A Comprehensive Analysis of CBCDACP in Wireless Sensor Networks

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***Abstract-* As wireless sensor networks are equipped with sensor nodes which have a limited energy and sensing capabilities, a good routing protocol must be designed to make the network energy efficient. In [1] we proposed a centralized routing protocol called Central Base Station Controlled Density Aware Clustering Protocol (CBCDACP) where the base station centrally performs the cluster formation task. In CBCDACP, an optimum set of cluster heads is selected by using a new cluster head selection algorithm focusing on both the density of the sensor nodes and the minimum distances among the cluster head and its neighbor nodes. It calculates the optimum set of cluster head by first selecting the candidate node, then calculating the minimum distance and also calculates the density and finally executing the main BS setup algorithm. In this paper, a comprehensive analysis of CBCDACP algorithm is stated varying the simulation parameters to demonstrate the robustness of this algorithm and explaining the algorithm blocks of CBCDACP. The simulation performance of CBCDACP is then compared with some clustering-based schemes such as Static-Clustering, Low Energy Adaptive Clustering Hierarchy (LEACH), Centralized LEACH (LEACH-C). Simulation results show that CBCDACP can improve system life time and energy efficiency in terms of different simulation performance metrics over its comparatives**.

***Index Terms--*Wireless Sensor Networks, Energy efficiency, Setup phase, Density factor, Cost function, Steady-state phase.**

I. INTRODUCTION

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion pollutants at different locations. Wireless sensor networks consist of hundreds to thousands of low-power multi functioning sensor nodes, operating in an unattended environment with limited computational and sensing capabilities. In addition to one or more sensors, each node in a sensor network is typically equipped with a radio transceiver or other wireless communications device, a small microcontroller and an energy source, usually a battery. These inexpensive and power-efficient sensor nodes works together to form a network for monitoring the target region. Through the cooperation of sensor nodes, the WSNs collect and send various kinds of message about the monitored environment (e.g. temperature, humidity, etc.) to the sink node, which processes the information and reports it to the user. [2] The development of wireless sensor networks was originally motivated by military applications such as battlefield surveillance. Recent developments in this technology have made these sensor nodes available in a wide range of applications in military and national security, environmental monitoring, and many other fields.

As the vastly deployed remote sensor nodes sense data and then send to the far control center or the base station, so for the transmission of different amount of data the nodes lose a certain amount of energy. Because the two key resources**:** communication bandwidth and energy are more limited than in a tethered network environment, the design of Wireless Sensor Networks is an important challenge [3]. Energy efficiency is the main issue in the design of wireless sensor network for energy constrained sensor nodes.

In [1], we proposed CBCDACP where base station performs the most energy intensive task of cluster formation. The nodes having higher Density Factor (DF) are selected as cluster head so that the energy consumption is minimized as well as network lifetime is maximized. In this paper, we actually drove comprehensive simulations on CBCDACP to analysis it thoroughly and to represent its robustness as a cluster based algorithm for wireless sensor networks.

The remaining part of the paper is organized as follows: related work is briefly discussed in Section II. In Section III we discuss the network and radio models. Section IV describes CBCDACP routing protocol architecture in detail. In Section V, we simulate CBCDACP thoroughly by using NS-2 simulator and compare its performance with other prevalent routing protocols. Finally, we present our conclusion in Section VI.

II. RELATED WORK

In Flat networks all the nodes are same. Protocols in flat networks based on flooding and gossiping. Flooding means sending message Omni directionally to reach it destiny nodes. Since flooding, so it consumes huge energy and nodes drain energy rapidly. So this strategy is not too convenient in WSN. Gossip is based on the

Manuscript received January 31, 2010; revised April 18, 2010; accepted May 11, 2010.

doi:10.4304/jcm.5.8.627-636

strategy that messages are send not Omni directionally but to randomly subset of nodes. So energy consumption is less as it is not like flooding but there is no warranty that the message will arrive to the destined node. Others flat propose have been studied and detailed in [4] like SPIN [5], Directed Diffusion [6] and AIMRP [7].

In minimum-transmission-energy protocol (MTE), nodes route data destined ultimately for the base station through intermediate nodes. The intermediate nodes are chosen such that the transmission energy is minimized.

In Static-Clustering protocol first clusters are formed and remain unchanged for the entire system. The static clustering protocol is identical to LEACH except the clusters are chosen a-priori and fixed. The clusters are formed using the simulated annealing algorithm as in LEACH-C [8].

To meet the requirements of wireless sensor network LEACH (Low-Energy Adaptive Clustering Hierarchy), application-specific protocol architecture is developed [9]. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control. The advantages of this approach are that no long-distance communication with the base station is required and distributed cluster formation can be done without knowing the exact location of any of the nodes in the network. But here as the cluster heads are selected depending on a probability so that optimum set of cluster cannot be found.

