An Efficient Approach to Select Cluster Head in Wireless Sensor Networks

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***Abstract*—Enhancing lifetime of sensor nodes should be considered as the key design objective in Wireless Sensor Networks (WSN). A sensor node can only be equipped with a limited energy supply and it loses its energy during data communication. In some application scenarios, replenishment of energy resources might be impossible since the sensor nodes are distributed in remote environment. Hence, the nodes lose their energy quickly and become dead. The frequent topology changes due to the die of sensors make the network quite unstable. A good cluster head selection protocol is, therefore, required to enhance system lifetime and data communication. This paper proposes a new methodology for cluster head selection based on sensor nodes' energy per unit cost. Experimental study shows that the proposed method, by adopting few selection criteria on choosing cluster head, increases the system lifetime and maximize data communication in comparison to existing dominant approaches.**

***Index Terms*—Cluster Head Selection, Enhancing Lifetime, Sensor Nodes, Energy Dissipation**

I. INTRODUCTION

As part of the continued advances in Micro-Electro-Mechanical Systems (MEMS), Wireless Sensor Networks (WSN) has and will play a vital role in our daily lives. WSNs have a wide area of use, from medical to military, and from home to industry [1]. WSNs consist of low-power multi-functioning sensor nodes, operating in an unattended environment, with limited computational and sensing capabilities. A sensor node is a node in a wireless sensor network that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network. The base stations are one or more distinguished components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end user [2]. Base Station is a central server by which users take information about environment. Cluster head maintain communication among sensors in a cluster and base station. Selecting cluster heads, before the routing takes place, is an important issue since location and energy level of cluster heads tends to make an effect on WSN. The basic objective of cluster head selection is to make the network useful and efficient [3]. Proper cluster head selection assures the proper clustering and proper clustering enables bandwidth reuses and increase system capacity by using the network topology among senders and receivers.

When studying the overall network design problem in WSN, there are many important aspects that need to be taken into consideration, such as the lifetime of node, smaller size of the sensor node, its hardware complexity and ultra-low energy consumption. Among them, enhancing lifetime should be considered as the key design objective, since a sensor node can only be equipped with a limited energy supply [4]. Sensors node last till their energy is fade away [5]. In some application scenarios, replenishment of energy resources might be impossible, and therefore sensor node lifetime shows a very strong dependency on battery lifetime [6]. The frequent topology changes due to the die of sensors make the network quite unstable. A good cluster head selection protocol is, therefore, required which is able to enhance the system lifetime and maximize data communication.

There are few existing protocols in WSNs in order to select cluster heads. A number of existing works select cluster heads randomly. As a result, same node can selected for current round, which was selected for previous round. The cluster may or may not be divided equally. There are some other works in the area of cluster head selection which fails to consider load balancing among cluster heads. Hence, it causes more loads for data recreation and processing for the cluster heads. For this unequal balancing, few heads die quickly for more energy consumption. The existing works, based on direct communication among the sensor nodes, need more energy to transmit data to base station and hence, the nodes die quickly. Hence, the research on efficient cluster head selection becomes necessary to enhance system life-time and maximize data communication in WSNs.

In this paper, Energy-Cost Ratio Based Cluster Head determining Protocol (ECRBCP) is proposed to select the cluster heads. Energy-Cost of networks is determined by the ratio of total amount of energy for all cluster heads to total network costs. For cluster head selection, nodes are chosen from the candidate nodes which have higher Energy-Cost ratio. Experimental analysis shows that

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ECRBCP outperform existing dominant approaches with respect to enhancing system lifetime and amount of data communication.

The remaining part of the journal paper is organized as follows: related work in Section II. In Section III, the network architecture and radio models are discussed. Section IV describes proposed methodology for determining cluster head. In Section V, experimental analysis of the proposed method is illustrated. Finally, Section VI concludes the paper.

II. Related Work

In Minimum-Transmission-Energy routing (MTE) [7], nodes route data destined ultimately for the base station through intermediate nodes. The intermediate nodes are chosen such that the transmit amplifier energy is minimized. Nodes adjust their transmit power to the minimum required level to reach their next-hop neighbor. This reduces interference with other transmissions and reduces the nodes energy dissipation. Communication with the next-hop neighbor occurs using a CSMA MAC protocol, and when collisions occur, the data are dropped. When a node receives data from one of its upstream neighbors, it forwards the data to its next-hop neighbor. This continues until the data reach the base station. Depending on the radio characteristics the total energy expended in the system might actually be greater using MTE routing than using direct communication protocol. In MTE routing, the nodes closest to the base station will be used to route a large number of data messages to the base station. Thus these nodes will die out quickly. In addition, since in the area nearer to the base station, nodes become dead, this area of the environment is no longer monitored. As a result, in these communications, there occurs more energy loss among router.

In static-clustering protocol [7], clusters are formed at first and remain unchanged for the entire system. The static clustering protocol is identical to LEACH [8] except the clusters are chosen a-priori and fixed. The clusters are formed using the simulated annealing algorithm as in LEACH-C [9]. Static clustering includes scheduled data communication from the cluster members to the cluster-head and data aggregation at the cluster-head. As the cluster head and the cluster remain same for each round, the selected static cluster head die quickly and thus the network lifetime cannot be maximized.

To meet the requirements of wireless micro-sensor network, LEACH, application-specific protocol architecture is developed. LEACH is a clustering-based protocol that includes the following properties: (a) randomized, adaptive, self-configuring cluster formation, (b) localized control for data transfers, (c) low-energy media access, and (d) data processing. In LEACH, the nodes organize themselves into local clusters, with one node acting as the cluster-head. All non-cluster-head nodes must transmit their data to the cluster-head, while the cluster-head node must receive data from all the cluster members, perform signal processing functions on the data (e.g., data aggregation), and transmit data to the remote base station. Therefore, cluster-head is more energy-intensive than other nodes. In the scenario, where all nodes are energy-limited, if the cluster-heads were chosen a priori and fixed throughout the system lifetime as in a static clustering algorithm, the cluster-head sensor nodes would quickly use their limited energy. Once the cluster-head runs out of energy, it is no longer operational. The LEACH incorporates randomized rotation of the high-energy cluster-head position such that it rotates among the sensors in order to avoid draining the battery of any one sensor in the network. In this way, the energy load associated with being a cluster-head is evenly distributed among the nodes. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized intervention. In LEACH, distributed cluster formation can be done without knowing the exact location of any of the nodes in the network and any sensor node can act as cluster head. So, proper cluster head selection is not possible over time.

