{E_{CHi}^{res}} \right\} \quad (3)$$

It represents the addition of fraction of remaining power of all sensors in a group to the power intensity of head of that cluster.

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

$$\text{Fitness} = \alpha \text{ x } f1 + (1 - \alpha) \text{ x } f2 \quad (4)$$

By reducing the fitness function, it is projected that the group development and the CH election of WSN can be optimized for growing the competence of energy expenditure within the arrangement.

The constant α denotes the donation of $f1$ and $f2$ in the fitness function. To avoid the election of the sensors having small residual energy to be the CH, the CH sensors are elected from the group of applicants. Merely the sensors having energy intensity more than the mean power intensity of the entire sensors in the set-up can be the CH applicants.

*WSN Cluster Head Election Problem Mapping with HSA***:** Harmony Search algorithm is developed based on the characteristics of the flower pollination.

STEP 1: Initialize optimization problem and set parameters

To direct the CH selection, SHSARP utilizes inhabitants of solutions that progress toward optimizing the required fitness function i.e. to reduce the intra group spaces and optimize the energy expenditure in arrangement. For this purpose a fitness function is formed using eq. 4. Other parameters of the algorithm like Population Size, Maximum Iteration, *HMCR* and *PAR* is set.

STEP 2: Prepare Candidate Set

To stay away from the election of the sensors having small energy intensity to be CH, the CH sensors are elected from the group of applicants. 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 applicants.

STEP 3: Initialization Population

A population is generated having solutions equal to Population Size. Each resolution vector is represented as Identification of k_{opt} CHs randomly selected amongst group of candidates. And generated population is evaluated using fitness function represented by equation 4. 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 through improvisation operators to create an evolved population.

A new harmony is generated using the improvisation procedure with three rules as follows:

(i) Harmony memory considering rule: For this rule, if *rand( )<HMCR*, then any one pitch is played randomly from musician's memory, where *HMCR* is the harmony memory consideration rate, and *rand( )* is a random number generated within the range [0, 1].

(ii) Pitch adjustment rule: For this rule, if *rand( ) < PAR*, where *PAR* is a pitch adjustment rate, then decision variables

obtained from the first rule is improved by playing an adjacent pitch of one pitch in Musician's memory.
(iii) Random initialization rule: If *rand()* < *HMCR* is not satisfied, then totally random pitch is played within the feasible range.

STEP 5: Update Population
The recently produced solution vector is examined in terms of the fitness function assessment. If the fitness function cost 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 devised. The IDs in this solution represents the elected CHs.

Steady State Phase: Through the steady state phase, the sensors get up and begin sensing information/parameters to be sensed. After that every sensor transmits the sensed data to its CH as per the TDMA time table. The CH must remain its receiver apparatus on to obtain whole information from the sensors in the group. While whole information has been obtained, the CH sensor executes dispensation to bundle the data into a single packet. This single packet is transmitted to the sink. After a specified instance, which is resolute a priori, the arrangement once again goes back into the group setup stage and fresh leaders (CHs) are resolute by means of HSA by the sink for next round.

V. SIMULATON RESULTS

The performance of the HSA for CH selection is examined using MATLAB. The 100m×100m network area is considered and BS is positioned at center i.e. 50m×50m.Important parameter which considered during the simulation are describes in Table 1.The performance of the proposed protocol is evaluated in terms of networklifetime and energy dissipationof network against LEACH, SEP and HSARP algorithms.

TABLE I

SIMULATION PARAMETERS

Parameter	value
Total number of nodes	100
Probability for CH election	0.05
Initial energy	1J
Network Dimensions	100m×100m
Locality of Base station	(50,50)
Radio electronics energy ($\mathbf{E_{elec}}$)	50 nJ/bit
Energy for Data aggregation($\mathbf{E_{DA}}$)	5 nJ/bit
$\boldsymbol{\varepsilon_{fris\_amp}}$	100 pJ/bit/m2
$\boldsymbol{\varepsilon_{two\_ray\_amp}}$	0.0013pJ/bit/m4

Figures 3 and 4show the result of LEACH, HSARP and SHSARP in premise of number of alive nodes per round and remaining average energy of node for homogeneous setup. In SHSARP, the stability period is larger as correlated to LEACH and HSARP as first node demise after a substantiallyhigher number of rounds. The reason behind this is optimal selection of CH considers residual energy of node. The energy utilization is counterbalanced among sensor nodes. Theproposed algorithm is improved inas compared with above said protocols.

