Journal of Theoretical and Applied Information Technology
31st December 2017. Vol.95. No 24

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

LIFETIME MAXIMIZATION OF HETEROGENEOUS WIRELESS SENSOR NETWORKS USING IMPROVED ENERGY AWARE DISTRIBUTED CLUSTERING APPROACH WITH RENDEZVOUS NODES AND MOBILE SINK

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ABSTRACT

Energy efficiency and its optimization are of paramount importance in data transmission in Wireless Sensor Networks. The lifetime of the deployed sensor node should be maximized with even distribution of the energy across the network so that the data transmitted is not lost .The MS helps in enhancing the lifetime of the network by reducing the energy spent in long distance transmission. The introduction of RN helps in storage and data transmission from CH to MS. In the proposed protocol I-EADC_RN, the field is divided into two regions Sensing region[A] and Storage region[B]. The nodes deployed within the storage region are called RN. The nodes deployed in the sensing region participate in CH selection based on average energy computed from the neighboring nodes. The RN store the collected data and transmit it to the MS when the MS comes near to them. The objective of the proposed algorithm is to maximize the effective lifetime of the network with the help of RN and MS, reduce energy hole problem with efficient distribution of energy among the network with the help of efficient competition radius assignment and by efficient mean of data transmission with the help of relay node selection based on energy spent in transmission and reception and the minimization of data loss with the help of data storage in the RN.

Keywords:- *CH-Cluster Head, RN-Rendezvous Node, RN-Region , Deployment Region, MS-Mobile Sink*

1. INTRODUCTION

Sensor nodes are lightweight components which are deployed in large number to sense the environment parameters and periodically forward them to the BS. The BS is a node which is assumed to have infinite amount of energy or more amount of energy when compared to other nodes in the network. The sensor nodes are provided with an initial amount of energy before deployment. These nodes are deployed densely in regions like agriculture field, forests, railway tunnels etc. This could require solar photovoltaic cell in a grid etc., as WSN require data from all regions [1-4].The longevity of a sensor network depends on the energy of the sensor nodes which is limited and is not rechargeable [5,6]. Hence the energy of these nodes has to be conserved. In order to conserve energy the concept of unequal clustering, multi-hop communication and role division has been introduced. The unequal clustering is used to distribute energy in the network based on its distance from the BS. Multi-hop communication is introduced to reduce the energy spent in long distance transmission. The division of role assignment for the nodes is used to reduce the overload on a particular node. Clustering with hierarchical topology is found efficient in continuous monitoring [7-10].

Several challenges faced in maximizing the network lifetime are as follows: The lifetime of the network has to be stable for a long period of time. The time until the first node dies is called Stable lifetime of the network. The time before 25% of the nodes die is known as the effective lifetime of the network. The time when the last node dies, it is the maximum lifetime of the network. But, as the lifetime requirement is application specific, considering the first node dead as the lifetime definition is not a generic one [11] as there are different types of sensor network nodes which addresses different applications [12]. Pre-determining the position of the sensor nodes and their deployment in specific areas is a bit tedious work and consumes more time in construction of the network. The introduction of unequal clustering is to reduce the burden of network installation.

The wireless network has dynamic topology for each and every round in the network lifetime because if a node dies in a round then that node has to be neglected from the cluster in the upcoming rounds. This could reduce the burden of the CH while updating the member list count. These frequent changes in the cluster size help in balancing the energy spent by the nodes in cluster.

The location information of the sensor nodes is a main factor which helps in determining the optimal routing path for the effective data routing to the BS. The location information of all the nodes in the network is the next process after the deployment of nodes. To overcome all these defects and to increase the efficiency of the network a new protocol has to be proposed which helps the nodes in the network to be alive for a long period in the network. There are number of multi-hop communication techniques having more energy efficient inter-cluster communication like Multi-hop LEACH [13][14][15], EADC [16], EDUC [17], etc.

2. RELATED WORKS

A number of strategies have been adopted such as mobility, MS, data compression, non-uniform clustering and traffic aggregation [18], node distribution [19], etc. for solving energy hole problem.The MS moves around the network with remaining energy and helps in reducing the energy spent in long distance transmission. An energy imbalance is created in the network when we move the BS. The cost spent in moving the BS is also considered in the proposed work. The data is relayed to the MS using multi-hop communication with the help of relay nodes. The MS periodically announces its position to the other nodes in the network using Beacon signal. There are different types of MS which are as follows:

1) In limited multi-hop relaying the sensor field is divided into regions and the MS is made to move in the middle of the region and the nodes transfer the data to the MS. As the MS moves the nodes in those regions transfer their data to the BS. But the MS moves to a defined point in one round and changes its position to another point in next round.

2) In a direct source sink transmission nodes are heterogeneous where some nodes have normal energy and a few nodes have energy greater than normal nodes. These nodes act as rendezvous point. The MS moves to these points to collect the data.

3) In passive data collection, the MS stations at each and every point in a round. The advantage of this method is that the lifetime of the network is maximized but the amount of data collected in a round is reduced.

4) In dynamic mobile BS the BS moves randomly anywhere in the network. The node with distance less than pre-determined distance (d_0) will transmit data to the BS.

5) In predictable mobility the MS moves to certain RN point based on several parameters like remaining energy, number of nodes and the distance between them. In this mode of mobility the data regarding the parameters has to be communicated to the BS prior to the data transmission phase.If data from any particular region is not received at the BS it is assumed that the nodes in that particular region have depleted their energy. This led the path to energy hole problem [20,21]. Energy hole problem can be rectified by several mechanisms:

1) Assistant approach [12]: In TTDD scheme, a number of assisting nodes is deployed having larger battery capacity and larger transmission range. These nodes form a relay region on the upper side of the sensor having lower initial energy.

2) Based on nodes distribution strategy: If more number of nodes is near RN region then nodes are to be deployed with pre-determined distribution function.