In order to produce better clusters by dispersing the cluster head nodes throughout the network a central control algorithm called LEACH-C [10] is developed. Unlike the LEACH, LEACH-C utilizes the central base station for the formation of cluster heads. During set-up phase of LEACH-C, each node sends information about its current location and energy level to the Base Station (BS). In addition to determining good clusters, the BS needs to ensure that the energy load is evenly distributed among all the nodes. To do this, the BS computes the average node energy, and whichever nodes have energy below this average cannot be cluster-heads for the current round. In LEACH-C, the nodes transmit their data to the cluster head node during each frame of data transfer and the cluster head aggregates the data and sends the resultant data to the BS. When the cluster head node's energy is depleted, the nodes in the cluster lose communication ability with the BS and are essentially dead. Furthermore a number of sensor nodes to be needed for the network ranges from hundreds to hundred-thousands, this technique will not appropriate [11].

In LEACH-F [12], the clusters are fixed and only the cluster heads are rotated. Here, a node should have to use a large amount of power to communicate with its cluster head when another cluster's head is nearer. For initial cluster formation, the LEACH-F also uses the same annealing algorithm as in LEACH-C. LEACH-F is more energy efficient than LEACH-C. But the LEACH-F cannot be implemented in practical real time systems, because the interference of signals is more. LEACH-F does not allow new nodes to be added to the system, and does not adjust its behavior based on nodes dyeing. That's why lifetime enhancement is tough.

Hang Su and Xi Zhang [1] have extended the existing analytical model to derive the optimized parameter and show its correctness by simulations. The analyses by the authors reveal the insight that the original analytical model underestimates the optimal number of clusters and thus needs to be modified. This research discusses the protocols for scenarios limited to sensors having correlated data. Nonetheless there are applications of

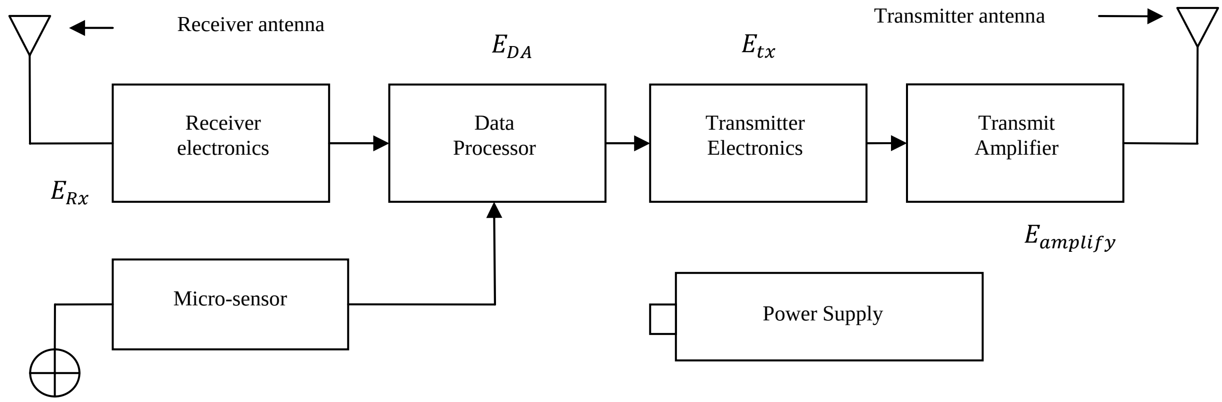

Figure 1: Radio energy dissipation model.

micro sensor networks devoid of the above limitation. For instance, sensor networks for medical monitoring applications may constitute dissimilar sensors located on and/or in the body which monitor vital signs. The prime focus of these networks is to maximizing quality of different parameters, which mainly forbids loss of information. In order to support the unique considerations of these networks, protocol architectures need to be developed.

III. Network Architecture And Radio Model

In ECRBCP, a sensor network model is considered with the following properties: (a) The base station is fixed and located far away from the sensor nodes, (b) Sensor nodes are energy constrained with uniform initial energy allocation, (c) Sensor nodes are equipped with power control capabilities to vary their communication power, (d) Each node in sensor network senses data and send to the local cluster heads to BS always, (e) Sensor nodes are immobile. As shown in the Figure 1**,** the sensor nodes are equipped with Transmitter antenna, Receiver antenna, Power Supply, Amplifier, Data Processor etc**.** Environmental information is sensed through micro-sensor, every kind of data operation is done through data processor and data communication through antenna [8]. The energy consumed throughout the entire sensor network can be described as the energy consumption for data communication to the cluster head that is energy communication factor $\boldsymbol{E_{tx}}$. Energy dissipation for data communication to the cluster head is

$$E_{tx} = E_{amplify} + E_{processing} \quad (1)$$

Where, $E_{processing}$ is the energy consumed for data processing and $E_{amplify}$ is the energy consumed for signal amplification. If communication distance between the communicating nodes is d, and two different channel models is used in this communication then free space model has power loss of d^2 .

IV. Proposed Methodology For Determining Cluster Head

In ECRBCP, the clusters are formed using the central control algorithm by dispersing the cluster head nodes throughout the network. The advantage of using the centralized clustering algorithm is that the BS forms the cluster which is the most energy intensive task, so that the energy dissipation of the sensor nodes decreases and network lifetime increases. Here all sensor nodes send their current location and energy level to the base station and the base station forms the clusters for the network by taking enhanced and effective processing of the current information of whole network. The operation of ECRBCP is divided into rounds. Each round begins with set-up phase when the clusters are formed, followed by a steady-state phase when the data are transferred from the nodes to the central base station through their respective cluster-heads. The selection of sensor nodes are done in round of few seconds and in each round five cluster heads are selected in case of not more than hundreds sensor nodes in the network.

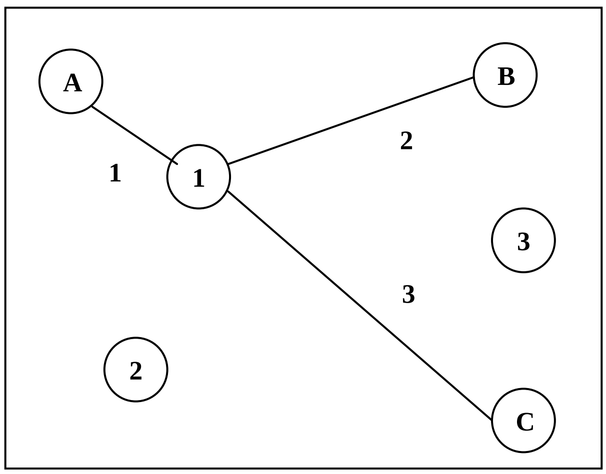

Figure 2: A sample Network Topology where circle denote node and edge denote distance in meter.