In order to produce a better cluster by dispersing the cluster head nodes throughout the network a central control algorithm called LEACH-C is developed. Like LEACH, LEACH-C is divided into rounds and each round begins with a set-up phase followed by steady-state phase. During set-up phase of LEACH-C, each node sends information about its current location and energy level to the BS (base station). BS computes the average node energy, and whichever nodes have energy below this average cannot be cluster-head for the current round. Using the remaining nodes as possible cluster heads, the BS finds clusters using the simulated annealing algorithm [10] to solve the NP-hard problem of finding k optimal clusters.

Although LEACH-C is an attractive energy efficient scheme, it reveals several limitations. It adopts an approximation algorithm for the selection of optimum set of cluster, but it cannot guarantee that the obtained cluster heads are truly an optimum set because of the approximation characteristic [11].

III. NETWORK AND RADIO MODELS

A. The Network Model and Architecture

CBCDACP assumed that the central base station is a high energy node with a large amount of energy supply. So to do the most energy intensive task base station is utilized in this protocol. In CBCDACP a sensor network model is considered like in [3] with the following properties:

- The base-station is fixed and located far away from the sensor nodes.
- The sensor nodes are energy constrained with a uniform initial energy allocation.
- The nodes are equipped with power control capabilities to vary their transmitted power.
- Each node in sensor network senses the data at a fixed rate and always has data to send to the base station.
- All sensor nodes are immobile.

B. The Radio Model

A typical sensor node consists of four major components which are a data processor unit, a micro-sensor, a radio communication subsystem that consists of transmitter or receiver electronics, antennae and an amplifier and a power supply. Like in [3], we assumed the sensor nodes are equipped with the components shown in the figure 1.

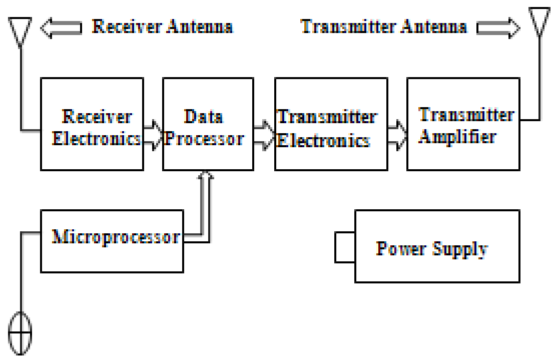

Figure 1. A typical sensor node with major components and associated cost parameters.

Although energy is dissipated in data processor unit, microsensor and radio communication subsystem but we only considered the energy dissipation in radio communication subsystem as the main objective of this paper is to maximize the network lifetime by developing an energy efficient network layer protocol.

TABLE I
ENEREGY CONSUMPTION FACTORS WITH EXPLANATION

E_{sense}	Energy dissipation for sensing data of a sensor node.
$E_{tx}(i)$	Energy dissipation for data transmission to the i^{th} sensor node. (Sum of $E_{processing}$ and $E_{amplify}$).
$E_{processing}$	Energy dissipation for data processing.
$E_{amplify}$	Energy dissipation for signal amplification.
$E_{chead(i)}$	Energy dissipation of the i^{th} cluster head for transmitting data to the base station. (E_{chead}=$E_{processing}$+$E_{amplify}$+$E_{agregation}$).
E_{total}	Total energy dissipation for the transmission of data from each sensor node to the base station.
N_{chead}	Number of cluster head at each round
N_{sense}	Number of sensor node that have the data to send.
N_{total}	Total number of sensor node in the sensor network.

In this radio model the energy consumed throughout the entire sensor network can be described as the energy consumption for data transmission E_{tx}, energy consumption for sensing data E_{sense}, and energy consumption for processing data $E_{processing}$. So energy dissipated for transmitting data to the cluster head,

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

Here $E_{amplify}$ is the energy consumed during data signal amplification. The major energy consumption factors in sensor networks are shown in a brief in Table I like [8]. Here we took in to consideration both the free-space model (d^2 power loss) and multi-path model (d^4 power loss). The free-space model is used for the communication between the cluster-head and the member nodes. The multipath model is used for the communication between the cluster head and base station.

According to the model the energy dissipation for transmitting *L*-bit message over a distance *D* is

$$E_{amplify}(L,D) = L\varepsilon_{fs}D^2 \quad : D < do \quad (2)$$

$$E_{amplify}(L, D) = L\varepsilon_{mp}D^4 \quad : D \geq do \quad (3)$$

Where, ϵ_{fs}=*10pJ/bit/*m^2 and ϵ_{mp}=*0.0013pJ/bit/*m^4 and $d_0 (= 86.2\ m)$ is the threshold distance.

In free space model, the transmission energy consumed is proportional to the square of the communication distance between the two communicating nodes as in (2) and for the communication between the cluster head and the base station multipath fading model as in (3) is used [8].