3) Transmission range adjustment: The adjustment of the sensor communication ranges. But this has restriction on the size of the sensor field.

4) Mobility of the sink: Mobility of the BS for the event driven network.

LEACH [22] (Low Energy Adaptive Clustering Hierarchy) falls under hierarchical networks. This protocol is self-organizing, adaptive clustering protocol which uses randomization to distribute energy load evenly across the network. The nodes which are deployed over the field are homogenous. The BS is static and fixed at a distance far away from the sensor field. The Cluster Formation Algorithm in LEACH: CH broadcasts an advertisement message (ADV) using CSMA MAC:

ADV=nodes ID + distinguishable header

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Based on the signal strength of the received ADV (RSS), each non-CH nodes determine the CH near them.

The key reason for using TDMA scheduling in intra-cluster communication is to prevent collision among the data messages transmitted and for the conservation of energy of the non-CH nodes. During their scheduled period the CH communicates to the cluster members. At this point the nodes are awake after which they go to sleep in order to conserve the energy. TDMA schedule is used to send data from cluster members within a node to their CH. The main idea in implementing TDMA is to help in collision in the cluster. The CH aggregates the received data from its member nodes in the cluster. The communication is via a direct sequence spread spectrum (DSSS), where each cluster uses a unique spreading code in order to reduce interference during inter-cluster communication. Data is sent from the CH to the BS using a fixed spreading code and CSMA. Assumption made during construction of the sensor network is that each node is time synchronized and starts the setup phase at the same time. The BS sends out synchronized pulses to the nodes and the CH is awake all the time.

This HUCL protocol [22] is a hybrid of static and dynamic architecture. In static clustering, the clusters are formed once which reduces the overhead of CH node being elected. When the set-up begins in each and every round, energy is spent in transmitting control message to acquire information regarding the neighboring nodes and the routing path. Due to these control messages the overhead of the CH which in turn drains the energy of the CH. In order to overcome these defects, a dynamic clustering model is introduced in which CH is elected only once in several rounds. In DEEC [15], CH selection is based on the ratio of the residual energy of the node and the average energy of the network.

Due to imbalance in the previous existing protocols like LEACH, the author [23] has proposed a protocol which evenly distributes the work load among the member nodes and helps in reducing energy hole problem. The clusters use multi-hop communication to relay the data from the node where the data is generated to the destination (BS).

The Improved energy aware distributed unequal clustering protocol [15] is a heterogeneous protocol for wireless sensor network. The computation of the competition radius is based on three different parameters. They are: 1) remaining energy, 2) number of neighboring nodes and 3) the distance to the BS. When compared to other protocols explained earlier the relay node selection is with respect to the remaining energy after data transmission.

3. PRELIMINARIES

In our proposed protocol, the field is divided into two regions: Sensing region and Storage region. Heterogeneous nodes are deployed randomly in both the regions. The initial energy of the nodes are divided into two level where out of 100% of the deployed 80% of them are normal nodes and the remaining nodes are assumed to have energy greater than the normal nodes. The RN are combination of the normal and advance nodes. The MS is made mobile within a predetermined region. The MS in the proposed I-EADUC_RN pass only through the mid-line of the y-axis dimension.

The objective of the proposed algorithm I-EADUC_RN is:

1) To maximize the lifetime of the network with the help of RN and MS.
2) To reduce energy hole problem with efficient distribution of energy among the network with the help of efficient competition radius assignment.
3) The efficient mean of data transmission with the help of relay node selection based on energy spent in transmission and reception.
4) The minimization of data loss with the help of data storage in the RN.

Two level heterogeneity is used. The RN region is pre-determined. The role of the nodes at the initial stage is minimum. Once in every 100 rounds, the MS comes to its initial position.

3.1. Energy Model:

The energy spent in transmission Eq. (1) is respect to the distance. The energy [24] spent increases with fourth power of distance when the distance is greater than threshold distance (do).

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$$E_{tx}(l,d) = E_{tx-elec}(l) + E_{tx-amp}(l,d)$$

$$= \begin{cases} L*E_{elec} + l*E_{fs}*d^2, & d < d_{th} \\ L*E_{elec} + l*E_{amp}*d^4, & d => d_{th} \end{cases} \quad \text{---} \; (1)$$

The energy spent in reception Eq. (2) is same with different distance,

$$ER_x(l) = E_{rx}\text{-}_{elec}(l) = l*E_{elec}, \quad \text{---} \; (2)$$

3.2. Data Aggregation:

In the data aggregation model, the data collected by the CH is aggregated using infinite compressibility model. Regardless of the number of nodes in the cluster, the CH aggregates the collected data packets into a single data packet of fixed length.

4. PROPOSED PROTOCOL

In the proposed model of I-EADUC_RN, the idea of introduction of the RN node is to improve the effective lifetime of the network and hence the lifetime of the network before 25% node dead is more when compared to the other existing protocols. I-EADUC_RN phases:

1. Set-up phase,
2. Steady state phase.

4.1. Set-Up phase:

In the initial phase the nodes are randomly deployed with MS positioned at y-axis/2. The BS broadcasts a beacon signal with less amount of energy so that nodes closer to the BS receive the highest signal strength. This process is repeated till all the nodes in the network receive the beacon signal from the BS. With the received signal strength, each node computes its distance from the BS.