Energy-Cost of networks is determined by the ratio of total amount of energy for all cluster heads to total network costs. The cluster head candidates are selected from living nodes whose energy is higher than the average energy. For cluster head selection, nodes are chosen from the candidate nodes depending on higher Energy-Cost ratio. A network will have higher Energy-Cost ratio if the network reserve more power among cluster heads for reliable data transfer. For calculating a neighbor node for any living node X, it follows the following equation:

$$Neighbor\ (X) = \min\ (dist\ (1), dist\ (2), dist\ (3), \ldots \ldots.., dist\ (P)) \quad (2)$$

$$Here, 1, 2 \ldots P = Set\ of\ candidate\ nodes\ dist\ (i) = Absolute\_Distance\_Between(X, i)$$

Figure 2 is a sample topology where A, B, and C are candidates for cluster heads and 1, 2, 3 are non-cluster head nodes; distance between node 1 and A = 1m; distance between node 1 and B = 2m; and distance between node 1 and C = 3m. Then we have to determine that, under which cluster head, candidate node 1 will belong to. To determine the neighbor node for node A, B and C, the square distance is calculated between the candidate nodes and the non candidate nodes. If (x1, y1) be the coordinate of node 1 and (xa, ya) be the coordinate for node A, then the mathematical equation for distance calculation as

$$distance(A, 1) = (xa - x1)^2 + (ya - y1)^2 \quad (3)$$

In LEACH-C, to select the cluster head, Simulated Annealing algorithm [13] is used. The cost function *f(S)* in LEACH-C is defined as

$$f(S) = \sum_{i=1}^{N} \min\left(dist^2(i, s)\right) \text{ ,where } (s \in S) \quad (4)$$

Here, N is the number of sensor node and *dist (i, s)* is the distance between node *i* and node *s*. From last few equations, it can be derived that the Communication Cost (CC) is proportional to the Communication Distance (CD):

$$CC \propto CD \quad (5)$$

If the communication distance between cluster-head and the non cluster-head increases then the overall cost will increase and if the communication distance decreases then the overall cost will decrease. The energy consumed in data signal amplification can be expressed as

$$Energy\ Dissipation\ \propto CC \quad (6)$$

The communication cost is proportional to the energy dissipated. Hence, if the communication cost increases between the communicating nodes then more energy will be dissipated; and thus total energy consumption will also increase. Total Cost is determined by the summation of the minimum of the square distances between nearest neighbor among non cluster node and cluster head node. The relation of Energy-Cost and total cost can be shown as

$$Energy\text{-}Cost \propto \frac{1}{Total\ Cost} \quad (7)$$

Here, Energy-Cost and cost factor are related with vice-versa. So, as whole we can express energy-cost ratio and final expression of ECRBCP respectively

$$Energy\text{-}Cost \propto \frac{\sum \text{Energy of CLuster Head}}{Total\ Cost} \quad (8)$$

$$f(S) = \frac{\sum_{i=0}^{n-1} \text{Energy of CLuster Head}}{Total\ Cost} \quad (9)$$

Here, n=number of cluster head

Total cost for each candidate node all s in the set of candidate node S. In our analysis we found that, to minimize the communication cost those nodes are selected as cluster head that create a proper distribution of cluster heads in the network, that's why network coverage and load balancing is also addressed by this method. In ECRBCP the cluster head node's with higher sensor Energy-Cost ratio is more likely to become a set of cluster-head otherwise depends on probability as follows

$$P_d = \begin{cases} e^{-\frac{f(S)-f(S')}{\alpha_d}} & f(S') \le f(S) \\ 1 & f(S') > f(S) \end{cases} \quad (10)$$

Where, α_d= $1000e^{d/20}$ and P_d is compared with an arbitrary value in the range of 0 to 1 if it bigger than that arbitrary value, then nodes in S' is become set of new cluster heads. If P_d is smaller than the arbitrary value then a new S' is created until an optimum set of cluster heads is found.

This protocol requires that each node know its location in order to generate a topology map. Sensors send information about their current location to base station selects a optimum set of cluster head comparing a Energy-Cost function where the Energy-Cost for each set of cluster head is determined by the ratio of the sum of energy of cluster heads and minimum square distances of each cluster head with their member nodes. The total cluster formation process is divided into a number of parts. Such as Initial Candidate selection, energy calculation, distance calculation, Energy-Cost function determination and then finally cluster formation. The proposed cluster head selection methodology for ECRBCP is as follows:

INITIALIZATION

Let,
N →total number of alive nodes
P →number of Cluster Head per round = 5% of total alive nodes
C[] →Set of Cluster Head Candidate
E → The current energy of a particular node
distance[] →contains distance between nodes
CH[] → contains node selected as cluster head
currentE_[] → Contain Current energy of nodes

The following function named as FIND_MIN_DIST uses to determine network cost is calculated for ECRBCP:

```
FIND_MIN_DIST (
double * X1, double * Y1, int size1, double *
X2, double * Y2, int size2, int * ch_index, int * C)

1. int newIndex, double dsquare, double minDist
2. size1 ←N, size2 ← P
3.for i→0 to size1-1
   begin
      minDist = 1000000;
     for i→0 to size2-1
        begin
              if (C[k]) then
                  dsquare = (X2[i] − X1[i]) *
(X2[i] − X1[i]) + (Y2[i] − Y1[i]) * (Y2[i] − Y1[i]);
                      if (dsquare < min_dist) then
                            min_dist = dsquare;
                            new_index = j;
                      end if
              end if
```