So the total energy consumed in every round in the entire sensor network can be expressed by the following equation:

$$E_{total} = \sum_{i=1}^{N} E_{chead}(i) + \sum_{i=1}^{N_{total}-N_{chead}} E_{tx}(i) + N_{total}*E_{sense} \quad (4)$$

IV. CBCDACP Protocol Architecture

In CBCDACP, 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 CBCDACP 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. In CBCDACP the BS ensures that the energy load is evenly distributed among all the nodes by determining good cluster. It also minimizes the amount of energy for the non-cluster head nodes to transmit their data to the cluster-head by minimizing the total sum of squared distances between the non-cluster head nodes and the cluster-head nodes and also considering the density factor of each cluster head.

A. The Setup Phase

1. Cluster Head Selection

In CBCDACP, an optimum set of cluster heads is selected by the centralized clustering algorithm. In our proposed system, nodes having higher sensor density are selected as cluster heads and thus incur minimum cost.

2. Sensor Density and Neighbor Determination

The cluster head candidates are selected from the set of alive nodes whose energy is higher than the average energy in the current round. For cluster head selection, nodes are chosen from the candidate nodes depending on which have higher sensor density. A node will have higher density if it has more neighbor nodes at closest distance than others. For calculating a neighbor node for any alive node X, CBCDACP follows the following equation:

$$\text{Neighbor}(X) = \min(\text{dist}(1) + \text{dist}(2) + \text{dist}(3) + \cdots \ldots\ldots + \text{dist}(P)) \quad (5)$$

Where,
1, 2… P = Set of candidate nodes
dist (i) = Absolute_Distance_Between (X, i)

If *Neighbor(X) = dist (i)* So node X will be the neighbor of candidate node i. *No_of_Neighbor (i)* variable for candidate node i will increase one. So the density of candidate node i will be the value of *No_of_Neighbor (i)*.

In a summary, in CBCDACP the nodes which have energy above the average energy will be the cluster head if they have more neighbor nodes (sensor density) in their minimum distance than the others. So that the communication distance between the neighboring nodes and the cluster head nodes will be minimized i.e. the energy dissipation (E_{tx}) will be minimized according to equation (2). So according to (4), consequently the total energy (E_{total}) consumed in a round will be decreased. So in compendium, it will increase the life time of the sensor network.

Let us consider a scenario in Figure 2 which shows a sample topology of the sensor network. A, B and C are three candidate nodes for cluster head selection. In LEACH-C cluster head is selected randomly, so it may be A or B or C. So the neighbor nodes for cluster formation may be or may not be in the minimum distance of the selected cluster head. But CBCDAP selects cluster heads depending upon the higher sensor density among the candidate nodes that neighbor nodes dissipates less energy to transmit data to their local cluster head.

Let, Distance between node 1 and A is 1unit, Distance between node 1 and B is 2unit, Distance between node 1 and C is 3unit.

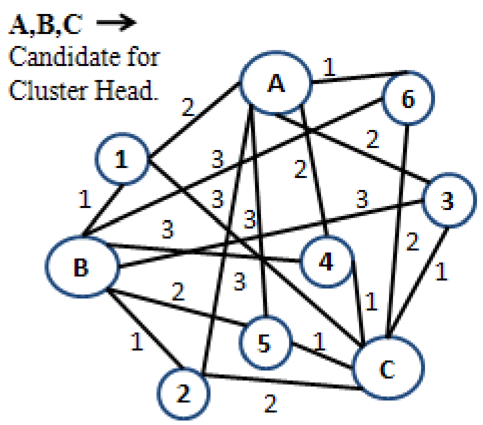

Figure 2. A sample Network Topology. The weight of every edge denotes the distance between the connecting nodes.

If (x_1, y_1) be the coordinate of node 1and (x_a ,y_a) for node A then the equation for distance calculation between node 1 and A is,

$$distance(A,1)= (x_a-x_1)^2+(y_a-y_1)^2 \quad (6)$$

The same equation can be used to find out the distance between node 1 and rest of the candidate nodes (B, C, and D). So the distance of node 1 from node A is 1, distance of node B is 2 and for node C it is 3.

Then using equation (5), we can determine node 1 is the neighbor of which candidate node. So node 1 is the neighbor of candidate node A.

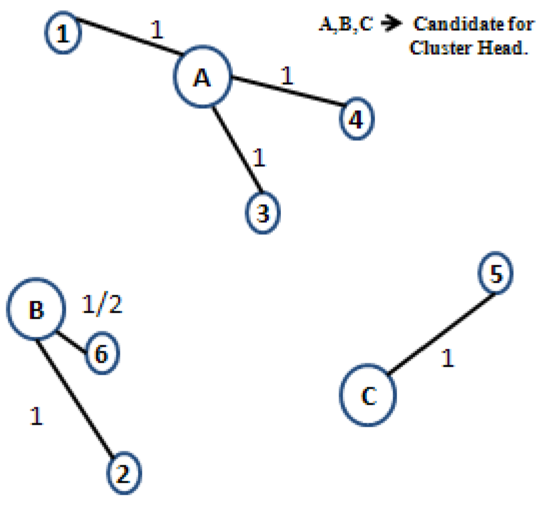

Figure 3. The nodes having smallest distance with a particular candidate node.