The set-up phase is divided into three sub-phases, each sub-phases is allotted a certain time space T1, T2, T3. The three sub-phases are

1. Neighbour node information collection (NNIC)
2. CH Competition (CHC)
3. Cluster Formation (CF)

At the beginning of set-up phase, a pre-determined region in the sensor field is denoted as Rendezvous region using Eq. (3) and the nodes within region are called RN which act as a mediator for data transmission from CH to BS.

$$\frac{ym}{2}(1 - Ry) \le yi \le \frac{ym}{2}(1 + Ry) \quad \text{---} \; (3)$$

ym represents y-axis dimension, yi represents the percentage of RN region to be covered [16]. The lesser the sub-phases, the lesser the energy spent in computation and more is the lifetime extension. Each sub-phase performs its function during the allotted time slots. For sub phase (1) - Neighbor node information collection starts its function in the beginning of 'T1', where each node broadcasts a node message which contains residual energy of the node 'i' and the node id of 'i'. Similarly each node in the sensor field shares their remaining energy with neighbor node in the field. So a node in the network can receive residual energy of other neighbor nodes at a pre-computed distance. Based on the received data, each node computes its average energy among its neighbor nodes Eq. (4). The node with remaining energy higher than the average energy gets a chance to participate in the CH selection.

$$Eavg_{res} = \frac{\sum_{j=1}^{nb} sj.Er}{nb} \quad \text{---} \; (4)$$

S_j represents the present node, $S_j.E_r$ represents the remaining of the neighbouring nodes, and Nb represents number of neighbours. At the end of the neighbour node information collection sub-phase, the wait time of each node is computed. Only based on this calculated wait time using Eq. (5) the node is to be elected as a CH for the present round or in the later rounds.

$$T = \begin{cases} \frac{Eavg_{res}}{Er} * T2 * Vr, & Er => Eavg_{res} \\ T2*Vr, & Er < Eavg_{res} \end{cases} \quad \text{---} \; (5)$$

This Vr [0.9, 1] is used to reduce the probability that two nodes send Head_Msg at the same time as random values generated are unique to each other. The node elected as CH transfer a Head_Msg to indicate their election as CH for the particular round. The node which doesn't receive any Head_Msg broadcasts a Head_Msg within its competition radius.

At the end of time 'T1', the CH computation begins to perform its function at the beginning of

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

time 'T2'. The parameters used for the computation of the competition radius using Eq. (6) are, residual energy, distance from BS and number of neighbour nodes. Based on this computation radius the number of member nodes to be included is decided.

$$Rc = \left[1 - \alpha\left(\frac{dmax - d(si,BS)}{dmax - dmin}\right) - \beta\left(1 - \frac{Er}{Emax}\right) + \gamma\left(1\frac{sj(nb)}{nbmax}\right)\right] Rmax \quad \text{--- (6)}$$

The α, β, γ represents weights (0, 1), Rmax represents maximum value of transmission radius, dmax, dmin represents maximum and minimum distance of nodes from BS, d(si,BS) represents distance of the jth node from BS, Er represents nodes residual energy, Emax represents maximum value of initial energy of the node in the network, Sj(nb) represents number of the neighbouring nodes in the jth node, Nbmax represents maximum value of neighbouring nodes. The nodes which fulfil the criterion of higher residual energy, greater distance from BS and lower number of neighbours should have larger competition radius. The cluster size of the node is controlled by the nodes distance, remaining energy and the number of neighbouring nodes in the network. The CH which is closer to the RN region has less competition radius, so it could balance its energy by spending less amount of energy in intra-cluster communication and spend its energy in relaying the data to the RN node which is at a minimum distance. The CH nodes broadcast a Head_Msg with the Rc (competition radius).

After the completion of the competition radius, the cluster formation sub phase starts at the beginning of time 'T3', where the nodes which are neither CH nor RN, join the CH which is within its competition radius and which CH is near to them based on distance. Then these nodes send a Joint_Msg to the CH which is at a minimum distance and the CH accepts the request and updates its Member_List. After the acceptance, the CH replies to the member nodes with a TDMA schedule. This TDMA schedule is used to reduce energy spent by the nodes in sensing the channel. So each neighbour node is assigned a separate time slot. The member nodes in a cluster will be awake only during the particular time allotted to them and go to sleep mode after that. In this way, the energy of the network is conserved. The member nodes of a cluster transfer data to the CH in single hop. This is known as intra-cluster communication. After the end of three sub-phases in the set-up phase, the steady state phase of the data transmission phase begins. Each member node in the cluster, transfers the data sensed by them to their respective CH. Then the CH aggregates the collected data and transfers this compressed data to the RN node in the RN region which is at a minimum distance to it. If the CH is far away from the RN region then data is relayed from one CH to the CH in the next layer. The next layer CH selection for relaying the data is based on the remaining energy of the CH 'j' after transferring the data to the RN node with minimum distance in the RN region. Next relay node Calculation using Eq. (7)

$$Erelay = \frac{sj.Er - sj.count \cdot Erx \cdot DM - (sj.count + 1) \cdot EDA \cdot DM - ETx \cdot DM}{Emax} \quad \text{---(7)}$$

$sj.Er$ represents current residual energy of the jth node, Sj.count represents number of member nodes of the jth node, ERx represents energy cost in receiving the data from its members DM represents packet length of the received data from the members, EDA represents energy spent in aggregating the received data from the members, ETx represents energy spent in transmitting the data packet from the CH.si to CH.sj over the relay distance and from the relay node to the RN node with minimum distance, Emax represents maximum value of remaining energy initially available in the network. i.e., the one with high remaining energy will be elected as the next hop relay node. The CH sj with higher value of Erelay (i.e., the CH with highest remaining energy) is elected as the next relay node. The relay node then transfers the data to the MS if the sink comes within a predetermined distance. For each and every CH elected, to be elected as a RN node a minimum distance is assigned to it. If the RN node dies then the next RN node with minimum distance is elected as the RN node with minimum distance for that CH.