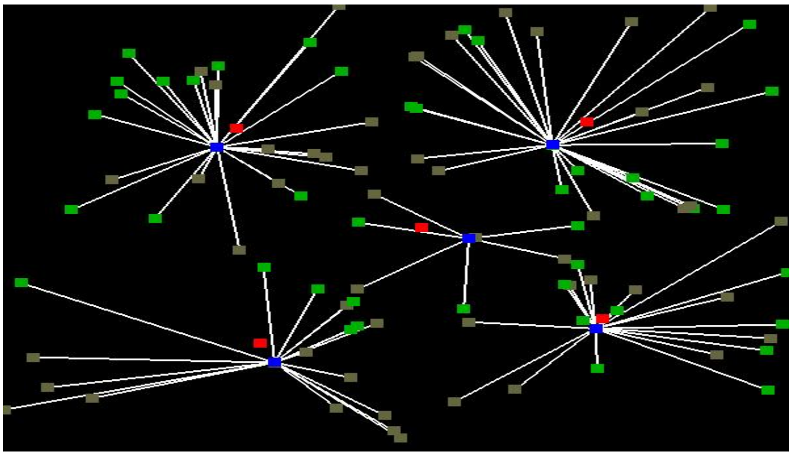

Figure 3: Clustering View of ECRBCP.

end
cost += min_dist;
ch_index[i] = new_index;
end
return cost;

The above function returns the cost of each set of cluster head, where the cost of each set of cluster head is defined by the sum of the minimum of the square distances of the cluster heads with its member nodes. This function also determines the neighbors of a cluster head. A node becomes a neighbor or member of a cluster head node only when it has the minimum cost with that cluster head node than others. Here X1, Y1 denotes the x and y coordinates respectively of any non cluster head or cluster node. And X2, Y2 denotes the x, y coordinate of cluster head nodes. By using following procedure cluster heads are selected:

1. Initialization
2. Calculate average energy of sensor nodes, $E_{ave} = \sum_{i=0}^{n-1} E_i$
3. Determine the nodes that are eligible for being Cluster Head
for I → 0to N-1
begin
allnodes[i]=true;
if($E_i < E_{avg}$*)*
C[i]=false;//not eligible for being cluster head
else
C[i]=true;//eligible for being cluster head
end if
end
4. Find initial set C of P nodes for the Simmulated Anneling(SA) algorithm from eligible nodes
5. Find the energy-cost ratio of the initial set, C of CH node
/*chIndex[i] denotes the ith cluster head node of a set and nodeUnder array contains the no of member under a single Cluster head node, cluster Index array contains the node number of Cluster head for each node.*/
for I → 0 to P
begin
Energy_Cos +=currentE_[chIndes[i]];
end
/*determine the sum of the minimum of the square distances for each set of cluster head.*/
minCost = FIND_MIN_DIST(XN, YN, N, XC, YC, P, clusterIndex, allnodes);
Energy_Cost /=minCost; // summation of cluster heads energy divided by communication cost
6. Determine Cluster_Head_Energy value by adding current energy of cluster head in set C
7. Total_Network_Cost is determined by the summation of the minimum of the square distances between nearest neighbor among non cluster node {N-C} and cluster head node in set C. //Here N set of all nodes
8. Determine Energy-Cost ratio by dividing Cluster_Head_Energy/ Total_Network_Cost
9. Find new set C' of CH nodes
10. Determine Cluster_Head_Energy value by adding current energy of cluster head in set C'
11. Total_Network_Cost is determined by the summation of the minimum of the square distances between nearest neighbor among non cluster node {N-C'} and cluster head node in set C'. //Here N set of all nodes
12. Determine Energy-Cost ratio by dividing Cluster_Head_Energy/ Total_Network_Cost
13. Compare the ratio of C with C'
14. If energy-cost ratio of (C') > energy-cost ratio of(C), C' becomes new optimum. Otherwise depends on probability
15. Repeat 9 to 14 for a predefined times of iteration
16. Finally form the cluster with the optimum set of cluster head

The above procedure uses nodes energy at current round of iteration then compare with average energy of network and select cluster head randomly. Then SA is applied to maximizing the value of energy-cost function to determining good cluster head for reliable data communication within each round.

In Figure 3, blue nodes are selected for cluster head for a particular round. Red nodes denote virtual co-ordinates. Green nodes denote those nodes which have more than

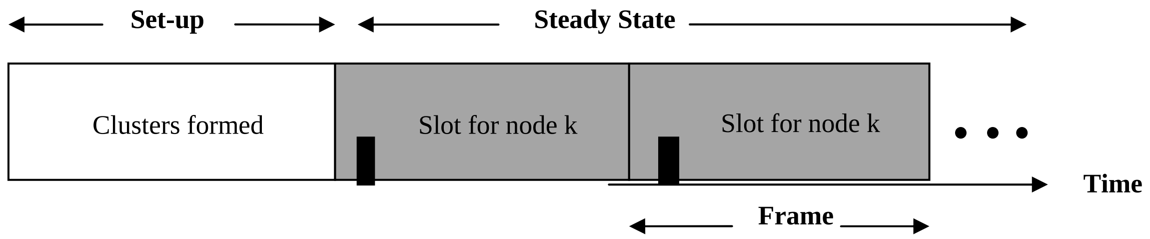

Figure 4: Time-line showing ECRBCP operation.

average energy and other nodes denote that they have not enough energy for cluster head. The steady-state operation is broken into frames where nodes send their data to the cluster-head (at most once per frame) during their allocated communication slot. Each slot in which a node transmits data is constant, so the time for a frame of data transfer depends on the number of nodes in the cluster.

In every time scheduling, above procedure are done in setup phase then steady-state begins. The steady-state operation is broken into frames where nodes send their data to the cluster-head at most once per frame during their allocated communication slot. Each slot in which a node transmits data is constant, so the time for a frame of data transfer depends on the number of nodes in the cluster. In addition, the set-up protocol does not guarantee that nodes are evenly distributed among the cluster-head nodes. Therefore the number of nodes per cluster is highly variable in ECRBCP and the amount of data each node can send to the cluster-head varies depending on the number of nodes in the cluster. To reduce energy dissipation, each non-cluster-head node uses power control to set the amount of communication power based on the received strength of the cluster-head advertisement. Furthermore, the radio of each non-cluster-head node is turned off until its allocated communication time. Since all the nodes have data to send to the cluster-head and the total bandwidth is fixed using a TDMA schedule is efficient use of bandwidth in addition to being energy efficient. The cluster-head must keep its receiver on to receive all the data from the nodes in the cluster. Once the cluster-head receives all the data, it can operate on the data (e.g., performing data aggregation) and then the resultant data are sent from the cluster-head to the base station. Since the base station may be far away and the data messages are large this is a high-energy communication. Figure 4 shows a flow graph of the steady-state operation. It also shows the time-line for a single round of ECRBCP, from the time clusters are formed during the set-up phase, through the steady-state operation when data are transferred from the nodes to the cluster-heads and forwarded to the base station. When a cluster-head has data to send, at the end of its frame it must sense the channel to see if anyone else is transmitting using the base station spreading code. If so, the cluster-head waits to transmit the data. Otherwise, the cluster-head sends the data using the base station spreading code.

