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Deterministic Partition Protocol In Zone Based Wireless Sensor Networks

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Abstract

In order to achieve very high level of energy consumption in Zone based Wireless Sensor Network with deterministically deployed heterogeneous nodes, it is important to reduce the communication load on the high energy nodes. Increased energy efficient paths results in extended network lifetime. Even though the role of Cluster Head is periodically assigned to the nodes within the zones, unbalanced energy consumption is really a challenging issue as the load on the Cluster Head intensifies based on the location of its members. In this paper, we propose a novel partition on zones for decreased intra-cluster and inter-cluster communication costs for increased energy conservation .We also propose additionally a simple energy efficient Multi-hop transmission approach across the partitions for prolonged network lifetime. Simulation results show constructive results yielding maximum stability period and throughput by creating dense clusters in the deterministic partitions.

Key Words: Wireless Sensor Networks, deterministic, intra-cluster, inter-cluster, zones, multi-hop, partition, dense clusters, stability, throughput.

Introduction

Wireless Sensor Networks (WSNs) have found a wide range of applications in military surveillances like movement and sound made by enemies, environment monitoring, monitoring remote fields, weather monitoring, fire detection, nuclear reactor control and traffic monitoring [1-5]. The sensor nodes have the ability to operate unattended which is very suitable for inaccessible areas. The nodes deployed in these areas can be efficiently utilized to sense various environmental parameters like temperature, pressure, wind speed, surface waves which can cause serious risks to humans. Natural disasters find efficient use of sensor networks where there is a need for quick ways to communicate crucial information to people living in disaster prone areas

Multi-hop hierarchy mechanism is applied in many of the WSN applications like reactive tasking[6],object tracking[7],energy efficient centralized data collection[8] ,multi-dimensional range querying[9] and scalable network monitoring[10] where the nodes organization and deployment requires minimal human intervention to facilitate unattended operation. Efficient utilization of the energy of sensor nodes is vital as they perform complex functions like sensing, data aggregation, data fusion, computation and transmission activities that drain the energy of the nodes.

A network with uneven sensor lifetimes raises a challenging situation. The lifetime of entire network depends on the two facts : how much energy in the each sensor node consumes over time and how much energy in each node is available for its use. As sensors die early in the far-away and near-by locations of the base station, data from the monitored area shrinks. To overcome this, evenly distributed sensors and even consumption of energy are required in the network model. To ensure uniform consumption of energy and have full area coverage, zone based hierarchical clustering algorithm was designed [11]. This paper aims to create deterministic partitions on the zones in [11] and apply multi-hop hierarchy clustering to reduce communication overload on the nodes.

The rest of the paper is organized as follows: Section 2 briefly describes the related work and motivation. Section 3 describes the underlying intuition of the proposed partition and deployment approach. Section 4 describes the radio dissipation model used. Section 5 describes the working of the proposed multi-level clustering heterogeneous protocol and deduces the total energy dissipated in a regional network model; simulation results are analyzed in section 6 and we conclude the paper with future work in section 7.

Related Work and Motivation

Data sensing and communication are the two primary tasks of wireless sensor networks. In practical sensing environment there is only one base station in a few meters radius from the sensor nodes. The batteries are not replaceable in the nodes and the lifetime of the network largely depends upon the batteries. Despite extensive successful research in this area, still there are many issues to be addressed.

Clustering routing algorithms proposed in the recent research years solved the problem of excessive energy consumption in direct transmission technique adopted between the sensor nodes and the base station. The first clustering routing protocol, Low-energy adaptive clustering hierarchy (LEACH) [12] was proposed where nodes are divided into clusters. A node is selected as a cluster head in every individual cluster and is responsible for data aggregation and acts as a control centre for the cluster. To balance the energy consumption, it proposes the rotation of the role of cluster head randomly in all the nodes. There may be some inefficient cluster heads which are located in edge of the network area and are very close to each other could minimize energy efficiency. The randomly selected cluster heads directly communicate with the base station. This incurs high energy dissipation due to far distance from the base station. In order to improve the performance of LEACH, EECS [13], LEACH-B [14] HEED [15] were proposed. HEED [15] elects Cluster Heads in probabilistic way based on energy and communication cost. Here there are still chances that an low energy node can become cluster head. However all these protocols follow single-hop communication where the cluster heads communicate directly with the *BS*. For long distance transmission with the *BS*, the energy dissipation can be very high as the rate of energy dissipation is directly proportional to the exponent of transmission distance. Shepard estimated that a packet with more than $2\rho^{-\frac{1}{2}}$ distance has to be routed through a relay node, where ρ is the density of the relay node area [11]. Routing with minimum energy consumption was achieved.