NNIC	CHC	CF	Mini Slot 1	Mini Slot 2	Mini Slot 3	Major slot 1	Mini Slot 1

Fig.1. The Concept of Major slot 'M' and Mini slot 'm'

In addition to these improvements the idea of major slot and mini slot adds an advantage to the protocol. The cluster formed is retained for few data transmission phases. Here the data transmission phase is divided into several major slots 'M' and each major slot contain several mini slots 'm'. The mini slot is the phase where actual data transmission takes place and at the end of allotted mini slot count a major slot occurs. The major slot is the phase where the CH rotation takes place. A new CH is elected within a previously formed cluster. The new CH is elected based on the remaining energy. The node with remaining energy greater than the remaining energy of the present CH and its distance to the present CH is minimum. This process of CH rotation occurs in each major slot. This process could help in reducing the overhead of the CH in every set-up phase. So the energy spent in control message transmission is conserved by this method of combination of static and dynamic clustering.

5. ALGORITHM

- For all nodes 1:n
- Role (i)=='N'
- If ($\frac{ym}{2}(1-Ry) \le yi \le \frac{ym}{2}(1+Ry)$)
- Role7 (i)='R'
- End
- If (distance (i, j) <= d && Role7 (i)=='N')
- Eave=Eave + remaining energy
- average energy for node 'i' = Eave/count
- if (average energy > remaining energy)
- wait time =$\frac{Eavg_{rer}}{Er} * T2 * Vr$
- if(average energy <= remaining energy)
- wait time= $T2 * Vr$,
- sort the wait time
- the nodes with less wait time (role(i) =='C')
- the non-CH nodes sort CH based on distance, the closest one is the CH for that node
- role(i)=='M'
- transmit data from cluster member to CH
- transmit data from CH to selected relay node
- The relay node forwards the data to the RN which is at a minimum distance.
- Then the RN node transfer the data to the BS in single hop.

6. PROTOCOL ANALYSIS

i. The introduction of the concept of RN helps in reducing the overload of the CH and acts as an intermediary between the CH and the MS.

ii. The sink is made mobile in order to extend the lifetime of the network.

iii. The RN region helps in reducing long distance relaying of data as their location is in the mid of the sensor field.

iv. The remaining energy is computed among the neighbouring nodes so as to reduce the CH being elected.

v. The remaining energy, number of neighbour nodes and the distance from the BS is used in the computation of the competition radius helps in distributing the load of the CH in a cluster based on these parameters.

vi. The relay nodes selection is based on energy and distance so as not to deplete the energy of the next hop CH in relaying the data.

7. PERFORMANCE EVALUATION

There are four scenarios considered in order to prove the efficiency of the proposed protocol I-EADUC_RN. This simulation has been performed using MATLAB.

PARAMETERS	VALUES
Dimension	200*200,300*300,400*400
Number of nodes	100,200,200,600
Initial Energy	0.5 - 1.5 J
Energy consumed by radio electronics in transmit mode(E_{Tx})	50 nJ/bit
Energy consumed by radio electronics in receiving mode(E_{Rx})	50 nJ/bit
Energy consumed by the power amplifier on the free space model (E_{fs})	10 pJ/bit/m^2
Energy consumed by the power amplifier on the multi path model(E_{amp})	0.0013 pJ/bit/m^4
Energy consumed for data aggregation(E_{DA})	5 nJ/bit/signal
Rmax	110
c1,c2,c3 (i.e., α,β,γ)	0.33

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Four different scenarios are considered

- 200*200 m^2 with 100 nodes deployed
- 300*300 m^2 with 200 nodes deployed
- 400*400 m^2 with 200 nodes deployed
- 400*400 m^2 with 600 nodes deployed

7.1. Compared Study On Alive Nodes

The compares study on the live nodes in the sensor network field. The color indication:

- RED: I-EADUC (STATIC SINK) without Major slot and Mini slot
- BLACK: I-EADUC (STATIC SINK) with Major slot and Mini slot.
- GREEN: I-EADUC_RN (MS) without Major slot and Mini slot
- BLUE: I-EADUC_RN (MS) without Major slot and Mini slot

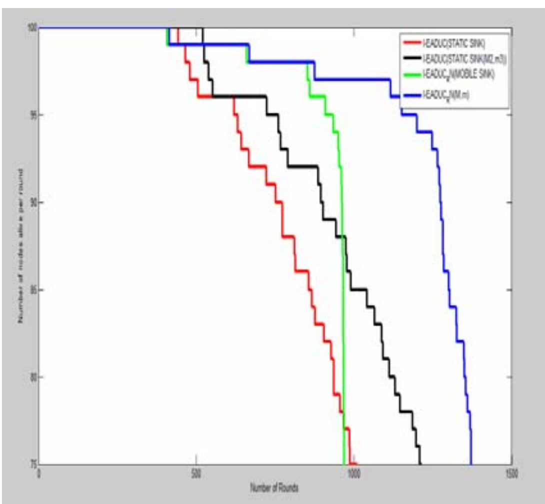

*Fig.7.1.1. 100 nodes deployed in 200*200 region with RN region from 84 to 116*

Tabulation.7.2.1. I-EADUC_RN (Static sink) without Major and Mini slot compared with I-EADUC_RN MS without and with major slot and mini slot.

ROUNDS	I-EADUC(STATIC SINK)	I-EADUC_RN (MS)	I-EADUC_RN (MS-M2,m3)
500	96	99	99
600	96	99	99
700	92	98	98
800	88	98	98
900	83	96	97
1000	71	18	97
1500	0	8	84

Tabulation.7.2.2. I-EADUC_RN (Static sink) with Major and Mini slot compared with I-EADUC_RN MS without and with major slot and mini slot.