Data aggregation is performed on all the unprocessed data at the base station or it can be performed locally at the cluster head. If the energy for communication is greater than the energy for computation, performing data aggregation locally at the cluster-head can reduce the overall system energy consumption, since much less data needs to be transmitted to the base station. The cluster-head must be awake to receive all the data from the nodes in the cluster. Once the cluster-head receives all the data, it performs data aggregation to enhance the common signal and reduce the uncorrelated noise among the signals. Assuming perfect correlation, all individual signals can be combined into a single representative signal. The resultant data are sent from the cluster-head to the base station. Otherwise, more energy could be required for data communication, since the base station may be far away from sensor nodes and communication messages are large.

This protocol is designed to enhance the system lifetime and data communication in WSN. In addition, ECRBCP is designed to enable maximum energy savings by enabling nodes to enter the sleep state where portions of the node are powered-down to save energy as often as possible.

V. EXPERIMENTAL ANALYSIS

In this section we mention the packages are required for simulation in order to compare with other existing dominant protocols and draw some outlines from the experiments.

NS-2 simulator [14] package (ns-allinone-2.27) is used with a MIT wireless sensor package [15] for the simulation of ECRBCP. We use hundred sensor nodes those are randomly located in the 100m × 100m to 1000m × 1000m network topology. The base station is located at (x=50, y=175). The number of cluster heads for each round is 5% of the total alive nodes as the optimal number of cluster heads for an energy efficient clustering mentioned in LEACH.

The performance of ECRBCP is evaluated in comparison to other existing dominant protocols such as LEACH-C, LEACH and Static Clustering in terms of system lifetime, energy-dissipation, and amount of data transfer. Throughout the simulation we measure the metrics: (a) Number of Alive node: Performance of a network depends on the lifetime of each node, if the lifetime of the nodes increase then the network performs well and sensors transmit more data to the base station. (b) Energy Dissipation: The lifetime of a node and the amount of data being transmitted by the nodes depend on communication cost among them. If the required energy to transmit data among nodes is reduced then energy dissipation will be reduced. (c) Data received: It is

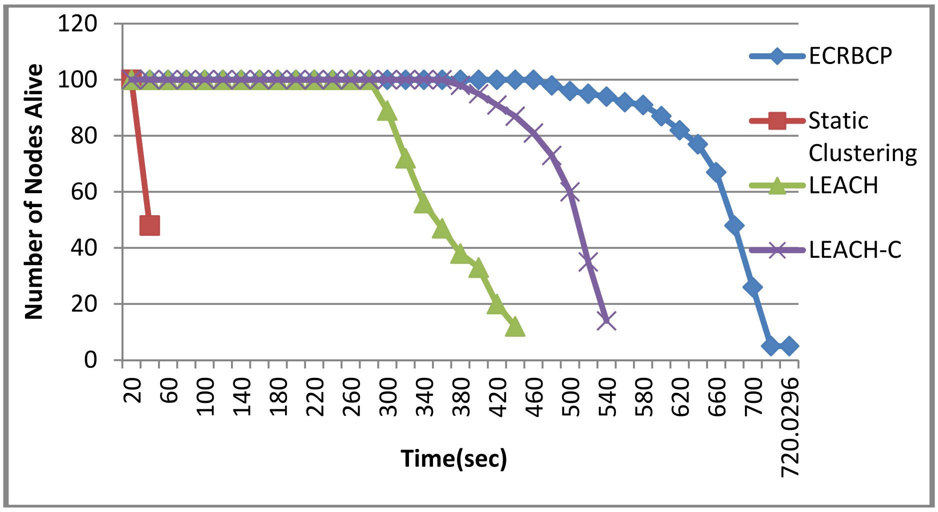

Figure 5: Number of Nodes Alive with respect to Network life time.

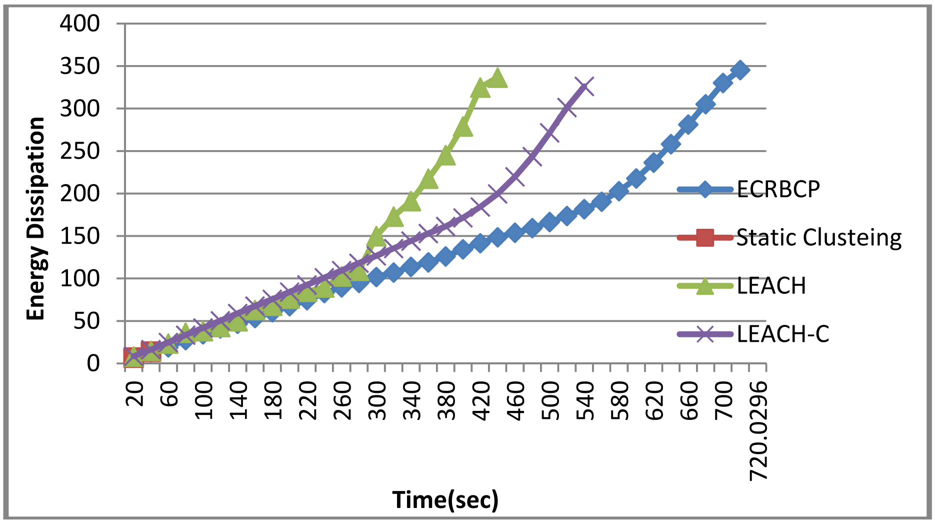

Figure 6: Amount of Energy Dissipation with respect to Time.

needed to know that how much data is received at the base station from the sensor networks. If the amount of data received is enough as it is expected then the network will perform well. (d) Initial energy: uniform energy supply is given among sensor nodes at the time of simulation start. (e) Network area: It denotes the area of the network as square meter. Few parameters such as cluster head, initial energy, network area, round time, location of base station were used in the simulation work. These parameters are listed in Table I.

