Performance Evaluation of Energy Efficient Protocols in Wireless Sensor Networks

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Abstract—*Reducing the energy utilization is an important element in the Wireless Sensor network (WSN). Many protocols have been designed for improving energy efficiency of the network. Clustering protocols have been proved to be one of the energy-efficient protocols in WSN. One of the basic and most popular protocols designed using the clustering approach is the LEACH (Low-Energy Adaptive Clustering Hierarchy).However, LEACH undergoes an issue of bad distribution of cluster heads, which is overcome by implementing a technique of selecting smart cluster head in LEACH known as SCHS (Smart Cluster Head Selection).Also another clustering protocol HEED (Hybrid Energy Efficient Distributed) which follows the principle of LEACH is considered for the study purpose. In this paper, a thorough analysis of three clustering protocols was carried out by keeping the network parameters same so as to conclude which protocol amongst the three utilizes the minimum energy and prolongs the network lifetime.*

Keywords—LEACH, SCHS, HEED, energy efficiency.

I. INTRODUCTION

Wireless Sensor Network comprises of large number of sensors that are deployed in different areas where each node of that network senses the respective data and sends to base station directly or via intermediate nodes by means of wireless communication. The sensor nodes have small computational capabilities, very limited battery life, etc. The batteries that are mounted on the sensor cannot be recharged nor can they be replaced. These sensor nodes that are deployed can be deprived from the human accessibility since the sensor area could be more prone to natural calamities or the area may be hazardous to human life etc. Nodes that are deployed, continuously do the job of sensing the data and transmitting it to the destination. This activity drains the energy of the battery. More energy is consumed at the time of transmitting the data as compared to sensing of the data. Thus the communication distance should be as minimum as possible. The direct transmission protocol is the conventional scheme in which the nodes send the sensed data to the base station. As all the nodes travel a distance to the base station, probably the entire network will be energy depleted at once and the wireless sensor network will be no more in existence [1].However, to reduce the transmission distance, efficiently organizing nodes into clusters is useful and it also reduces the energy consumption. In the clustering approach, sensors nodes are virtually grouped which comprises of one cluster head node that aggregates the sensed data from the cluster members and forwards it to the base station. This will reduce the energy consumption of each node since the transmission distance known as intra-cluster communication distance is short. However to enhance the network lifetime proper cluster heads selections should be implemented so that minimum energy is consumed. One of the basic protocols that implemented clustering for enhancing energy efficiency in WSN is known as LEACH (*Low-Energy Adaptive Clustering Hierarchy)*.In LEACH, the cluster heads are not fixed but each node decides whether it can be cluster head for that particular round depending on probabilistic equation. However, probabilities that elect the cluster head contributes in bad distribution of cluster heads [3]. SCHS is implemented on basic LEACH to overcome this bad distribution. Also another protocol known as HEED that follows the principle of LEACH but selects the cluster head on basis of residual energy of each node is considered for performance evaluation.

II. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)

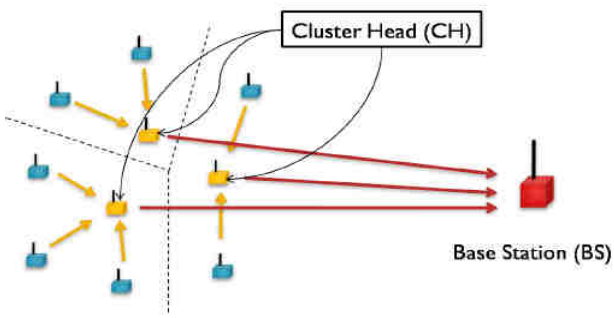

Fig.1:LEACH

LEACH is the first and basic hierarchical cluster-based routing protocol for wireless sensor network. In this protocol, the nodes play two distinct role as cluster head and cluster member as shown in Fig: 1.The cluster head is responsible for creating a TDMA (Time division multiple access) schedule and it sends aggregated data from nodes to the base station

(BS).The data is collected using CDMA (Code division multiple access).
This protocol is divided into rounds where each round consists of two phases;
Set-up Phase
(1) Advertisement Phase
(2) Cluster Set-up Phase
Steady Phase
(1) Schedule Creation
(2) Data Transmission

A. Set-Up Phase

In this phase, each node will decide independently, if it can become a cluster head or not depending upon the below equation as:

$$T(n) = \frac{p}{1 - p \times \left(r \times \mathrm{mod} \times \frac{1}{p} \right)} if n \in G$$

Where p is the number of clusters, r represents the round, T(n) is the threshold value (which is less than 1) and G denotes the set of nodes that have not become the cluster-head in the last 1/p rounds.

