# Modified Cluster Head Selection Method for DDR Routing Protocol in Wireless Sensor Networks

*T. P. Mithun and Megharaj Patil*
*R V College of Engineering, Dept. of TELECOM, Bangalore - 560059*

***Abstract*—** Today in Wireless Sensor Networks (WSNs), cluster based routing protocols with efficient energy utilization and that which are scalable for larger network area is a major research interest. In this research work we improvised an existing routing protocol mainly by adding few more factors in the Cluster Head (CH) selection criteria. By this new technique we increased the stability, network lifetime and network scalability in the WSNs. Finally we compared and verified our MATLAB simulation results with the existing results.

***Index Terms*—** Cluster Head, network lifetime, scalability, stability.



## I. INTRODUCTION

The advances in the sensor technology, low power electronics and also the low power radio design have led to the development of relatively smaller, cheaper and low power sensors that can be connected through a wireless network. These wireless micro-sensor networks represent a new paradigm for extracting data from the environment and enable there liable monitoring of a variety of environments for applications that include surveillance, machine failure diagnosis, and chemical/biological detection. The important challenges in designing these networks are two key resources i.e., communication bandwidth and energy. These resource constraints require advanced design techniques to make use of the available bandwidth and energy efficiently.

In order to utilize the available bandwidth and energy efficiently, better network protocols need to be developed. There are a lot of routing protocols that have been developed. In recent years, many routing protocols for WSNs have been proposed which can be classified into four classes: cluster based routing protocols, data centric routing protocols, geographic-based routing protocols and hybrid routing protocols. Here we are considering only cluster based routing protocol. In a cluster based hierarchical routing protocol sensor nodes are grouped in to clusters and each cluster has a CH. These CHs collect data from the nodes in their respective clusters and aggregate it and forwards it to the Base Station (BS) through single hop or multi-hop communication. Many cluster based routing protocols have been proposed such as; Density controlled Divide-and-Rule(DDR)[1], LEACH[4], LEACH-C[5], LEACH-SC[6]etc.

LEACH[4] is one of the first cluster based hierarchical routing protocols for WSNs. In this algorithm the CH selection in each round is based probabilistic approach. Therefore there is no uniform distribution of CHs that led to disconnected nodes.

LEACH-Centralized (LEACH-C) [5] algorithm is a further extension to LEACH. The added advantage of this protocol is, the nodes with less energy are not allowed to become CHs. But as the size of the network increased, the nodes at the far end are unable to reach BS.

LEACH-Selective Cluster (LEACH-SC) [6] is also an extension to LEACH. The CH selection process in LEACH-SC is same as that of LEACH. But where it differs from LEACH is in the formation of clusters. Here nodes choose CH that is nearest to the mid-point between itself and the BS and links itself to that cluster. But each round the number of CHs varies and is not scalable for larger networks.

Density controlled Divide-and-Rule (DDR) [1] is a static cluster based routing protocol. In DDR the nodes are static and uniformly distributed over the network. This helps to solve energy hole and coverage hole problems. But as the network area increases, there are scalability issues in this protocol.

In this work we have improved the existing Density controlled Divide-and-Rule (DDR) routing protocol for WSNs. The improvisation is mainly in the CH selection process. In this modified DDR the factors considered for CH selection are: minimum threshold energy of the sensor node; minimum distance from the central reference point i.e., BS and maximum number of neighbors at one-hop distance. In this way the stability and network lifetime are increased. Secondly, as the network area increases the multi-hop communications increases, but by using this technique we can minimize the multi-hop communications in the network, which helps in efficient utilization of the energy by uniformly distributing the load across the network. Thus the network scalability is increased.

## II. Protocol Design

In this section we discuss the design of this protocol. Firstly we discuss the clustering of the network area and then the energy expended in these clusters.

### A. *Clustering of the network area*

Basically this protocol is same as that of the DDR where static clustering is used. The base station is in the center of the network which first divides the network in to concentric squares and then these concentric squares are further sub-divided in to rectangular segments which form the clusters. The division of the network field is such that communication between node and the CH and the CH and BS is reduced.