ROUNDS	I-EADUC (STATIC SINK-M2,m3)	I-EADUC_RN (MS)	I-EADUC_RN (MS-M2,m3)
500	98	99	99
600	96	99	99
700	96	98	98
800	92	98	98
900	90	96	97
1000	85	18	97
1500	70	8	84

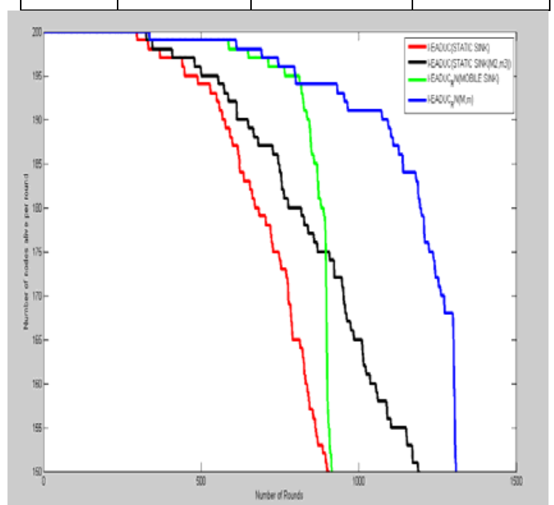

*Fig.7.1.2. 200 nodes deployed in 300*300 region with RN region from 126 to 174*

Tabulation.7.2.3 I-EADUC_RN (Static sink) without Major and Mini slot compared with I-EADUC_RN MS without and with major slot and mini slot.

ROUNDS	I-EADUC (STATIC SINK)	I-EADUC_RN (MS)	I-EADUC_RN (MS-M2,m3)
500	194	199	199
600	188	198	199
700	179	197	198
800	165	195	195
900	152	169	194
1000	122	141	192
1200	15	22	182

Journal of Theoretical and Applied Information Technology
31st December 2017. Vol.95. No 24

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Tabulation.7.2.4. I-EADUC_RN (Static sink) with Major and Mini slot compared with I-EADUC_RN MS without and with major slot and mini slot.

ROUNDS	I-EADUC (STATIC SINK-M2,m3)	I-EADUC_RN (MS)	I-EADUC_RN (MS-M2,m3)
500	195	199	199
600	192	198	199
700	187	197	198
800	189	195	195
900	175	169	194
1000	161	141	192
1200	154	22	182

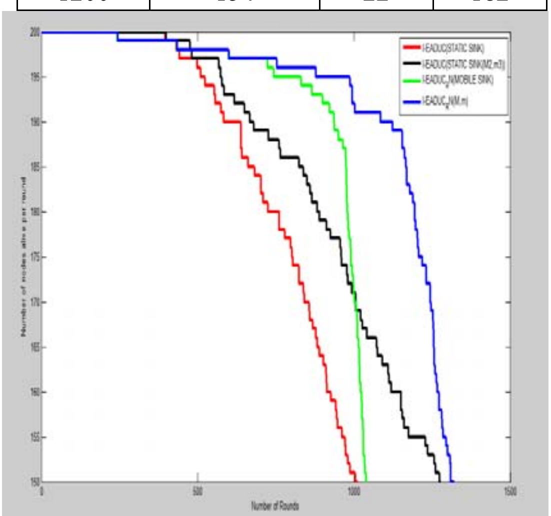

*Fig.7.1.3. 200 nodes deployed in 400*400 region with RN region from 168 to 232*

Tabulation.7.2.5. I-EADUC_RN (Static sink) without Major and Mini slot compared with I-EADUC_RN MS without and with major slot and mini slot.

ROUNDS	I-EADUC (STATIC SINK)	I-EADUC_RN (MS)	I-EADUC_RN(MS-M2,m3)
400	199	199	199
500	196	198	198
600	190	197	197
800	174	195	196
900	164	193	195
1000	150	171	191
1100	138	120	190

Tabulation.7.2.6. I-EADUC_RN (Static sink) with Major and Mini slot compared with I-EADUC_RN MS without and with major slot and mini slot.

ROUNDS	I-EADUC(STATIC SINK-M2,m3)	I-EADUC_RN(MS)	I-EADUC_RN(MS-M2,m3)
400	199	199	199
500	197	198	198
600	193	197	197
800	186	195	196
900	179	193	195
1000	171	171	191
1100	164	120	190

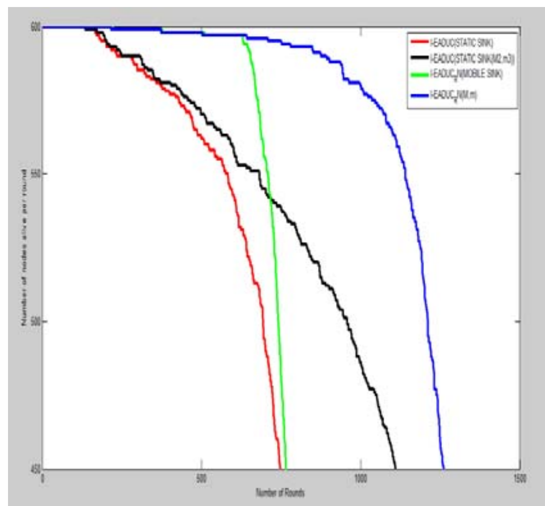

*Fig.7.1.4. 600 nodes deployed in 400*400 region with RN region from 168 to 232.*

Tabulation.7.2.7. I-EADUC_RN (Static sink) without Major and Mini slot compared with I-EADUC_RN MS without and with major slot and mini slot.

ROUNDS	I-EADUC(STATIC SINK)	I-EADUC_RN (MS)	I-EADUC_RN(MS-M2,m3)
500	562	585	597
600	546	597	597
700	492	556	596
1000	10	68	577
1100	0	62	565
1200	0	59	510
1300	0	55	389

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Tabulation.7.2.8. I-EADUC_RN (Static sink) without Major and Mini slot compared with I-EADUC_RN MS without and with major slot and mini slot.