Multi-Level clustering protocols [17-24] were proposed with the aim to further reduce energy consumption. The cluster heads in multi-level clustering are connected as chains and the cluster heads in the chains relay data to the BS. Akyildiz et al. has identified the critical criteria required for multi-hop routing in a network as minimization of energy, minimal hop, maximal power, maximal-minimal available power [1]. Aderohunmu proposed DLCC and MLCC protocols as dual-hop and multi-hop approach of LEACH and concluded that large networks with sparse deployments have significant network lifetime [24].

Some protocols were designed to communicate through multi-level communication mode for sensor nodes outside the range of each other [15], [25].

Zhang et al. used hop by hop transmission and direct transmission modes to balance energy consumption by the nodes [26]. Mhatre and Rosenberg proposed a hybrid method utilizing both the single and multi-level communication modes for data aggregation [27]. Vincze and Veda designed a mobile sink strategy with multi-level communication where the sink moves towards the events being sensed and the nodes communicate to the sink through multi-hop [28]. Xiangning et al. proposed an inter-cluster communication protocol based on LEACH [29].

iHEED extends HEED with the incorporation of multi hop routing between CH and BS[30]. But conventional protocols like Direct Transmission (DT) do not assure a balanced and uniform use of the sensor energy. SEP-E, a modified algorithm of SEP considers three-tier nodes by introducing intermediate nodes which serves as a bridge between normal nodes and advanced nodes [31]. SEP-E does not provide an ideal solution for energy dissipation, since normal nodes, intermediate nodes and advanced nodes are randomly deployed.

Z-SEP is a zone-based protocol where the sensing field is divided into zones and advanced nodes were in the furthest zone of the base station[32]. Advanced nodes were elected as cluster heads and normal nodes directly communicated with the base station.

Research work on sensor deployment has focused on maintaining the connectivity of the network and network coverage. All these approaches are not scalable[33-38]. Kaj et al. describes probabilistic analysis on multi-level cluster based communication with BS reducing routing complications and increasing network lifetime [39].

The cluster head in SEP-E protocol directly communicates with the sink no matter the distance between cluster head and base station is far or near. Also, the sensor nodes with different energy types of energy are randomly deployed in the field and unevenness of sensor usage. Data transmission incurs high energy dissipation for long distance nodes. The network partition and sensor deployment now becomes straightforward. Hierarchical routing protocol have advantages over flat routing protocol in terms of scalability , communication efficiency and network life as they make the nodes to work collaboratively together [40].

Existing Zone Based Clustering Algorithm: ZSEP-E Protocol

The performance and lifetime of WSNs is highly influenced by the clustering scheme. But the efficiency of the network is drastically affected by the early death of the sensor nodes which are far away from the base station. Zone-Based clustering protocol [11] was proposed to address this issue by partitioning the field and advanced nodes were deterministically deployed at pre-computed locations to reduce the network partitioning and instability.

Network Model and Specifications

Some assumptions were made about the underlying network model of area $A= X\times Y$ sq.mts. where $X=a$, $Y= b_1+b_2+b_3$, where $b_1=b_3$ and $b_1+b_2+b_3=a$ and the sensor nodes deployed. Fig.1 shows the ZSEP-E architecture.

A zone partition algorithm was used to partition the area A into three zones. Each zone was considered separately as a geographical division of the sensing field. Appropriate energy-level sensor nodes were deployed depending on the distance and orientation from the base station. m proportion of total number of nodes n were equipped with α times more energy than the *normal nodes* and referred as *advanced nodes*. b proportion of total number of nodes n were equipped with μ times more energy than the normal nodes and referred as *intermediate* nodes.