The equations for dividing the network are considered from [1] i.e., first the network is divided in to $n$ concentric squares where the value of $n$ depends upon $d$, which is the distance between two concentric squares. The value of $d$ is chosen such that it divides the network equally. Considering for a network area of 120m X 120m the value $d$ = 20. The value of $n$ is calculated using equation (1).

$$n = \frac{C_p(x)}{d} \qquad (1)$$

Where $C_p(x)$ is the x co-ordinate of the BS. As the area of the network increases, the value of $n$ also increases. Once we have the value of n and d then we can further segmentize the network in rectangular cluster using these following equations.

$$T_r(S_n) = \left(C_p(x) + d_n, C_p(y) + d_n\right), \qquad (2)$$

$$B_r(S_n) = \left(C_p(x) + d_n, C_p(y) - d_n\right), \qquad (3)$$

$$T_l(S_n) = \left(C_p(x) - d_n, C_p(y) + d_n\right), \qquad (4)$$

$$B_l(S_n) = \left(C_p(x) - d_n, C_p(y) - d_n\right), \qquad (5)$$

As the BS is placed in the middle of the network field the area of internal square being small therefore it is not further subdivided. The area between internal square and middle square is further subdivided in to equal area rectangular segments using following equations. Segment (S2). The layout of the network field after dividing it in to concentric squares and then further subdividing it in to clusters is shown in the figure 1.

$$B_l(S2) = B_l(I_s(x + d, y)) \qquad (6)$$

$$T_r(S2) = T_l(I_s(x, y + d) \qquad (7)$$

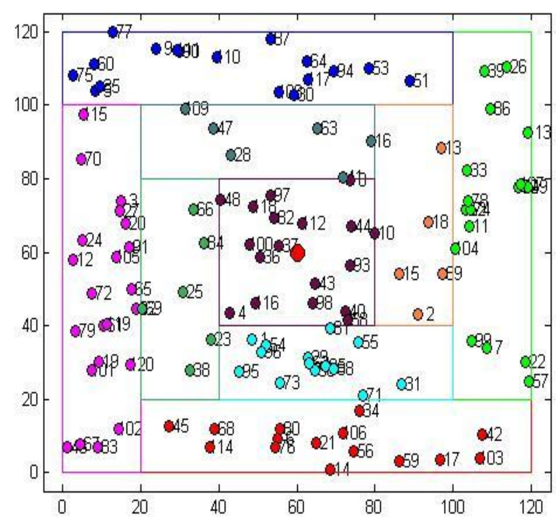

**Figure 1:** Network layout

## *B. Energy consumption by the nodes in clusters*

In this section the mathematical model for the consumption of energy by the nodes in the clusters that are formed. Energy consumption in transmission or reception of a 1-bit packet over a distance D as considered in DDR is obtained from [2].

Energy consumed in each cluster depends upon the number of nodes in the cluster and also in transmitting fixed amount of data. Equation 8 and 9 gives energy consumption by the nodes in the cluster.

Energy consumption in transmission:

$$E(Tx) = b * E_{elec} + b * E_{amp} * d^2 \quad (8)$$

Energy consumption in reception:

$$E(Rx) = b * E_{elec} \quad (9)$$

Where $b$ is the number of bits; $d$ is the distance between the node and the cluster head and other radio parameters are given in table 1.

### *C. Cluster Head selection*

The major part in any cluster based routing protocol is the selection of CH and also this article mainly focuses on improvised CH selection method. In DDR the CH selection is only based on minimum distance from central reference point i.e. BS but here we add other factors in CH selection process. There three factors that are considered for CH selection i.e., minimum threshold energy of the node, minimum distance from the central reference point and lastly the nodes having maximum neighbors at one hop distance. As this is a static network there are fixed number of CHs at any given time. CHs consume more energy in transmission and reception as compared to other nodes as the data received from other nodes in cluster needs to be aggregated and sent to BS. We adopt multi-hop communication in inter-cluster communication for reducing the distance and for this we use *Dijkstra's algorithm* to find shortest path to reach BS. Equations 10 and 11 give the mathematical model for energy consumed by CHs in transmitting and receiving data.

Energy consumption in transmission:

$$E_{CH}(Tx) = h * b * E_{elec} + b * E_{amp} * d^2 + \varphi \quad (10)$$

Energy consumption in reception:

$$E_{CH}(Rx) = h * b * E_{elec} \quad (11)$$

Where $h$ is the weighting factor that indicates how much more energy consumed by CHs than others sensor nodes; and $\varphi$ is data aggregation energy.

**Table 1:** Radio Parameters

| Operation | Energy dissipated |
|---|---|
| Transmitter/Reciever electronics | $E_{elec} = E_{Tx} = E_{Rx} =$ 50nJ/bit |
| Data aggregation energy | 5nJ/bit/signal |
| Transmit amplifer | $E_{amp}$ = 100pJ/bit/m$^2$ |

## III. RESULTS

In this section the experimental results of the modified DDR are presented. The results are compared with the DDR on the basis of four metrics that are considered earlier in the DDR i.e., stability period, network lifetime, throughput and optimum number of CHs. Here at the beginning the nodes are equipped with the initial energy of 0.5J. The considerations made for comparison are same as that of DDR. In the network area of 100m X 100m, 100 WSN nodes are being deployed. The radio parameters are as shown in the table 1.