ROUNDS	I-EADUC(STATIC SINK-M2,m3)	I-EADUC_RN (MS)	I-EADUC_RN(MS-M2,m3)
500	571	585	597
600	561	597	597
700	546	556	596
1000	480	68	577
1100	458	62	565
1200	423	59	510
1300	389	55	389

As you can infer from the above graph that the effective stability is more in Fig.7.1.4 when compared with Fig.7.1.3 because the number of nodes deployed within the RN region are large. Therefore the CH near the RN region has more chance of not losing its energy in data transmission from the CH to RN. This is due to the fact that even if a RN node which is at a minimum distance dies, the probability of selection of next RN could also be at a minimum distance. The RN transfers data to the BS till the BS is within a distance of d_0 (87.5m^2).

7.2. Residual Energy Compared Study:

The residual energy of the network is the remaining energy of sum of all alive node's energy in the network. Four different scenarios are considered

- 200*200 m^2 with 100 nodes deployed
- 300*300 m^2 with 200 nodes deployed
- 400*400 m^2 with 200 nodes deployed
- 400*400 m^2 with 600 nodes deployed

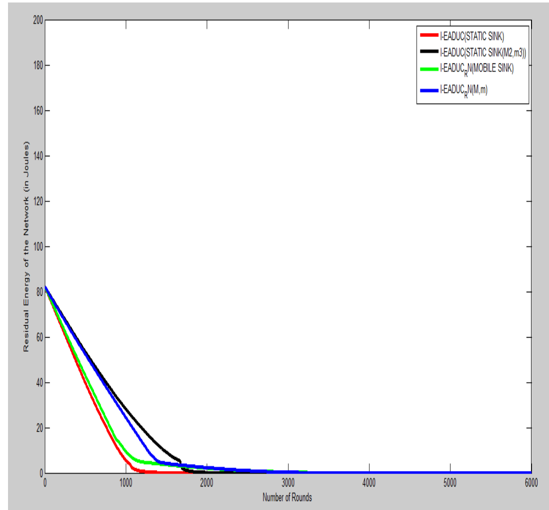

*Figure.7.2.1. The remaining energy of 100 nodes in 200*200 m^2*

*Tabulation.7.3.1. The compared tabulation of 100 nodes in 200*200m^2*

ROUNDS	I-EADUC (Static Sink)	I-EADUC (Static Sink) (M=2,m=3)	I-EADUC (MS)	I-EADUC (MS) (M=2, m=3)
300	60	66	62	66
400	50	60	52	60
500	38	50	40	50
800	30	47	35	45
900	14	37	16	36
1000	3	28	8	24

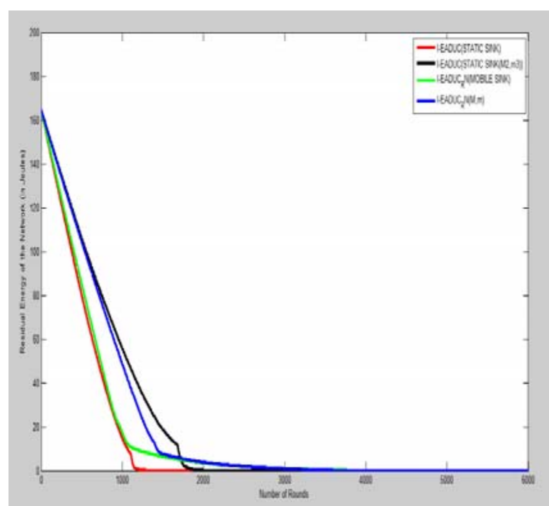

*Figure.7.2.2. The remaining energy of 200 nodes in 300*300 m^2*

*Tabulation.7.3.2. The compared tabulation of 200 nodes in 300*300m^2*

ROUNDS	I-EADUC (Static Sink)	I-EADUC (Static Sink) (M=2,m=3)	I-EADUC (MS)	I-EADUC (MS)(M=2,m =3)
300	130	140	130	140
400	99	118	100	118
500	80	110	85	108
800	40	75	41	70
900	25	65	25	60
1000	15	58	17	50

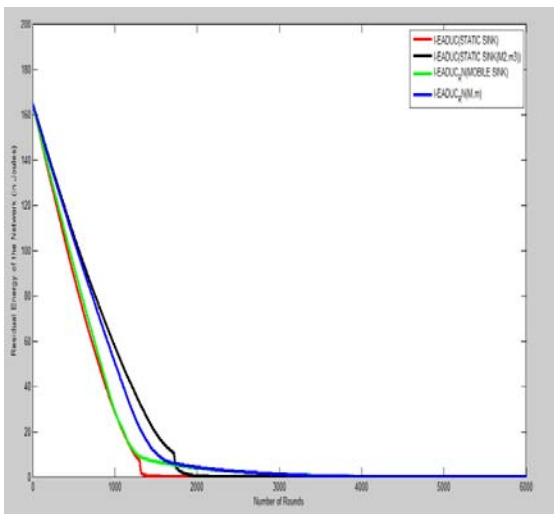

*Figure.7.2.3. The remaining energy of 200 nodes in 400*400 m^2*

*Tabulation.7.3.3. The compared tabulation of 200 nodes in 400*400m^2*

ROUNDS	I-EADUC (Static Sink)	I-EADUC (Static Sink) (M=2,m=3)	I-EADUC (MS)	I-EADUC (MS) (M=2 ,m=3)
300	120	128	120	128
400	105	119	108	118
500	90	109	92	108
800	49	75	51	70
900	41	68	42	61
1000	28	58	28	50