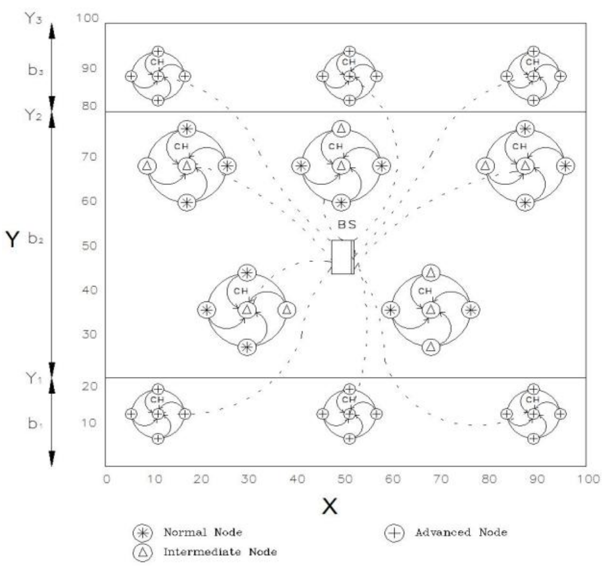

Figure 1: ZSEP-E Architecture

The zone partition algorithm is as follows:

1. *Zone1* = $a \times b_1$, lying between $0 \leq Y \leq Y_1$, deployed with $n \times \frac{m}{2}$ static homogenous energy-rich advanced nodes where $Y_1 = a \times \frac{m}{2}$.
2. *Zone2* = $a \times b_2$, lying between $Y_1 < Y \leq Y_2$, deployed with b proportion of static intermediate nodes and $(1\text{-}m\text{-}b) \times n$ normal nodes where $Y_2 = a \times Y_1$.
3. *Zone3* = $a \times b_3$, lying between $Y_2 < Y \leq Y_3$, deployed with $n \times \frac{m}{2}$ static homogenous energy-rich advanced nodes where $Y_3 = a$.

The problem of Un-balanced energy consumption

In a rectangular based zones like Zone1 and Zone3 even though role of CH is rotated periodically, some nodes dissipates energy at a higher rate because of the distance of its member when it becomes CH. This situation leads to network partitioning and reduced sensing coverage [41]. To overcome this unbalanced energy consumption and partitioned network, partition the zones Zone1 and Zone3 equally to reduce the cluster sizes considerably and maximize the usage of extra energy nodes in the zones.

Transmission energy and data receiving energy

Most of the protocol ignores the large signaling overhead that arises out of clustering in distributed nodes. As communication distance increases, transmission energy increases [42]. In a single hop environment with very large network area, the far away cluster heads from Zone1 and Zone3 can lead to loss of data from entire part of their zones. To overcome this routing over through a hop minimizes the transmission energy as the communication distance is decreased. Cluster heads spends more energy than cluster members in data aggregation and transmitting. A hop through an extra high energy node (intermediate) if available nearer to the Sink in more or less straight line with the Sink which acts as a gateway consumes less transmission energy than the direct communication with the Sink[43]. If gateway is not available in line with the Sink, the hop is through the cluster heads nearer to the Sink.

Radio Energy Dissipation Model

We consider the radio energy dissipation model used by Heinzelman et al. in our proposed framework as shown in the Fig.2 [12].

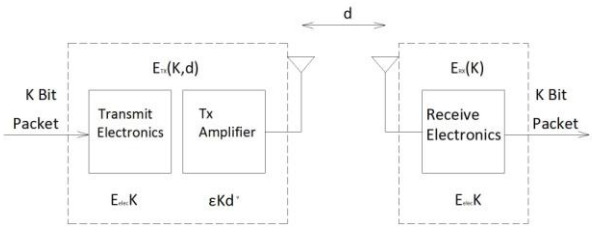

Figure 2: Radio Energy Dissipation Model

According to the model, the energy expended by the radio to overcome the free space *(fs)* or multipath loss *(mp)* and to transmit k bits of data over a distance d in the acceptable Signal-to-Noise Ratio is given by (1),

$$E_{Tx}(k,d) = \begin{cases} K.E_{elec} + K.\epsilon_{fs}.d^2 & if\ d < d_0 \\ K.E_{elec} + K.\epsilon_{mp}.d^4 & if\ d \geq d_0 \end{cases} \quad (1)$$

d_0 is the distance threshold and is calculated by equating the two expressions $d=d_0$, we have $d_o = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$

where E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit, ϵ_{fs} and ϵ_{mp} depend on the transmitter amplifier model.