In the advertisement phase, the cluster heads inform their neighbors with an advertisement packet that they have become cluster heads. Cluster member nodes choose the advertisement packet with strongest received signal strength. In the next cluster setup phase, the member nodes inform the cluster head that they have become a member to that cluster with "join packet" containing their IDs using CSMA. After the cluster-setup phase, cluster head knows the number of cluster members and their respective IDs. Within the cluster, based on all messages received r, the cluster head creates a TDMA schedule, pick a CSMA code randomly, and broadcast the TDMA table to cluster members.

B. Set-Up Phase

While data transmission, nodes send their data during their allocated TDMA slot to the cluster head. This transmission here uses a minimum amount of energy (choice made on the received strength of the cluster head advertisement). The radio of each cluster member node is turned off until the node allocates the TDMA slot; this minimizes energy dissipation in these nodes. When all the data is received, the cluster head aggregate these data and send it to the base station.

III. SMART CLUSTER HEAD SELECTION (SCHS)

This is a scheme that can be implemented with any distributed clustering approach. In SCHS, the network area is divided into two parts: border area and inner area [5]. Only inner area nodes are eligible to become cluster head as shown in Fig: 2. this reduces the intra-cluster communication distance.

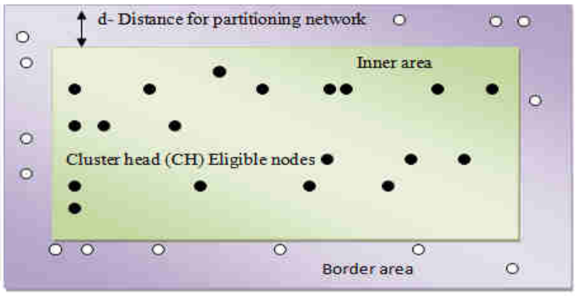

Fig.2: Division of Network Area

Division of area is an important issue for SCHS. Let d is the distance for partitioning of area that starts from boundary of the field up to the distance d is border area and the remaining inside area is inner area. The border area sensor nodes do not participate in cluster head selection. Only the inner area nodes participate in cluster head selection. As the cluster head is always selected from the inner area in our scheme, therefore the cluster head is always close to center of the cluster. When this scheme is implemented on LEACH protocol, the bad-distribution drawback shown in Fig 3, is automatically vanished which perhaps reduces the intra –cluster communication distance and improves the energy efficiency of the WSN.

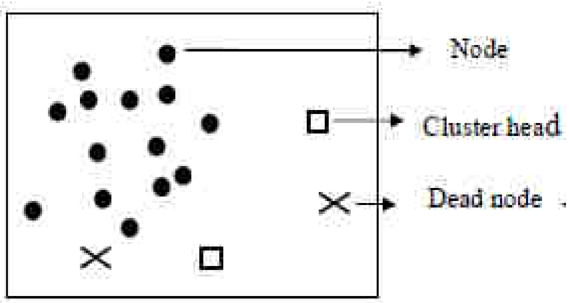

Fig.3:Possible bad-distribution of cluster head in LEACH

In the set-up phase, each node is checked whether it belongs to border area or it belongs to inner area. If a node belongs to the inner area, it will participate for cluster head role and if it belongs to border area then it will be a cluster member. Cluster heads announce their status message and wait for the response from other nodes. Cluster head makes the TDMA schedule for the cluster members. In the steady phase, the nodes wake up as the allotted time slot arrives and sends the data to cluster head. To conserve energy, nodes go back to sleep state and wait until the next wake up slot. Cluster head aggregates the data and forwards the data to base station. The steady phase is repeated till the round time is over. After completion of round time, set-up phase is executed again [5].

IV. HYBRID ENERGY EFFICIENT DISTRIBUTED (HEED)

This is a distributed clustering scheme in which cluster heads are selected timely according to node's residual energy and a secondary parameter is the intra-cluster communication cost. Cluster head is selected in HEED depending on the highest

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residual energy and minimum communication distance. The average minimum power required by M nodes within the cluster to reach cluster head is given by equation as:

$$AMP = \frac{\sum_{i=1}^{M} \min(pi)}{M}$$

Where min(*pi*) is the minimum power level required by a node and M is the number of nodes within the cluster. HEED undergoes three phases as [6].