The neighbor node set for
Candidate node A= {1, 3, 4}
Candidate node B= {2, 6}
Candidate node C= {5}

So the sensor density of node A is 3, node B is 2 and node C is 1. So for this sample sensor network topology, candidate node A is selected as the cluster head for this current round.

3. *Cost Function Calculation*

In LEACH-C, Simulated Annealing algorithm [10] is used to select the cluster heads. Here the group of cluster-heads for the last state is defined by *S* and the group of cluster heads for the current state is defined by *S'*. The cost function of the set *S* is defined as *f(S)* and the cost function of *S'* is defined as *f(S')*. If the value of *f(S)* is smaller than *f(S')* then the probability for a node with smaller cost *f(S)* to become a cluster head gets bigger. The cost function *f(S)* in LEACH-C is defined by the equation (7).

$$f(s)=\sum_{i=1}^{N} \min\left(dist^2(i,s)\right) \text{ where } s \in S \quad (7)$$

Here N is the number of sensor node and *dist (i,s)* is the distance between node *i* and node *s*. So here the relation between the cost function and the communication distance is given as:

$$\text{Cost function} \propto \text{Communication Distance (CD)} \quad (8)$$

So if the communication distance between cluster-head and the non cluster-head increases then the overall cost will increase and vice versa.

On the other hand, according to equation (2) if the communication distance (D^2) is minimized then the energy consumed for signal amplification ($E_{amplify}$) will be minimized and thus the transmission energy (E_{tx}) will be minimized and so that the total energy consumed (E_{total}) in each round in the entire sensor network will be minimized according to equation (4). In equation (4) all terms except the E_{tx} are constant. E_{tx} is the sum of $E_{amplify}$ and $E_{processing}$. $E_{amplify}$ varies depending upon the communication distance between the cluster head and the member of the cluster. $E_{processing}$ is a nearly constant value depending on the processing byte length. So,

$$\text{Total energy dissipation} \propto Communication\ Distance\ (CD) \quad (9)$$

As the communication distance is proportional to the energy dissipation, if the communication distance increases between the communicating nodes more energy will be dissipated and thus total energy consumption will also increase. So in consequently, the system life time will be decreased which affect the whole network. The average distance between a cluster head and the cluster member nodes is expected to be reduced.

CBCDACP improves the equation of cost function by introducing another factor that is the density factor (DF). In cluster head selection process, it is considered that a candidate node which has more neighbors compared to the other candidate nodes has more probability to become a cluster head. As those nodes which has higher sensor density (density factor) are selected as the cluster head so that less transmission energy is dissipated for data transmission for the neighbor nodes to their corresponding cluster heads. As energy dissipation is minimized, the network lifetime will be maximized. For each candidate node, nodes are selected as neighbor nodes which remain in their minimum square distance. So as the distance between candidate node and neighbor nodes is minimized and thus the overall transmission energy will minimize. The relation between cost function and the density factor can be written as:

$$\text{Cost function} \propto \frac{1}{\text{Density Factor(DF)}} \quad (10)$$

So if the DF of a candidate node increases, the cost function will decrease and vice versa. So that by using equation (8) and equation (10) the relation of cost function can be shown as:

$$\text{Cost function} \propto \frac{\text{CD}}{\text{DF}} \quad (11)$$

Where CD is the communication distance between candidate node and non candidate node, DF is the density factor of each candidate node.

In CBCDACP, the cost function of equation (7) is modified and formed as following equation:

$$f(S)= \frac{\sum_{i=1}^{N} \min\left(\text{dist}^2(i,s)\right)}{\sum_s \text{DF}}, \text{ Where } s \in S \quad (12)$$

Here DF defines the density factor for each candidate node *s* in the set of candidate node *S*. In CBCDACP, it is possible to get more optimum set of cluster heads than other prevalent protocols, because here we considered both the density of each candidate node and the distance among non candidate nodes and candidate nodes for cost function calculation. So according to equation (12), cost function is the tradeoff between DF and CD.

Then the determined cost function for each node is used for calculating the probability P_d for cluster head selection which can be shown as

$$P_d=\begin{cases} e^{-(f(S')-f(S))/\alpha_d} & f(S')\geq f(S) \\ 1 & f(S')<f(S) \end{cases} \quad (13)$$

Where α_d = 1000 $e^{d/20}$

P_d is compared with an arbitrary value in the range of 0 to 1. If it is bigger than that arbitrary value, then nodes in S' are become the new cluster heads. If not then a new S' is created again and d is incremented and this procedure continues to select the new set of cluster head until an optimum set of cluster-head is found.

4. *Cluster Head Selection Algorithm*

INITIALIZATION

N → Total no of alive nodes
P → No of Cluster heads per round
C[] → Set of Cluster head Candidate (Whose current energy is above the average energy)
E → The current energy of a particular node
Distance[] → This array contains the distance value between two nodes.
NeighborOf[] → Contains the no of neighbours of a candidate node
CH[] → Contains the nodes selected as cluster heads

Algorithm 1: Cluster head candidate selection algorithm.