To receive k bits of data, the radio expends,

$E_{Rx} = kE_{elec}$.

We assume the radio channel to be symmetric i.e. k bits of data requires the same amount of energy to be transmitted from node A to node B and vice versa.

Proposed Multi-Level Clustering Heterogeneous Protocol

Chen et al. concluded in [44] to divide the network area into zones by considering the distance and clustering among the zones and cluster heads with high energy acts as relay nodes, balances the energy consumption of the zones.

Network Model

Our task is now to design a deterministic partition for the network of square area $A=X\times Y$ with Zones in [11] into regions so that clusters are formed locally within those regions with the reduced communication distance within the members of its respective clusters.

Let us assume that Yi where i =1 to 3 be the coordinates in the network that divides the network into zones Zone1, Zone2 and Zone3 as in [11].

The total number of nodes is given by *N as*,

$$N = (n_1 + n_2 + n_3) \quad (2)$$

where n_1 is the number of advanced nodes with m proportion of N, n_2 is the number of intermediate nodes with b proportion of N and n_3 are the number of normal nodes. We assume that n_3 is equipped with initial energy E_0, n_1 and n_2 and are equipped with α and μ times more energy than E_0 respectively.

The m proportion of n_1 advanced nodes is deployed in *Zone1* and *Zone3* so that *Zone1* and *Zone3* have same density as in [11]. The b proportion of *n2* intermediate nodes and n_3 normal nodes are deployed in *Zone2* as in [11].

1) Homogeneous Regions:

First we choose to divide the homogeneous zones *Zone1* and *Zone3* into regions R_1, R_2 and R_3, R_4 respectively in such a way that they are all equal in area and deployed with nodes from their respective zones.

2) Heterogeneous Regions

Now there is a bound on how we partition *Zone2*. Selected the coordinates X_i *so that* X_i=Y_i where i = *1 to 3*. Selected the vertical axes with coordinates (X_i,Y_j) where $i=1$ and j=*1to 2* and (X_i,Y_j) where $i=2$ and j=*1 to 2* which forms a concentric square with the Network Area *A* so that two rectangular regions R_5 and R_6 and one Square Region R_7 are derived from *Zone2* .

Let n_{11}, n_{12}, n_{13} and n_{14} be the advanced nodes in regions R_1, R_2, R_3 and R_4 respectively. So,

$$n_1 = (n_{11} + n_{12} + n_{13} + n_{14}) \quad (3)$$

Also let n_{21} be the intermediate nodes in Region R_5 and R_6 and n_{22} be the intermediate nodes in Region R_7. So,

$$n_2 = (n_{21} + n_{22}) \quad (4)$$

Let n_{31} be the normal nodes in regions R_5 , R_6, and n_{32} be the normal nodes in R_7.

$$n_3 = (n_{31} + n_{32}) \quad (5)$$

Clusters are formed in all the regions. Nodes associate with their higher energy *CHs* for intra- cluster communications. *CHs* of all the rectangular regions use relay *CH* in square region R_7 for inter-cluster communications.

The regional heterogeneous setting of the proposed protocol is shown in Fig.3.

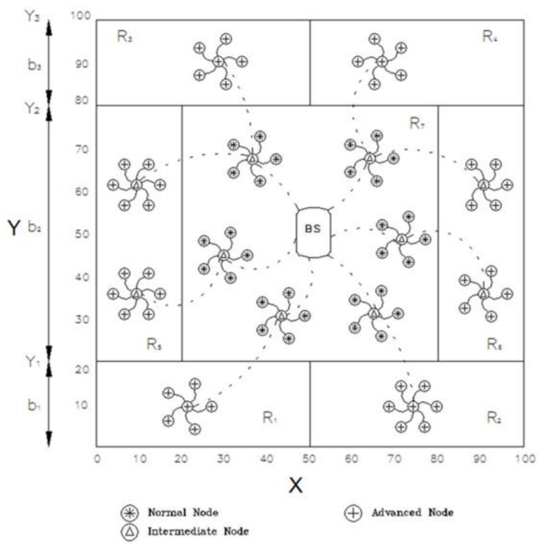

Figure 3: Regional Heterogeneous Settings

Cluster Setup Phase and Steady State Phase

The operation of the protocol is broken down rounds with each round consisting of *Region Settling Phase (RSP)* and *Region Transmission Phase (RTP)*. During *RSP*, maximum number of clusters is formed in the regions based on the number of alive nodes. During *RTP*, aggregated information from all the cluster heads are transmitted to the base station.