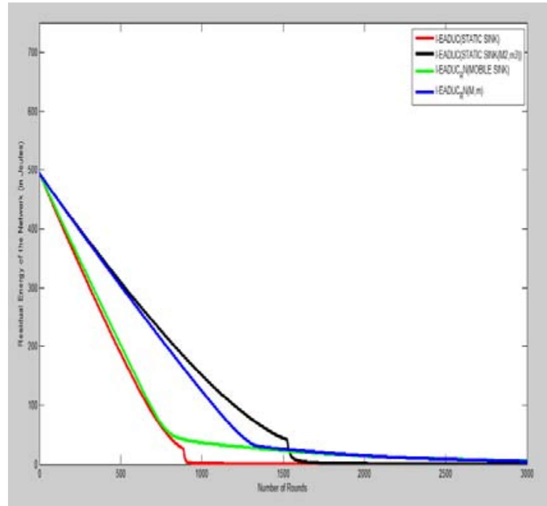

*Figure.7.2.4. The remaining energy of 600 nodes in 400*400 m^2*

*Tabulation.7.3.4. The compared tabulation of 600 nodes in 400*400m^2*

Rounds	I-EADUC (Static sink)-without M,m	I-EADUC (Static sink)-with M,m	I-EADUC_RN (MS)-without M,m	I-EADUC_RN (MS)-with M,m
300	313	379	322	379
400	257	362	264	362
500	175	309	193	305
600	130	298	146	292
1000	0.33	180	39.3	162
1300	0.2	109	32	75
2000	0	0	21	21

Compared view to I-EADUC and I-EADUC_RN without (M,m):

As inferred from the above graph the remaining energy of the I-EADUC as compared to I-EADUC_RN without Major slot and Mini slot is less in the beginning stage as more number of nodes are alive in the I-EADUC_RN and after that at the later stage the remaining energy of the I-EADUC_RN is low. This is because the nodes spend the same amount of energy but in the beginning stages the energy is spared by the RN nodes and after that as one or more RN nodes at a minimum distance to CH starts dying the CH has to spent more energy in transmitting data to the next RN node with minimum distance.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Compared view to I-EADUC and I-EADUC_RN without (M,m):

As you can infer from the design flow that the energy spent is similar in both the cases of I-EADUC and I-EADUC_RN but the difference is that the energy spent is evenly distributed in the case of I-EADUC_RN. From the above graph, it is inferred that the remaining energy is more or less same for I-EADUC and I-EADUC_RN. But in I-EADUC_RN the effective lifetime is more and hence more number of nodes are alive and this leads to more energy spent in control message transmission and the energy is also spent in transmitting data to the MS and hence they decrease rapidly when compared to I-EADUC.

7.3. CH Count Compared View On Average Energy:

There are two scenarios considered

- 400*400 m^2 with 200 nodes deployed
- 400*400 m^2 with 600 nodes deployed

When comparing the previous existing protocol I-EADUC with the proposed I-EADUC_RN the average energy of the network is low. For this reason the CH count goes low. This is because the energy spent is more and balanced for a certain period of time and as loss keeps on increasing the network goes off all of a sudden even then there are few nodes with energy greater because of not being used (RN nodes which are not at a minimum distance to the CH close to the RN region) and the CH close to the RN region also lose only less amount of their energy.

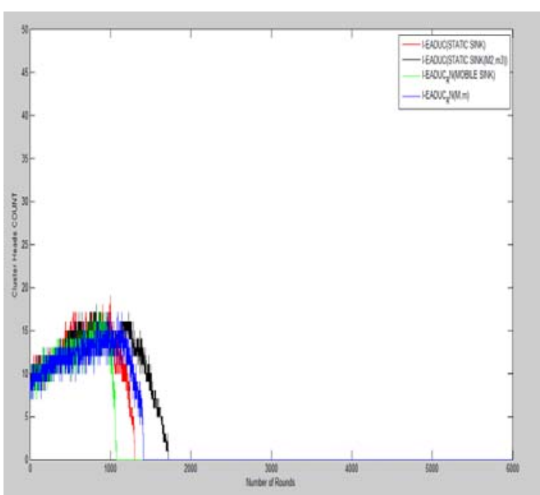

*Figure.7.3.1. The CH count at 400*400 m^2 with 200 nodes*

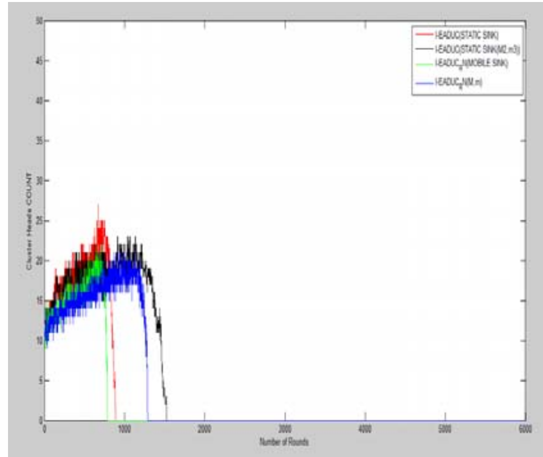

*Figure.7.3.2. The CH count at 400*400 m^2 with 600 nodes*

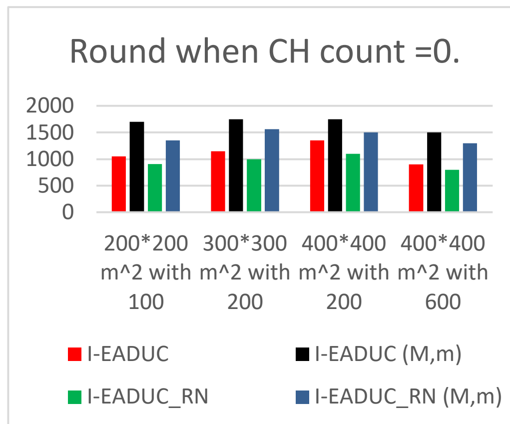

*Figure.7.3.2CH count at 400*400m^2 with 600 nodes*

7.4 Throughput Compared Study:

The proposed algorithm compared with the previously existing algorithms using simulation in MATLAB under different scenarios.