A. Initialization Phase

In HEED clustering is triggered in every $T_{CP} + T_{NO}$ seconds to select new cluster heads where T_{CP} is time required to create a cluster and T_{NO} is the time interval between the end of a T_{CP} and start of a subsequent T_{CP}. In every round, before the start of execution each node sets its probability of becoming a cluster head which is given by

$$CHprob = Cprob * \frac{Eresidual}{E\max}$$

where *C*prob = Initial percentage of cluster heads among all *n* nodes, and *E*residual = Estimated current residual energy in the node, *E*max = Maximum energy.

B. Repetition Phase

In repetition phase, every sensor goes through several rounds until it finds the cluster head which will use the least transmission power. If it hears from no other cluster head, the sensor elects itself as a cluster head and sends an announcement message to its neighbors informing them about the change of status. Finally, each sensor doubles its own CHprob value and goes to the next round of this phase. It will stop executing this phase when its CHprob attains the value one.

C. Finalization Phase

At last, each sensor node makes a final decision on its status. A node can either elect to become a cluster head according to its CHprob or join a cluster according to cluster head messages within its cluster range. HEED has a processing time complexity of *O*(*n*) per node, where *n* is the number of nodes in the network. Also it has a message exchange complexity of *O*(1) per node, that is, *O*(*n*) in the network. The probability of becoming cluster head for two nodes within each other's cluster range is very less. HEED protocol, which terminates after a constant number of iterations.

V. ENERGY MODEL

Sensor nodes are deployed randomly in wireless sensor networks to monitor certain area and forward the sensed data to base station via cluster head. Most of the energy is dissipated while communicating within sensor nodes in network. Hence an Energy dissipation model is shown in fig:4.

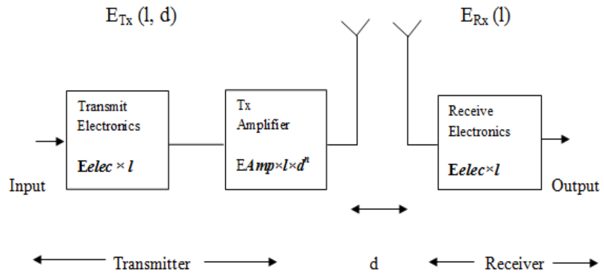

Fig.4: Radio energy dissipation model [5]

According to the energy model proposed in [7], energy is consumed while transmitting and receiving the sensed data. For sending m-bit of data over a distance d, the total energy consumed by the node in transmitting is given by

$$ETx(l,d) = \begin{cases} Eelec * l + Efs * l * d^2 & d \le do \\ Eelec * l + Emp * l * d^4 & d \ge do \end{cases}$$

While the energy expended on receiving the data is given by

$$ERx(l) = Eelec * l$$

Where do is the crossover distance which is given by,

$$do = sqrt\left(\frac{Efs}{Emp}\right)$$

VI. SIMULATION RESULTS

Performance of the three clustering algorithms with the help of simulations is presented in this section. This work uses MATLAB as the software simulation tool. All simulations are conducted considering a wireless sensor network with 50 nodes which are randomly distributed in a 50 × 50 field m^2 area. The base station is placed 75 m away from the sensing region. Simulation parameters are listed in Table 1.

Table.I: Simulation Parameters

Network area	$50*50m^2$
Number of nodes	50
Distance of base station	75 m
Number of clusters	5
Initial Energy	0.5J
Eelec	50nJ/bit
Efs	$10pJ/bit/m^2$
Eamp	$0.0013pJ/bit/m^4$

A) Simulation results for Node death rate is presented in Table II with respective graph

Table.II: Simulation results for Node Death Rate

Sr.No	Number of rounds	Number of alive nodes		
		LEACH	SCHS	HEED
1	0	50	50	50

2	100	50	50	50
3	200	50	50	50
4	400	50	46	50
5	600	50	37	50
6	800	21	38	53
7	1000	7	30	34
8	1200	7	23	20
9	1500	1	19	16
10	1800	0	9	15

Following graph is about the node death rate, where node death rate is defined as number of alive nodes at a time.