Region Settling Phase

We also assume that the base station and the nodes deployed are static and *BS* is located at the center of network area as in [11]. So the BS is here at center of the concentric square i.e. region R_7. Local awareness of the nodes is through Global Positioning System (GPS). Communication with *BS* happens through two hops exploiting the radius *R* of connectivity around the base station. The method chooses an optimal path using less energy for transmission among the cluster heads to the *BS*. Mekkaoui et al. [45] has concluded that the two- hop communication mode is the most energy efficient strategy when the relay node is at the midpoint of the total transmission radius [45].

In this method, we assess the impact of dual communication mode among the cluster heads of the different region levels. Efficient cluster formation is necessary for extended lifetime of the network. During RSP, clusters are formed locally in the various regions of the network and CHs are elected based on the maximum residual energy of the nodes in their respective regions and minimum distance from the region R_7.When data packets are communicated within the clusters during RTP, control information of the nodes like the residual energy and location information are piggybacked to their CH in the round. Local election of CH in the clusters for the next round is performed by the current CH based on the control information in the data packets. In this way, the overhead incurred by the global election of the CH by the BS is reduced to local election by the CH in the clusters of the regions. The nodes with maximum energy and lying in the mid-point of the transmission radius in region R7 are elected as cluster heads for relaying the data sent by the CHs in all the other regions.

Region Transmitting Phase

During *RTT*, the non-cluster heads transmit their data to their *CH*. The *CH* aggregate the data and transmit the aggregated data to the relay CH found within the minimum transmission range i.e, located within the radius *R* of the base station enabling inter-cluster communication in the network. They forward the aggregated data to the BS. The non-CH nodes within the transmission range of the *BS* send their sensed data directly to the *BS* using Direct Transmission Technique.

To efficiently use the battery of every single sensor, the cluster heads and relay CH are re-established at every round.

The Proposed algorithm

1. Formation of clusters in all the Regions R_i (i = 1 to 7)
2. Choose G_i from the cluster heads in R_7 in line with each R_i where (i= 1 to 6) towards the BS.
3. If any of the G_i is null ,select the higher energy node in R_7 in line with respective R_i and also within the distance λ where λ is the half of the diagonal of R_7 .
4. From all the cluster heads in R_i forward the data through G_i to the BS where i = 1 to 6.

Total Energy Dissipation in the proposed Multi-Hop Regional Network Model

In this section, we derive the total energy dissipated in the multi-hop regional network model. We assume and consider the scenario shown in Fig. 3. The protocol adopts the multi-hop communication strategy for a node in a region to communicate to the *BS*. We identify three types of nodes in different levels of functionality across the regions to communicate to the base station viz. *Level1*, *Level2*, *Level3*. *Level1* nodes are the non-cluster heads which sense and transmit the data to their *Level2* cluster heads. *Level2* cluster heads aggregate the data from their cluster members transmit the data to their nearest relay *CH*. *Level3* nodes are the intermediate nodes acting as relay *CH*, *G* which forward the data to the base station.

In a sensing field with N nodes, let the energy required by Level1 non-cluster heads to sense and transmit the data to Level2 cluster heads be E_1. Let E_2 be the energy required by the Level2 cluster heads to receive and aggregate the data from Level1 nodes from regions R_1, R_2, R_3, R_4, R_5 and R_6. Let E_3 be the energy required by Level2 cluster heads to transmit the data to its nearest Level3 relay CH. Finally, let E_4 be the energy required by the Level3 CH to aggregate and transmit the data to the base station.