Figure 5 shows the simulation curve of different protocol like ECRBCP, LEACH-C, LEACH and Static-Clustering. Where, x-axis denotes time and y-axis denotes number of node alive. This graph shows the number of nodes alive with respect to network life time in a 100*100 m^2 network area. The network lifetime depends on the time when the sensor nodes remain alive in a network. The simulation is started using 100 nodes. When the duration of nodes die is long, the network lifetime is also long. First node die is an important factor for evaluating overall network performance. First node alive time for ECRBCP is much better then LEACH-C and others. It also shows that the lifetime of the nodes of ECRBCP is longer than LEACH-C, LEACH, and also Static-clustering [3], [5], [7]. So the network lifetime of ECRBCP is longer than other protocols.

TABLE I.
SIMULATION PARAMETERS

Parameter	Value
Simulation Area(x, y)	100×100 to1000×1000m^2
Node's Initial Energy	2-5 joule
Simulation Time	3600 seconds
Base Station Location	(50,175)
Number of Nodes	100
Desired no. of Cluster	5
Round Time	20 seconds

Figure 6 shows the simulation curve of the amount of energy dissipation with respect to time in a 100*100 m^2network area. Here x-axis denotes time period and y-axis denotes energy dissipation of the network.

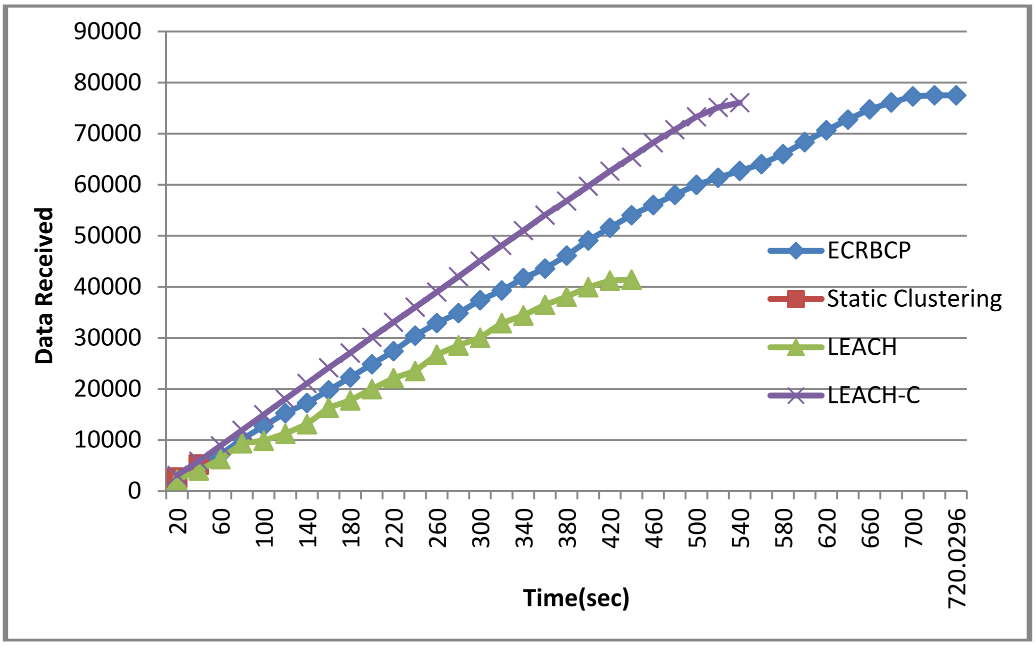

Figure 7: Amount of Data Received with respect to Network life time.

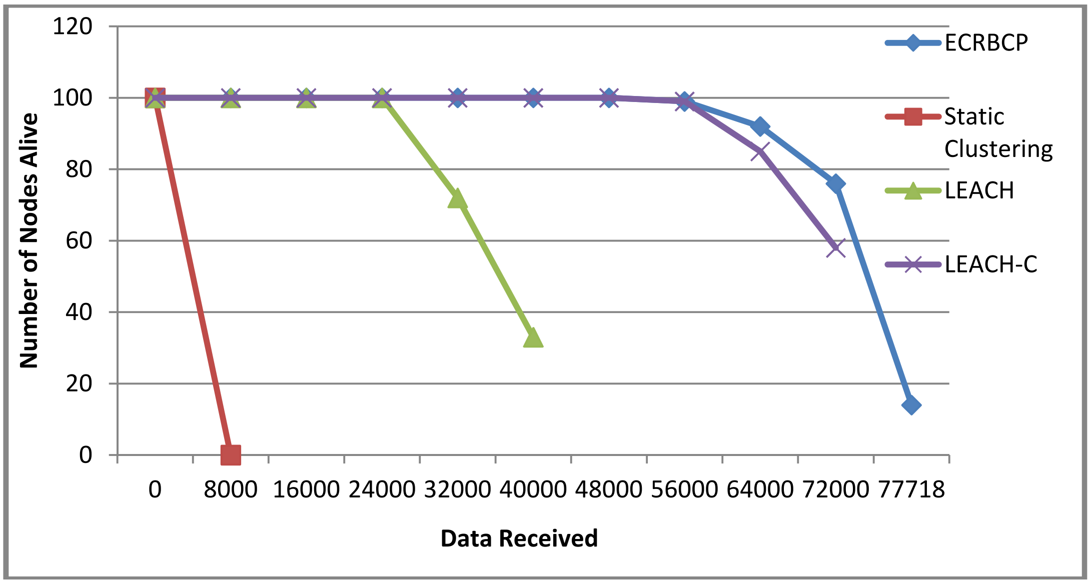

Figure 8: Number of Nodes Alive with respect to Amount of Data Received.

It can be observed that till 540 seconds, energy dissipation rate of ECRBCP is less than LEACH-C, LEACH, and Static-clustering, and that of LEACH-C is less than LEACH.

Figure 7 shows the simulation curve of the amount of data received with respect to network life time in a 100*100 m^2 network area. Where x-axis denotes time period and y-axis denotes data reception by the base station. The curve shows that till 540 seconds, the amount of data received by base station using ECRBCP is higher than LEACH but less than LEACH-C whereas LEACH-C is higher than LEACH and Static-Clustering. After 540 seconds, the amount of data received by base station using ECRBCP tends to increase than LEACH-C. Using simulation parameters as shown in Table I, 2% more data can be received using ECRBCP than LEACH-C and the difference will be more, if more initial energy for sensors is used.