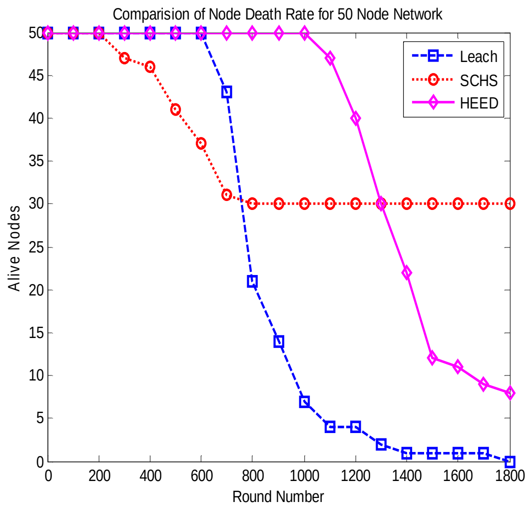

Fig.5: Comparison of Node death Rate of LEACH, SCHS and HEED

B) Similarly Table III gives the simulation result for energy consumption rate followed by its respective comparative graph. Energy consumption rate is defined as the energy consumed by the whole network against time.

Table.III: Simulation results for Energy Consumption Rate

Sr. No	Number of rounds	Energy Consumption in Joule		
		LEACH	SCHS	HEED
1	0	0.03	0	0.019
2	100	3.13	1.07	1.89
3	200	6.19	2.18	3.81
4	400	12.04	4.32	7.70
5	600	18.6	6.16	11.42
6	800	23.43	7.33	14.87
7	1000	24.76	8.34	16.94
8	1200	24.9	9.35	17.91
9	1500	25.06	11.37	18.50
10	1800	25.08	12.38	18.53

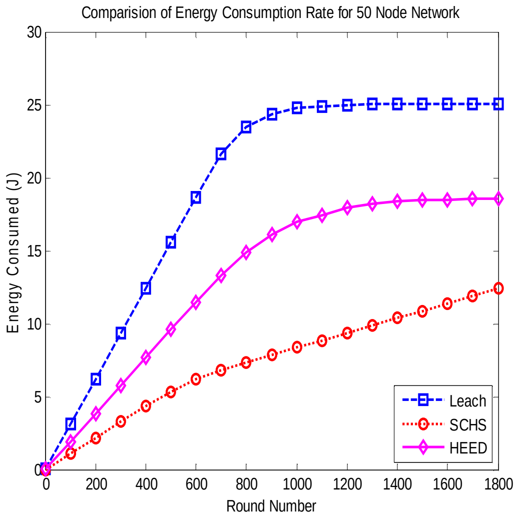

Fig.6: Comparison of energy consumption of LEACH, SCHS and HEED.

C) Table IV gives the simulation result for Network Lifetime rate followed by its respective comparative graph. Network Lifetime is the major element for energy efficient prtocols.

Table.IV: Simulation results for Network Lifetime

Sr.No	Rounds	50×50 M^2 with 50 nodes		
		LEACH	SCHS	HEED
1	1800	117.06	131.20	334.96

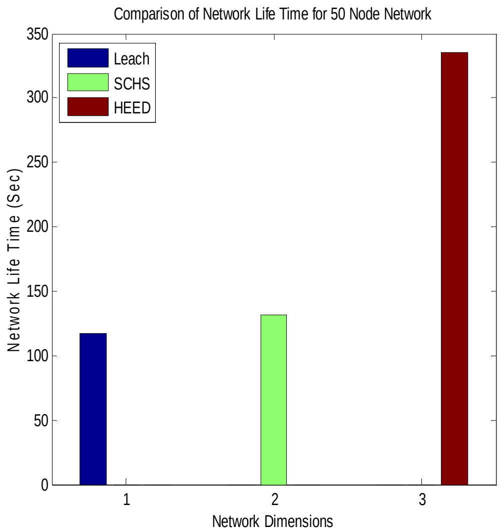

Fig.7:Comparison of Network Lifetime of LEACH, SCHS and HEED.

VII. CONCLUSION

In this we have eliminated major problem of previously proposed LEACH algorithm. Firstly, the issue of bad distribution of cluster heads is solved by portioning the area as border area and inner area. Thus cluster members communicate with the elected cluster head within the inner area and so energy required to communicate with the cluster heads is within tolerable limits. HEED is another clustering protocol that follows the principle of LEACH, in which communication overhead is very less. We could draw conclusion from the result that node death rate and energy consumption of HEED is much lower than SCHS and LEACH. Thus HEED will prolong the network lifetime as compared to SCHS and HEED.

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