Thus the expected energy expended per bit by the Level1 non-cluster heads will be,

$$\frac{E_1}{k} = E_{elec} + \epsilon_{fs} d_{toCH}^2 \tag{6}$$

Actually $d_{toCH}^2 = \frac{M^2}{2\pi C_2}$ in Eq. (6) becomes,

$$\frac{E_1}{k} = E_{elec} + \epsilon_{fs} \frac{M^2}{2\pi C_2} \tag{7}$$

The *Level2* cluster heads C_{21} in R_1, R_2, R_3, *and* R_4 expends energy in receiving and aggregating data is given by,

$$\frac{EC_{21}}{k} = E_{elec}\left(\frac{n_1}{C_{21}} - 1\right) + E_{DA}\frac{n_1}{C_{21}} \tag{8}$$

The term $\left(\frac{n_1}{C_{21}} - 1\right)$ is the number of non-cluster head nodes for each *Level2* cluster heads in R_1, R_2, R_3, *and* R_4.

The *Level2* cluster heads C_{22} in R_5, R_6 expends some energy in receiving and aggregating data is given by,

$$\frac{EC_{22}}{k} = E_{elec}\left(\frac{N_m}{C_{22}} - 1\right) + E_{DA}\frac{N_m}{C_{22}} \tag{9}$$

where $N_m = (n_{21} + n_{31})$ .The term $\left(\frac{N_m}{C_{22}} - 1\right)$ is the number of non-cluster head nodes for each *Level2* cluster heads in R_5, R_6.

The energy per bit E_2 at *Level2* cluster heads C_2 is given by,

$$\frac{E_2}{k} = (n_1 + N_m - C_2)\frac{E_1}{k} + (n_1 + N_m - C_2)E_{elec} + (n_1 + N_m) E_{DA} \tag{10}$$

where $C_2 = (C_{21} + C_{22})$ The *Level2* cluster heads will transmit the aggregated data to *Level3* relay *CH*. The transmission energy per bit $\frac{E_{TxC2}}{k}$ is given by,

$$\frac{E_{TxC2}}{k} = E_{elec} + \epsilon_{fs}\frac{M^2}{2\pi G_1} \tag{11}$$

n_{22} intermediate nodes in R_7 act as Relay *CH* for inter-cluster communication. The overall energy per bit required by *Level3* relay *CH* to receive, aggregate the energy from *Level2* cluster heads is given by,

$$\frac{E_{G_1}}{k} = E_{elec}\left(\frac{C_2}{G_1} - 1\right) + E_{DA}\frac{C_2}{G_1} \tag{12}$$

The members of Level3 relay *CH* are *Level2* cluster heads. Hence, *Level3* relay *CH* will have ($\frac{C_2}{G_1}$ - 1) non-*CH* members. The overall energy per bit expended by *Level3* relay *CH* to receive and aggregate the data is given by,

$$\frac{E_3}{k} = 2(C_2 - G_1)E_{elec} + \epsilon_{fs}\frac{M^2}{2\pi}\left(\frac{C_2}{G_1} - 1\right) + C_2 E_{DA} \tag{13}$$

The overall energy per bit E_4 required by *Level3* relay *CH* and non-CH to transmit the data to the base station is given by,

$$\frac{E_4}{k} = (G_1 + G_2)\left(\mathrm{E_{elec}} + \epsilon_{fs}\, d_{toBS}^2\right) \tag{14}$$

where G_2 are the non-CH in region R_7.

Finally, the total energy per bit expended in a regional dual-hop network model per round is given by adding equations (10), (13) and (14)

$$\frac{E_{sum}}{k} = (2N_1 + 2N_m)E_{elec} + \epsilon_{fs}\frac{M^2}{2\pi}\left(\frac{n_1}{C_2} + \frac{n_m}{C_2} + \frac{C_2}{G_1}\right.$$

$$\left. -2\right) + E_{DA}(n_1 + N_m - C_2) + (G_1 + G_2)(_{\mathrm{fs}}\, d_{toBS}^2 - \mathrm{E_{elec}}) \tag{15}$$

Performance Evaluations

In this section, we present the important results from our simulation studies for the proposed multi-level clustering protocol using MATLAB. The goal of the simulation studies is to demonstrate that our approach can dramatically extend the network lifetime of sensor nodes while maintain an even energy consumption rate in the regions. The base station is deployed in the center of the network region. We follow the radio energy dissipation model discussed in section 4 and conduct 10 trials with different network area and number of nodes to get the average simulation results. Table I shows the simulation parameters used in the protocol.