Figure 8 shows the simulation curve of number of nodes alive with respect to amount of data message received in a 100*100 m^2 network area. Where x-axis denotes date reception and y-axis denotes number of node alive. After passing around 8000 unit of data to the base station, all the nodes of Static-Cluster are died and after passing around 40000 units of data packets to the base station, all the nodes of LEACH are died. But all nodes of both LEACH-C and ECRBCP are alive till around 60000 units of data packets are received by the base station. Then the die rate of nodes is increased for both of LEACH-C and ECRBCP. Using simulation parameters, it is showed that there is a proportional relationship among the parameter used for this figure. Though ECRBCP

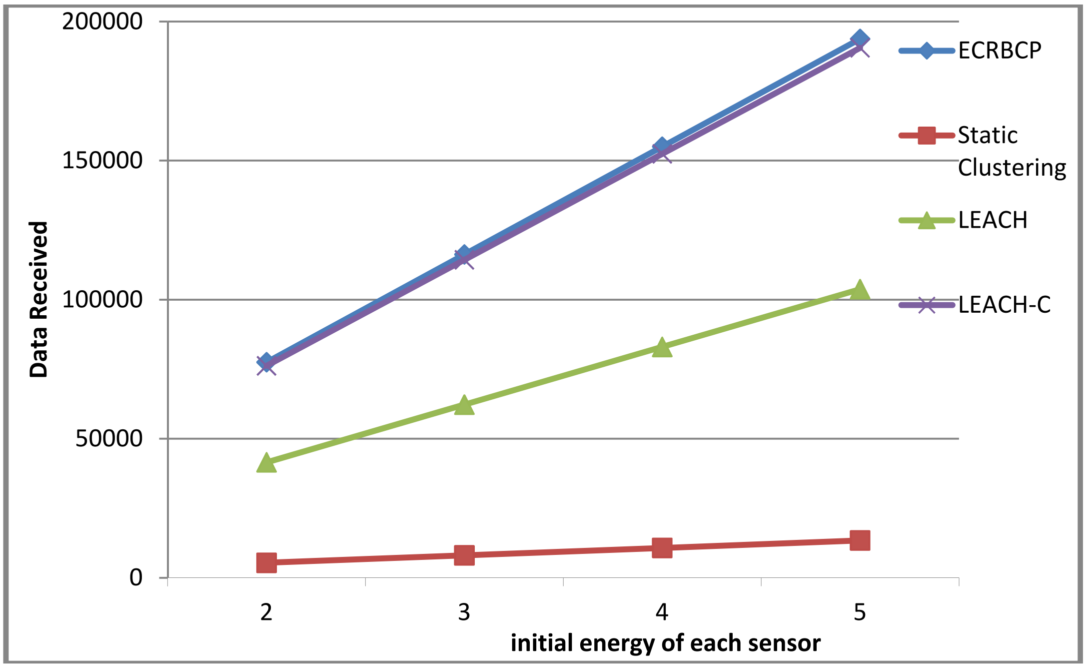

Figure 9: Data Received with respect to initial energy of each sensor.

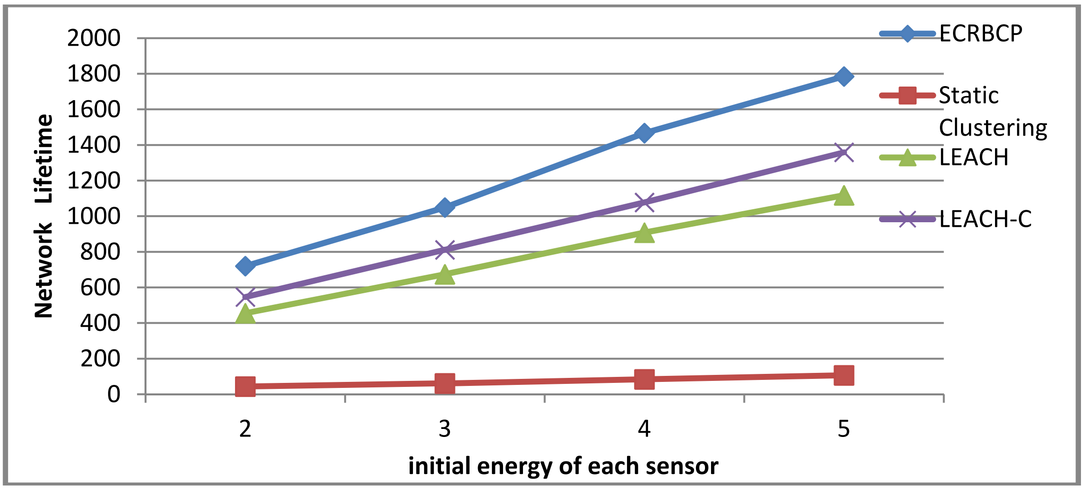

Figure 10: Initial energy of each sensor vs. Network Lifetime.

shows better result than other, some fluctuation can be occurred due to networks' undesired characteristics.

Figure 9 shows the simulation curve of total amount of data received by the base station with respect to uniform initial energy of each sensor. Where x-axis denotes initial energy of each sensor and y-axis denotes data received. Each curve denotes a method and in this graph each of the curve moves upward depending on the increase of initial energy of each sensor. Let a curve LEACH and see increase of one joule of uniform initial energy of each sensor of the network gives a large amount of total energy in the network for a simulation. As a result we get more amounts of data received by the base station. This graph denotes that there is a proportion relationship among uniform initial energy of each sensor nodes and total number of data received by the base station. If we use more initial energy for each sensor then get more data. And if we carefully observe that, 5 joule of initial energy of each sensor is used then we can make differentiation among the ending point of LEACH-C and ECRBCP. For large amount of initial energy of each sensor we must get better result for ECRBCP than LEACH-C.