The protocol simulation in the MATLAB environment is executed as same as for DDR to compare the results. We can see that the modified DDR is 88 rounds more stable than DDR. As the number of CHs are same in each round and due to multi-hop communication to reach BS minimizes the communication distance which increases the stability period of the network. This can be noticed by comparing figure 2 and 3.

From figure 2 the network lifetime is almost same as DDR. But as the network area increases as in table 2 for 200m X 200m both stability and network lifetime increases. The stability is 122 rounds better than DDR and network lifetime is 92 rounds better. Balanced energy utilization and avoidance of coverage hole due to better CH selection increases the network lifetime and stability and makes it even more scalable than DDR.

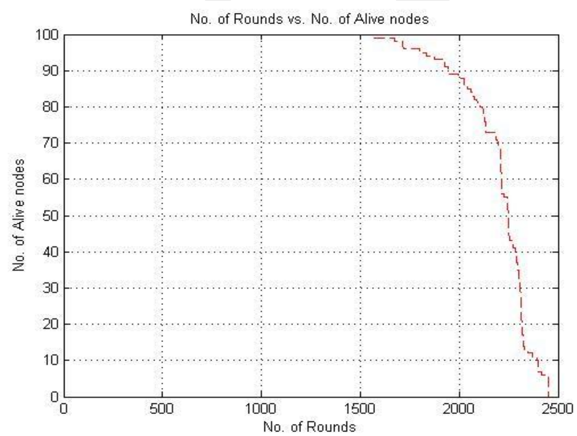


**Fig 2:** Modified DDR network stability graph

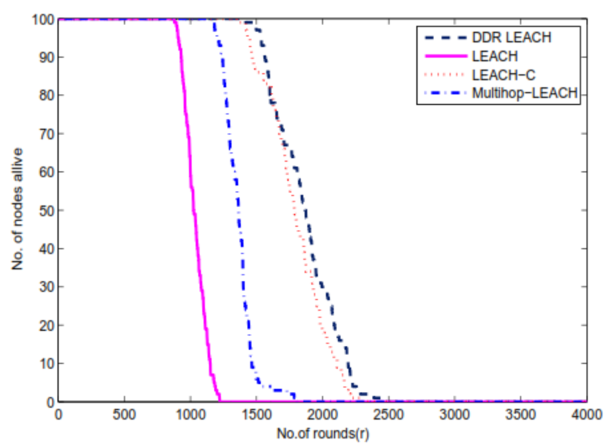


**Fig 3:** DDR Network stability graph for comparison.

Note: Figure courtesy[1]

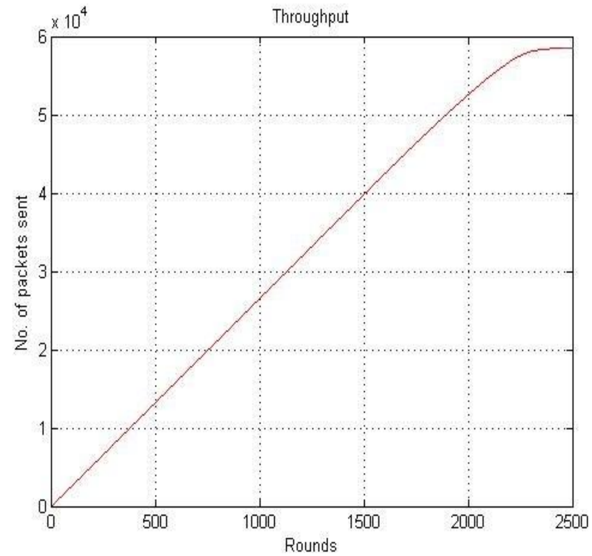


**Fig 4:** Throughput

**Table 2**: Comparison of Modified DDR and DDR for Stability

| Protocol | Area | No. of nodes | First node death round | Last node death round |
|---|---|---|---|---|
| Modified DDR | 100m X 100m<br>200m X 200m | 100<br>200 | 1578<br>1326 | 2492<br>2362 |
| DDR | 100m X 100m<br>200m X 200m | 100<br>200 | 1496<br>1204 | 2490<br>2270 |

By increasing network area and number of nodes with a ratio of $1m^2$ per node; for 120 nodes we divide network area in to three concentric squares and in case of 150 and 200 nodes we divide network area in to five and six concentric squares respectively. But from the above results it can be clearly noticed that, even though as the network area increases, which increases the overhead on CHs near BS, there is improvement in stability and network lifetime compared to DDR.

## IV. Conclusion

The focus in this article was on increasing the energy efficiency of the DDR, which is mainly based on static clustering. The major modification we made to the DDR is in the cluster head selection process. While selecting a CH in a given cluster the parameters taken into consideration are: minimum threshold energy of the node, distance from the central Base Station and the nodes having maximum no. of neighbors at a single hop distance. This change in the CH selection process better stable period and network lifetime compared to DDR.

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