(This algorithm separates the set of candidate nodes (C). The nodes whose current energy is greater than the average energy are selected as candidate nodes.)

1.Calculate average energy, $E_{ave} = \frac{1}{N}\sum_{i=0}^{N-1} E_i$

2. Repeat for total number of alive nodes
   If nodes current energy is above the average energy
      then it will become candidate for cluster head
   else
      become not eligible for cluster head for the current round

Algorithm 2: Distance calculation algorithm

(This function returns the square distances between two nodes)

MAXDISTANCE ($X1, Y1, X2, Y2$)

1. Calculate distance between two nodes
   1.1. d=(X2-X1)*(X2-X1)+ (Y2-Y1)(Y2-Y1); ;
   1.2. **return** d;

Algorithm 3: Density calculation algorithm

(This algorithm calculates the no. of neighbor nodes under a candidate node, where the neighbors are calculated depending on the minimum distance among the candidate node and the member nodes)

1. Let, XN_i , YN_i Denotes the X, Y-coordinate respectively of i^{th} node. And XC_j ,YC_j denotes the X, Y-coordinate respectively of j^{th} candidate node.
2. Initially min=1000000.0
3. Repeat steps 4 to 9 for each alive node, N_i
4. Repeat steps 5 to 9 for each candidate node, C_j
5. Call MAXDISTANCE(XN_i, YN_i, XC_j, YC_j)
6. If node N_i is at closest distance with candidate node C_j then N_i will become the neighbor of C_j
7. Update NeighborOf[C_j]= NeighborOf[C_j]+ 1, for candidate node C_j
8. Repeat step 9 for each candidate node, C_j
9. Update min= 1000000.0;

Algorithm 4: Minimum Distance calculation algorithm

(This 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.)

1. Initialize *size1* to *N* and *size2* to *P*
2. Repeat steps 3 to 7 for each alive node, $\boldsymbol{N_i}$
3. Initially *minDist* = 1000000.0
4. Repeat steps 5 to 7 for each cluster head node, $\boldsymbol{C_i}$
5. Find the square distances of each node with each candidate node
6. If the distance is less than *minDist* then update *minDist* by the value calculated at step 5.
7. Calculate the Sum of the square distances for each candidate node of a set.
8. Return the Sum of the square distances as cost for each set.

Algorithm 5: Cost Function calculation algorithm

(This algorithm performs the task of Cost Function calculation. Cost Function, f(S)= $\frac{\sum_{i=1}^{N} \min(\text{dist}^2(i,s))}{\sum_s \text{DF}}$, where $s \epsilon S$. Here *DF* defines the density factor for each node *s* in the set of candidate node *S*)
1. Let *nodeNum* contains the value of the total number of member nodes of a set of cluster head.
2. Calculate *nodeNum* for each set of cluster head.
3. Determine the cost for each set of cluster head from algorithm 4.
4. Finally calculate the Cost Function, *f(S)* for each set of cluster head as following:
cost function =
cost (found at step 4)/nodeNum (found at step 2)

Algorithm 6: BS setup algorithm

(This algorithm performs the task of total cluster formation)

1. Calculate the cluster head candidates from algorithm 1
2. Find initial set *C* of *P* nodes for the Simulated Annealing algorithm.
3. Calculate Density for each candidate node from algorithm 3.
4. Find the cost of the initial set, *C* of cluster head nodes from algorithm 5.
5. Form the initial cluster.
6. Iterate the following steps for *Iters* no of times to find the optimum set of cluster head.
6.1 Call *Simmulated Annealing*
6.2 Calculate density for each cluster head of the new set from algorithm 3.
6.3 Calculate cost function for each set of cluster head of the new set from algorithm 5.
6.4 Compare the cost of the previous set, C with the cost of the current set, C'.
6.5 If cost of C' is less than the cost of C, then C' become the new optimum. Otherwise C may still become the new optimum.
7. Finally form the cluster with the optimum set of cluster head.

After the cluster heads and their associated clusters are found the base station broadcast a message that contains the cluster head ID. If a node's cluster head ID matches its own ID, the node is a cluster head otherwise, the node determines its TDMA slot for data transmission and goes to sleep until it is time to transmit data. After the TDMA schedule is known by all nodes in the cluster, the set-up phase is complete and the steady-state operation (data transmission) can begin.

B. The Steady State Phase

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 transmission 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 CBCDACP 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 transmission 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 transmission 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.

To remove the radio interference caused by neighboring clusters CBCDACP uses code-division multiple access (CDMA) codes. Here each cluster is assigned is a unique spreading code so that the nodes in the cluster use to distinguish their data transmission from those of nodes in neighboring clusters. When the data gathering process is completed the cluster head uses the same spreading code assigned to the cluster to transmit the data back to the base station.