200*200 m^2 with 100 nodes deployed**:**

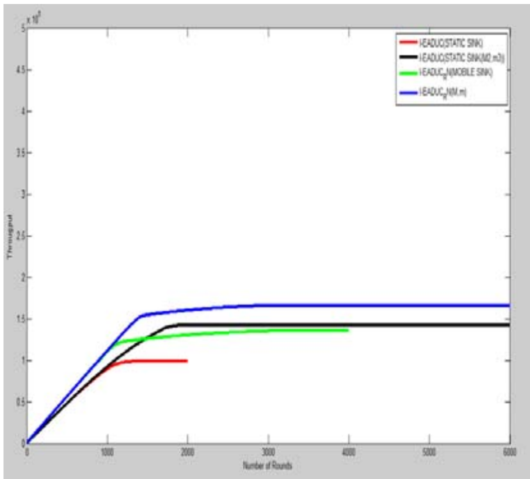

*Fig 7.4.1 Cumulative Throughput of data packets in 200*200 with 100 nodes.*

300*300 m^2 with 200 nodes deployed:

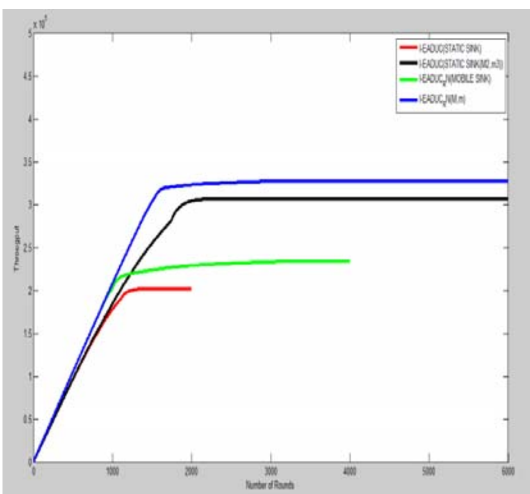

*Fig 7.4.2. Cumulative Throughput of data packets in 300*300 with 200 nodes.*

400*400 m^2 with 200 nodes deployed:

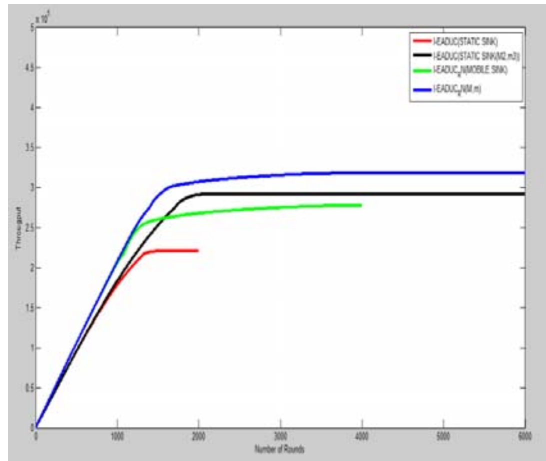

*Fig 7.4.3 Cumulative Throughput of data packets in 400*400 with 200 nodes.*

400*400 m^2 with 600 nodes deployed:

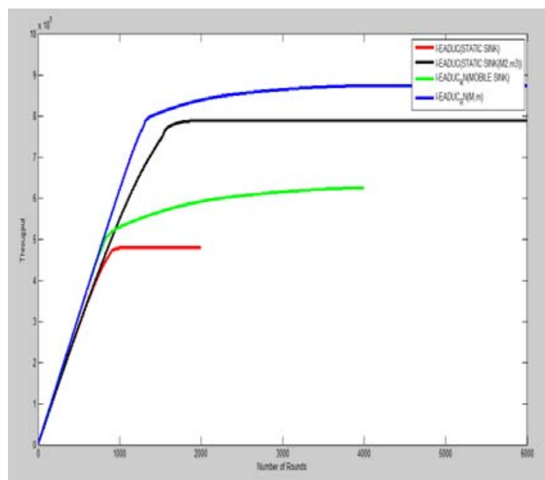

*Fig 7.4.4 Cumulative Throughput of data packets in 400*400 with 600 nodes.*

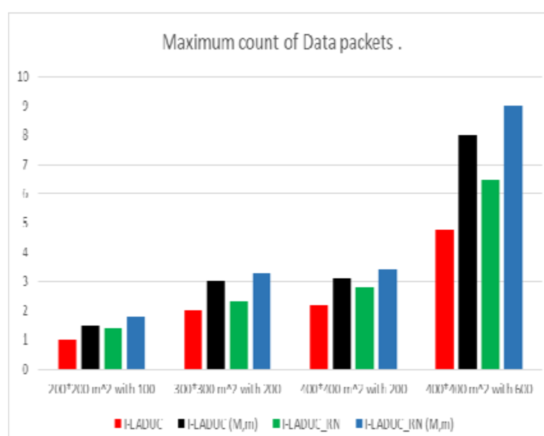

Fig 7.4.5 Throughput of data packets

The above plot reveals that as the number of alive nodes is more, then number of data packets reaching the BS will be high. In the proposed I-EADUC_RN the data packets from the RN node reaches the BS only when the distance between the RN node and the BS is less than d_0. As the MS come to its initial position once in 100 rounds, there would not be much delay in the data packets reaching BS as the distance constrain for data transmission is d_0.The throughput is the count incremented by one when a packet reaches the MS. The throughput is cumulative of all the packets reaching the BS from the start till end. The packet count of proposed algorithm increases as the number of alive nodes is more so the CH count is maintained; therefore the number of packets reaching the BS is high. The compression deployed here is less advantageous as the packet size is only reduced to a single packet of fixed length.

8. RESULT

As the proposed I-EADUC_RN shows increase in efficiency , the effective lifetime of the network that is before 25% of the nodes death,this protocol is comparatively more efficient. The inclusion of the Static and Dynamic CH concept has proven to reduce the CH overhead. As compared to I-EADUC_RN without (M,m) the I-EADUC_RN with (M,m) is more efficient and the lifetime of the network is also increased. The further research can be made on this protocol by introducing mobile RN concept.

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