Table 1: Simulation parameters

Parameters	Value
E_{elec}	50nJ/bit
EDA	5nJ/bit/signal
E_0	0.5J
K	4000
ϵ_{fs}	10pJ/bit/m2
ϵ_{mp}	0.0013pJ/bit/m4
d_0	70m

We simulate a multi-hop clustered wireless sensor network with dimensions *100m × 100m* and *200m × 200m* and *100* nodes. We evaluate the performance of the network with the region dimensions shown in Fig. 4.

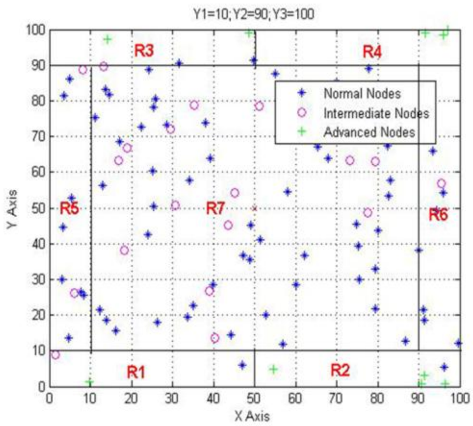

Figure 4: Node Distribution With Y_1=10, Y_2=90, Y_3=100

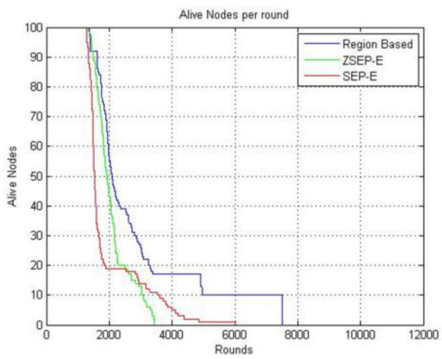

Figure 5:(a)

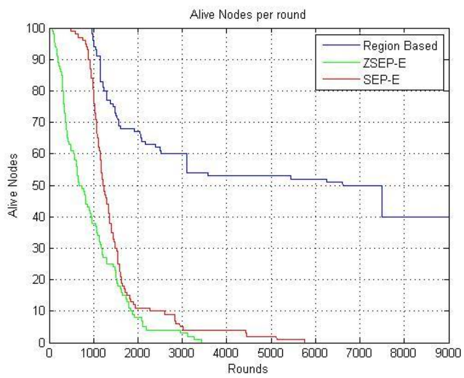

Figure 5: (b)

Figure 5: Network Lifetime Analysis of Network (a) 100m×100m (b) 200m×200m with 100 nodes

Three important properties of the network are evaluated for the proposed region-based approach: Network lifetime in terms of alive nodes, throughput and the rate of energy dissipation in the regions. For each property, we demonstrate the comparisons of accuracy with SEP-E and ZSEP-E.

Fig.5 presents the impact of regional multi-level setting for *100m×100m* and *200m×200m* on network lifetime with 100nodes and BS in the centre.

Fig.5 (a) shows that in a *100m×100m* network, the first node dies at 1502 rounds in the proposed region based protocol, ZSEP-E 1361rounds and SEP-E 1342 rounds. Fig.5 (b) depicts that in a *200m×200m* network, the first node dies at 856rounds in the proposed protocol, ZSEP-E 78rounds and SEP-E 535rounds. The stability period of the proposed protocol is well due to the fact that more powerful are deployed in the far-away regions of the field. With increase in the dimensions of the area, the transmission range increases but the hop length decreases and hence the overall energy consumption is reduced considerably.

Fig.6 shows the throughput of the network with *100m×100m* and *200m×200m* with 100nodes and BS in the centre.