V. PERFORMANCE SIMULATION

A. Simulation Framework

1. *Simulation Environment:* In order to analyze the performance of the CBCDACP protocol, we used NS-2 simulator [12] [13] because it is simple and powerful. We used the network simulator package

ns-allinone-2.27 with a mit wireless sensor package [14]. One hundred sensor nodes are randomly deployed in a vast range of network topology ranging from 100m × 100m to 1000m × 1000m. The base station is located at (x=50, y=175). We used the same energy model and transmission power control as used in LEACH-C. The simulation parameters are shown briefly in Table II. 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 [9].

Table II
Simulation Parameters

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

2. *Performance Metrics:* To compare the performance of the proposed protocol with the prevalent ones we consider the following metrics:

a) *Number of nodes alive:* It is an important metric in the simulation of a sensor network. The performance of a network depends on the lifetime of its nodes. If the lifetime of the nodes is higher, the network performs well and also transmits more data to the base station.

b) *Amount of energy dissipation:* The lifetime of a node and the amount of data being transmitted by the node depend on the energy level of the node. If the required energy to transmit data to the base station is very low for a node then lifetime of a node automatically increases and also the performance of the network.

c) *Amount of data received:* This metric determines how many data messages are received at the base station from the network. If the amount of data received is enough as we expect then we can assume that the performance of the network is well.

d) *Network lifetime:* This determines how long the network will send data to the base station. So higher network lifetime will incur great network performance.

B. Simulation Results and Analysis:

In simulation process we ran our simulation for 100×100 network area to 1000×1000 network area. For our simulation robustness in our enhanced simulation we ran our program with varying the network area. And after all data analysis it shows that our proposed protocol provides much better solution than other protocols.

Figure 4. Shows the simulation curve of different protocols like CBCDACP, LEACH-C, LEACH and Static-Clustering. It shows the number of nodes alive with respect to network life time in a 100 × 100 network area. We know the network lifetime depends on how long the sensor nodes remain alive in a network. When the time duration of nodes

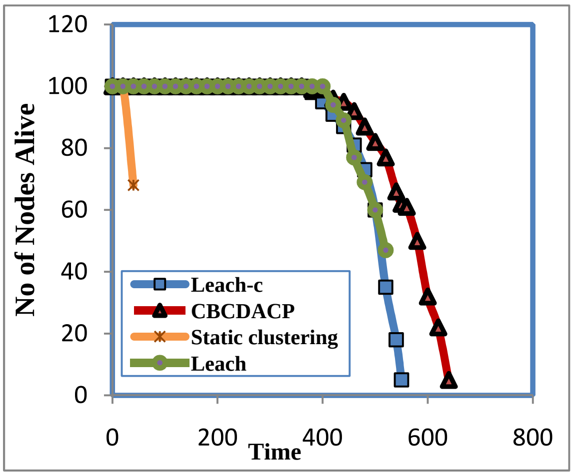

Figure 4. Number of nodes alive with respect to network life time.

die is long, the network lifetime is also long.The curve shows that the lifetime of the nodes of CBCDACP is longer than LEACH-C, LEACH, and also Static-clustering. Our proposed protocol provides much better solution than considered protocol.

For getting data of number of alive node with respect to amount of data message received we vary the network area and got a good result. Figure 5. Shows the simulation curve for the number of nodes alive with respect to amount of data message received in a 700 × 700 network area for different protocols like CBCDACP, LEACH-C, and LEACH.

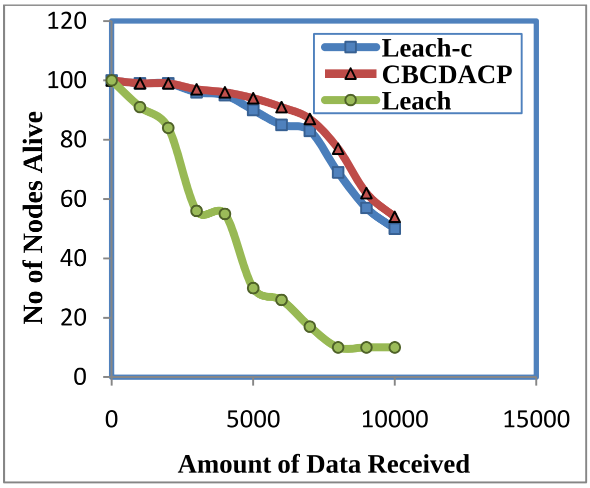

Figure 5. Number of nodes alive with respect to amount of data received.

It shows that the number of alive nodes of CBCDACP with respect to amount of data received is greater than that of the existing protocols LEACH-C and LEACH. It provides that the network lifetime of CBCDACP is longer than other routing protocols.