Figure 10 shows the simulation curve of network lifetime with respect to initial energy of each sensor. Where x-axis denotes initial energy of each sensor and y-axis denotes network lifetime. An increase of one joule of initial energy of each sensor of the network gives a large amount total energy in the network for a simulation. As a result, lifetime for all method can be obtained. This graph denotes that there is a proportional relationship among initial energy of each sensor and network lifetime. It can be observed that, if 2 joule of initial energy of each sensor is used then clear differentiation among the network lifetime of each method can be drawn. So, for large amount of uniform initial energy of each sensor

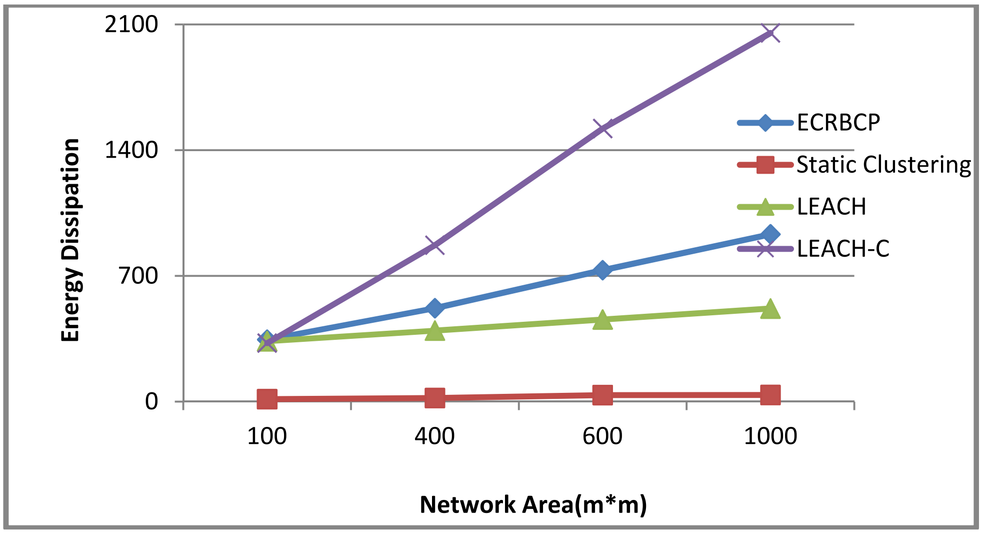

Figure 11: Amount of Energy Dissipation with respect to Network area.

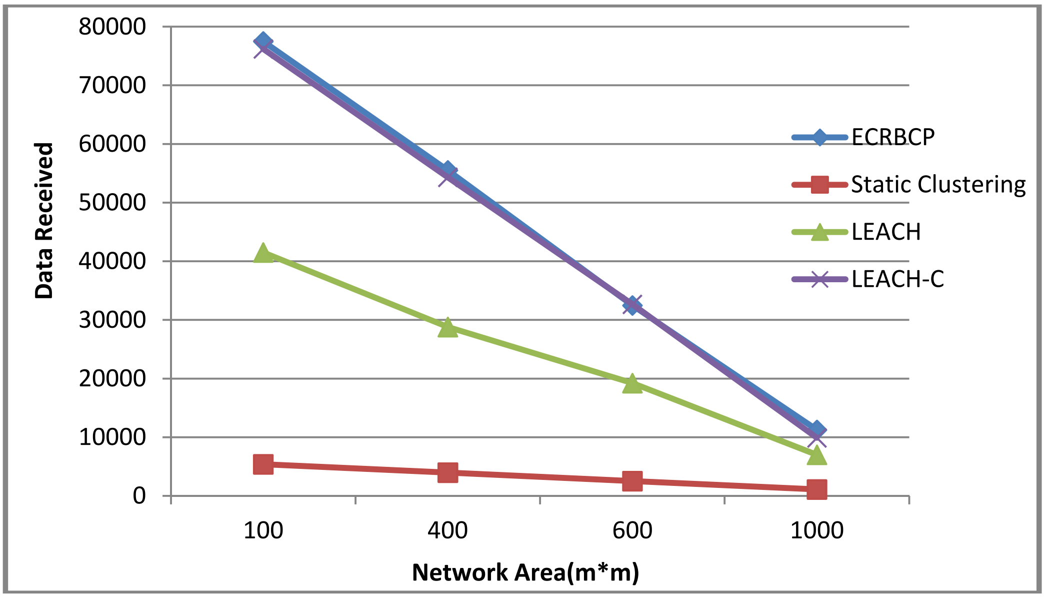

Figure 12: Amount of Data Received with respect to Network area.

make more percentage of differentiation between ECRBCP and other methods.

Figure 11 shows the simulation curve of energy dissipation with respect to network area. Where x-axis denotes network area and y-axis denotes energy dissipation. In this case, 2 joule is used as initial energy of each sensor node. When the network area increases then dissipation rate for each method is increased. In Static-Clustering and LEACH, energy dissipation are less than ECRBCP and LEACH-C. Since network lifetime of Static-Clustering and LEACH-C is too short. Among ECRBCP and LEACH-C, energy dissipation for ECRBCP is less than LEACH-C for any network area. This analysis is also a very important factor for large scale application of sensor networks.

Figure 12 shows the simulation curve of data received by base station with respect to network area. Where x-axis denotes network area and y-axis denotes data received by base station. We use 2 joule as initial energy of each sensor node. When the network area increases then dissipation rate for each methods is increased. So amount of data received by the base station decreases. In case of Static-Clustering and LEACH we got less data reception by the base station than ECRBCP and LEACH-C. Among ECRBCP and LEACH-C there are some fluctuation was occurred for lower initial energy of each sensor node. And we accomplished our goal to pick network scenario for long time as well as data for a large area of networks.

The comparisons show that ECRBCP has large advantages than other routing protocols. ECRBCP is effective because it increases the network lifetime, reduces the energy dissipation for data communication. One of the important factors for network lifetime increase is that the time required for first node die in simulation. Time taken for first node die of ECRBCP is better than other methods. As ECRBCP serve longer time than other methods, the network can serve for a long period, producing high-level information about an environment that is monitored by the sensor nodes.

VI. CONCLUSIONS

This paper proposes a new approach to select cluster head based on higher energy-cost ratio where energy-cost ratio is determined by the ratio of total amount of energy for all cluster heads and total network costs. ECRBCP contributes to the study of wireless sensor networks by addressing the problem of increasing system lifetime and maximizing data communication via proper cluster head selection. ECRBCP utilizes the high-energy base station to perform most energy related tasks. ECRBCP shows its better performance, in considering four simulated metrics: a) number of nodes alive, (b) energy dissipation, (c) data received, d) initial energy, and e) network area, than existing dominant approaches.

In this paper we found that, to minimize the communication cost among sensors to cluster heads to base station, those nodes are selected as cluster heads that creates a proper distribution of cluster heads among the network, that's why network coverage and load balancing issue are also addressed by this method.

In this paper few specified methodologies are shown to enhance system lifetime and maximize data communication in wireless sensor networks. There are few other open scopes, to extend this research. For the selection of cluster head, few issues should be dealt with, e.g., total amount of data in previous round of data communication, remaining energy for the current round, and distance between cluster head and each sensor node. Furthermore, a high performance approximation algorithm, instead of Simulated Annealing Algorithm, can be developed to get a better solution.

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