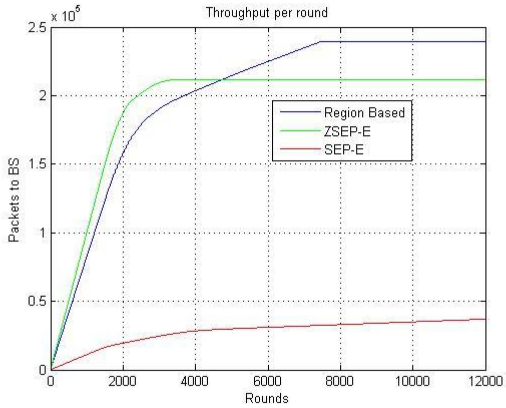

Figure 6: (a)

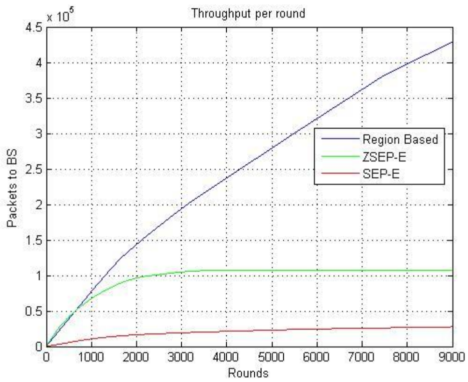

Figure 6: (b)

Figure 6: Throughput of The Network (A) 100m×100m (B) 200m×200m With 100 Nodes

Fig.6 (a) and (b) shows that for the proposed region based protocol is performing considerably good as the number of packets to the *BS* is high when compared to the other protocols. The number of alive nodes is directly proportional to the throughput of the network. Region based protocol works better for higher network dimensions and in certain fixed rounds higher throughput is possible.

Fig.7 shows region based rate of energy dissipation for the network sizes *100m×100m* and *200m×200m* with 100 nodes. The Figure shows that with increase in network dimensions, the regions R_5 and R_6 perform poorly. This leads due to the fact that in those regions, there is uneven energy consumption. Future work is to avoid the sudden decrease in energy in these regions.

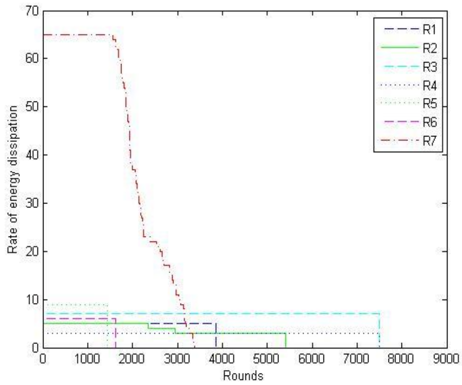

Figure 7: (a)

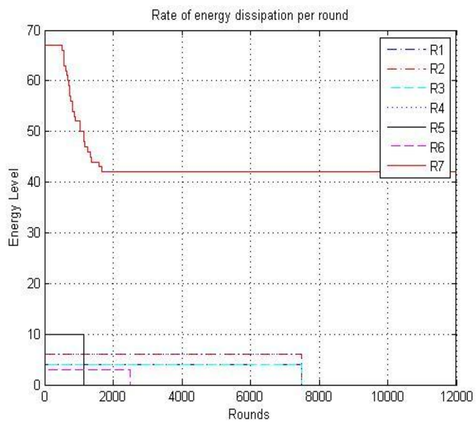

Figure 7: (b)

Figure 7: Rate of Energy Dissipation of Regions (A) 100m×100m (B) 200m×200m With 100 Nodes

Conclusion and Future Work

In this paper we presented a multi-level clustering protocol for a region based network model that organizes the nodes effectively to perform data gathering with the deterministic partition of zones into regions. This hierarchical model improves the communication efficiency of high energy nodes which are very critical in certain specific applications. These high energy nodes are in the far-away regions of the network to support even energy consumption and avoid early network hole. Based on this model, we observed even energy consumption in Homogenous regions and overall enhanced network lifetime than the existing protocols considered. The performance of the network was studied using simulation results from MATLAB. The number of alive nodes, throughput and the rate of energy dissipation in the regions were studied with varying network dimensions. The replenishment of nodes in Homogenous regions becomes easier as the energy dissipation in those regions are even which can be helpful in some specific applications.

Our work identifies the gateways for hierarchical clustering in the concentric square region comprising the BS which are more or less in line with the BS for the cluster heads in the outer regions. These gateways play a key role in prolonged network lifetime if it is a high energy node and it is in line with the cluster heads of outer regions. To find and build this clustering around these gateways with little overhead open avenues for future development.

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