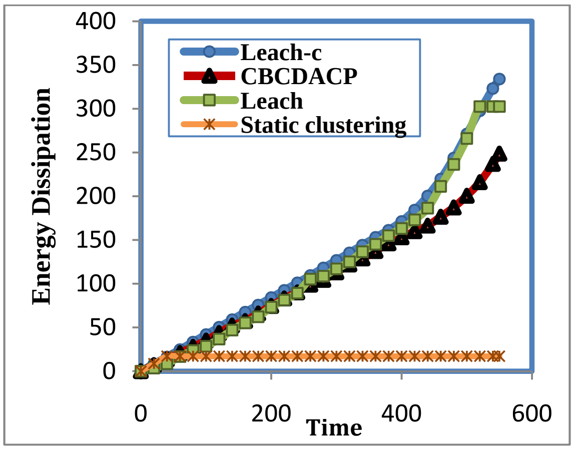

Figure 6. Amount of energy dissipation with respect to Time.

Figure 6 shows the simulation curve of the Amount of energy dissipation with respect to time in a 100× 100 network area. If the required energy to transmit data to the base station is very low for a node then lifetime of a node automatically increases and also the performance of the network. From the curve it is shown that the energy dissipation of CBCDACP is smaller than LEACH-C, LEACH, and also Static-clustering. So the network lifetime of CBCDACP is longer than other routing protocols.

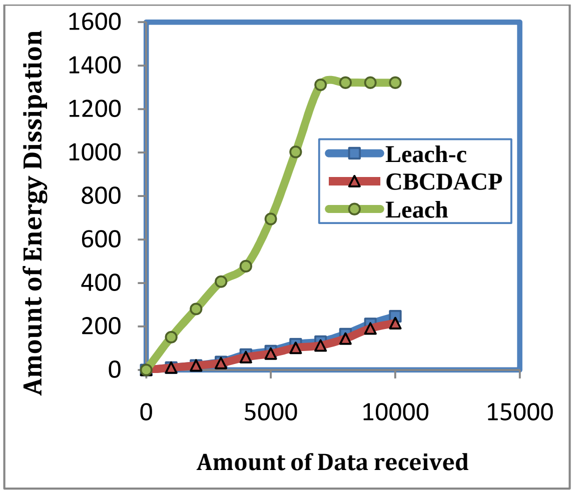

Figure 7. Amount of energy dissipation with respect to amount of data Received.

As energy dissipation is the main factor that we considered so we vary network and ran our simulation to see how much energy is dissipated with respect to received data. Figure 7 shows the amount of energy dissipation with respect to amount of data message received in a 700 × 700 network area for the protocols CBCDACP, LEACH-C and LEACH. From the curve it is shown that for the same amount of data transfer less energy is dissipated in CBCDACP than LEACH-C and LEACH. So the lifetime of the network is increased.

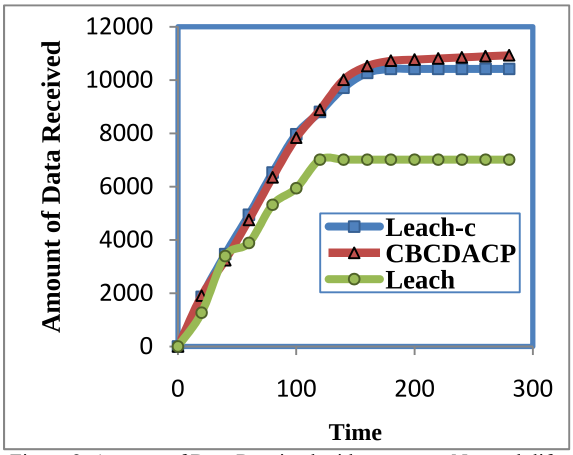

Figure 8. Amount of Data Received with respect to Network life time.

Figure 8 shows the amount of data received with respect to network life time in a 700 × 700 network area for the protocols CBCDACP, LEACH-C and LEACH. The curve shows that for the amount of data received with respect to network life time of CBCDACP is more than LEACH-C and LEACH. And it shows that the network performance of CBCDACP is better than other routing protocol.

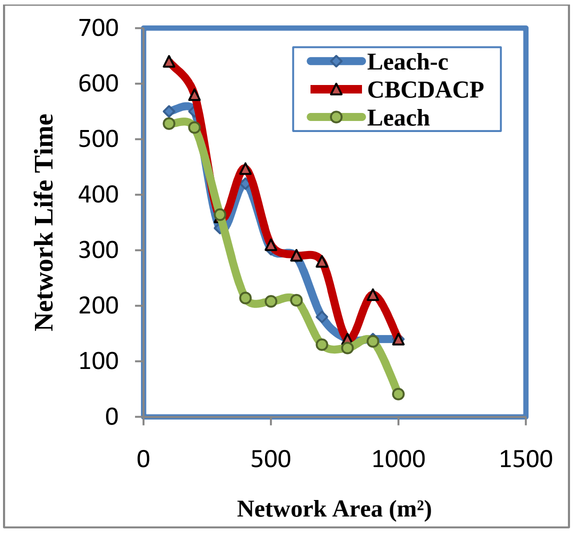

Figure 9. Network life time with respect to network area.