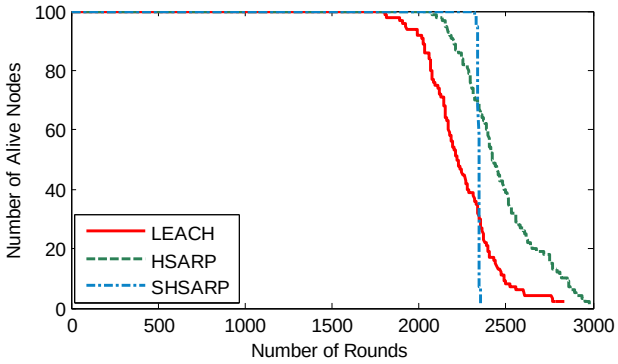

Fig. 3 Network lifetime comparison of LEACH, HSARP and SHSARP

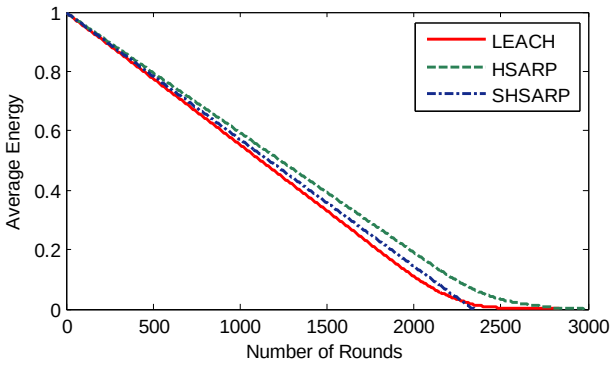

Fig. 4 Average energy remaining comparison of LEACH, HSARP and SHSARP

Similarly, figures 5 and 6show the result of SEP, HSARP and SHSARP in premise of number of alive nodes per round and remaining average energy of node for heterogeneous setup.SHSARP protocol is proposed for heterogeneous WSNs. Since nodes are heterogeneous in terms of energy, so the total energy of the network has been increased as compared to homogeneous network used in LEACH.

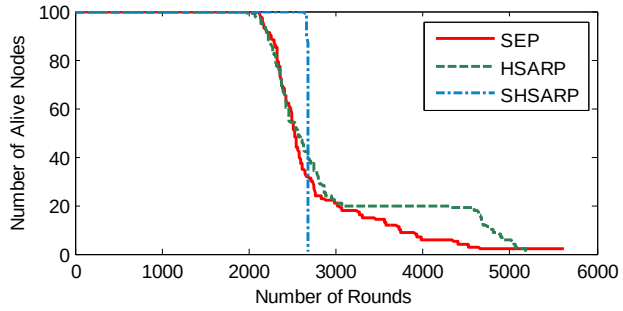

Fig. 5 Network Lifetime Comparison of SEP, HSARP and SHSARP for heterogeneous setup

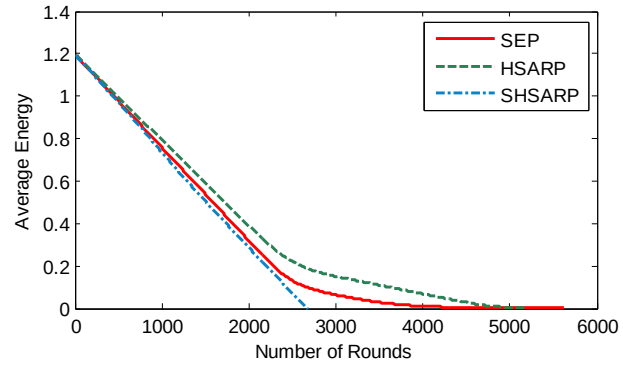

Fig. 6 Average energy remaining comparison of SEP, HSARP and SHSARP

TABLE 2

ANALYSIS OF NETWORK LIFETIME OF SIMULATED PROTOCOLS FOR HOMOGENEOUS SETUP

WSN Setup 1	LEACH	HSARP	SHSARP
First Node dead	1805	2072	2321
Half nodes alive	2215	2424	2342
All nodes dead	2838	2977	2354

TABLE 3

ANALYSIS OF NETWORK LIFETIME OF SIMULATED PROTOCOLS FOR HETEROGENEOUS SETUP

WSN Setup 2	SEP	HSARP	SHSARP
First Node dead	2117	1983	2647
Half nodes alive	2522	2555	2677
All nodes dead	5614	5178	2686

Table2, 3 and 4 demonstrates the round number of First Node Dead and Last Node Dead for both types of WSNs. The individual outcomes in these tables confirm that HSARP can expand the time until Last Node Dead more than SHSARP (in all run). On the other hand, the constant phase of SHSARP until First Node Dead is enlarged in comparison to that of HSARP by 10%–25%.

TABLE 4

ROUND COUNT OF FND, AND LND FOR WSN WITH 20% HETEROGENEITY

WSN Setup	**HSARP**		**SHSARP**	
	FND	**LND**	**FND**	**LND**
1	**2072**	**2977**	**2321**	**2354**
2	**1983**	**5178**	**2647**	**2686**

From these statistics it can be clarified that SHSARP algorithm outperforms the HSARP in terms of stability period.

VI. CONCLUSION AND FUTURE WORK

In WSNs, the extensive concerns in designing of routing protocols isextend the stability period, reduce the energy consumption and extend lifetime of system. In SHSARP, CH selection leans on the residual energy of node. In this way, utilization of energy reduces to some extent and stability period for FND increases. The simulation results indicate that SHSARP outperforms as compared to LEACH, SEP and HSARP in terms of stability period.

Future work comprises the exertion of sensor mobility into network.Further, multi-hop communication may be applied for data transmission between BS and CH.

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