To establish that our proposed protocol provides better result in every factor, in our extended simulation we determined the network life by varying network area from 100×100 to 1000×1000. Figure 9 shows the life time of the network with respect to network area. The network area varies from 100×100 to 10000×1000 square meter. From the curve it is shown that the Network life time of CBCDACP is longer than the Existing LEACH-C and LEACH. So the performance of CBCDACP is better than other routing protocols.

Figure 10 shows the amount of energy dissipation with respect to network area. The network area varies from 100×100 to 1000×1000 square meter. From the curve it is shown that the energy dissipation of CBCDACP is smaller than the Existing LEACH-C. Though the energy dissipation of LEACH is smaller than both the CBCDACP and LEACH-C, the network lifetime and amount of data received of CBCDACP is larger than that of LEACH and LEACH-C. Thus the overall network performance of CBCDACP is better than other routing protocols.

To prove our simulation robustness we ran our simulation considering every factor. In our extended simulation we determined how many nodes may alive in network area if we vary the simulation area.

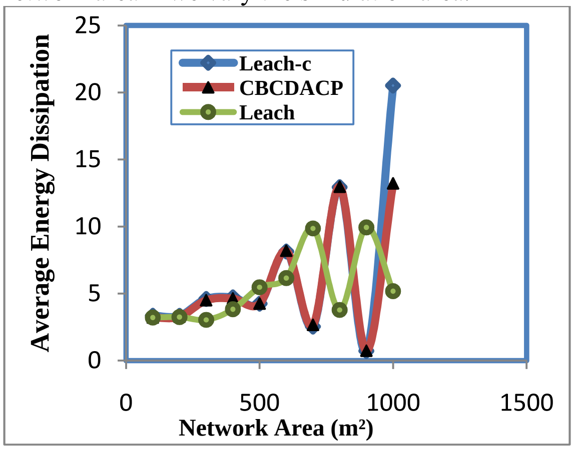

Figure 10. Amount of average energy dissipation with respect to network area.

And it shows that our protocol does not provide best result but it can provide better one.

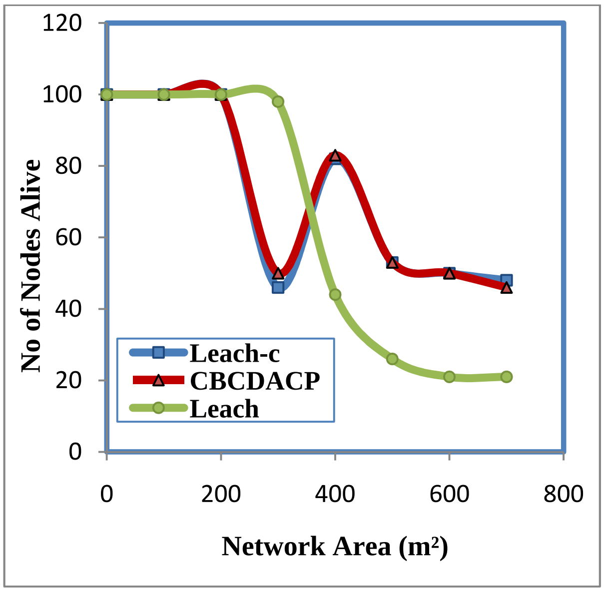

Figure 11. Number of Nodes Alive with respect to Network area.

Figure 11 shows the number of alive nodes with respect to network area after a certain network life time. The network area varies from 100×100 to 1000×1000 square meter. For 800×800 to 1000×1000 network areas, after that certain network life time, there is no alive node for LEACH. So in the curve network areas from 100×100 to 700×700 are considered. The curve shows that the lifetime of the nodes of CBCDACP is almost better than LEACH-C and LEACH. It shows that considering the varied network area the network lifetime of CBCDACP is longer than other routing protocols.

VI. CONCLUSION

CBCDACP is an enhanced cluster based routing protocol for wireless sensor networks where for cluster head selection, it considers the density factor of each candidate node and the minimum squared distance between the cluster head and the neighbor node. By considering the minimum squared distance and the density factor of each candidate node a cost function is determined and eventually by comparing the cost function an optimum set of clusters are formed. In this paper, we formulated a comprehensive analysis of CBCDACP in wireless sensor networks. We briefly explained the algorithm blocks that it uses for cluster selection process. Finally we ran a through simulation to demonstrate its robustness compare to the prevalent ones. For the simulation process we vary the different simulation parameters to analyze it more vastly. After all these analyses, it shows that in CBCDACP the ratio of node die is much better than the other protocols. It can provide large amount of data with respect to a less energy dissipation and so on.

As a future work direction it is possible to get better performance in sensor network if a high performance approximation algorithm can be established instead of Simulated Annealing algorithm. So that the proposed CBCDACP will be more effective in cluster selection process and consequently it will enhance the performance of wireless sensor networks.

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