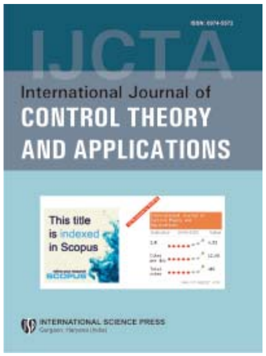

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Energy Efficient Routing in Unequal Clustering with Dynamically Variable Cluster Size Within Tracks for Lifetime Improvement in MWSN

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Abstract: Extensive research is ongoing in Mobile Wireless Sensor Network (MWSN) to improve network lifetime and handling mobility. Unbalanced energy consumption among sensor nodes cause premature death of some nodes. Unequal clustering has been proved as one of the successful technique to balance energy consumption in large WSN. Most works on unequal clustering considers cluster size within track to be fixed ,cluster members are within one hop distance. However it is difficult to find a fixed number of nodes within cluster head(CH) range in all rounds to form clusters in MWSN, as nodes change position continuously due to mobility.CH may not be able to find enough nodes to form cluster, as nodes might be out of CH range. This work is carried out with dynamic cluster size within tracks in two hop region and preferential relay node selection for inter cluster communication to cover maximum distance in every hop. By the virtue of position, nodes range varies while participating in inter cluster communication. Dynamic cluster size and relay node preferential selection improves network life and reduces number of hops for inter cluster communication.

Keyword: *Unequal cluster, Tracks, Variable cluster size, MWSN, Network life.*

1. INTRODUCTION

[1] MWSN are more versatile than static sensor networks as they can be deployed in any scenario and cope with rapid topology changes. [9] Wireless Sensor Network(WSN) do not support monitoring of habitat or in carrying out search and rescue operations, as all sensor nodes are static in nature. Such applications are well supported by MWSNs. [16] There are many protocols proposed for other wireless networks which can handle mobility *i.e* mobile ad-hoc networks. However, these protocols cannot be used directly in MWSNs' due to resource constraints like limited battery power of sensor nodes, computational speed, human interface of node and density of nodes in network. Leading into a special category of algorithms for WSN with sensor node mobility or sink mobility or mobility in both. The ability of MWSN to inter connect virtual and physical world has made them popular these days. Mobile sensors are similar to WSN sensors in functioning .Mobility can be achieved by attaching nodes to any randomly moving elements moving with very low speed in the sensing area

and are position aware. Due to mobility MWSN face more challenges than WSN, such as handling resources efficiently and managing the routes to sink as nodes position changes continuously causing physical topology of network to change, leading for reclustering often. Lot of control messages are to be exchanged to determine the new location, in turn depletes more battery power decreasing network life.

Clustering is one of the popular technique used to achieve energy efficiency. Based on some predefined conditions nodes are grouped and a group leader is either elected or selected and called as CH. These coordinates activities among cluster members, members can only communicate with CH and CHs collects data from members and transmit to sink directly or by constructing routes to sink. Therefore CH selection/ election is challenging and plays an important role in improving network life. Electing CH and relieving member nodes from communicating directly with sink, reduces nodes energy usage. But CH spend more energy than members as it collects data in cluster and also participates in CH to sink communication causing energy imbalance. To improve network life CH rotation is performed among cluster members.[2]"LEACH" is one of the popular clustering protocol with periodic CH rotation for achieving energy efficiency. This protocol is for small networks or small areas .As it has pre determined number of clusters and CHs communicate directly with sink, CH distribution cannot be performed in an acceptable way. [8] CH rotation helps in energy balancing among cluster members but CHs near sink depletes more energy in inter cluster communication as they act as relay nodes to most of data packets generated in network i.e hot spot problem. [3]"LEACH-Mobile" is an improvement of LEACH to overcome "hot spots". Creates clusters and identifies member nodes and carries out intra cluster communication within specified TDMA slot. Hence improves data success rate even in a dynamically changing environment.

[8] In clustering, nodes perform their duties at different levels and energy expenditure at different levels are different. Clusters member nodes are spending less energy than cluster heads, leading to unbalanced energy expenditure among nodes at different levels. If cluster size is maintained constant throughout sensing field, far away cluster heads from sink spend less energy on inter cluster communication, as they relay less inter cluster data of other clusters. Whereas cluster heads near sink spend more energy for inter cluster communication as they route more number of packets to sink. This creates energy consumption imbalance in the network and cause premature death of some nodes, causing energy holes decreasing network life. Therefore if their cluster size is smaller than far clusters energy balancing can be achieved, this is called as "unequal clustering" technique .This is a one of most accepted mechanism to address hotspot problem . Cluster size around sink area is small than far region cluster size. As small clusters spend less energy in intra communication and participate more in inter cluster communication, energy consumed is balanced .

In this work cluster size is varied from track to track and also within track. Cluster size within a track is not maintained constant as in earlier works. Tracks have different range for cluster formation hence cluster size also varies from track to track. Variable size within tracks is adopted as it is difficult to find a fixed number of member nodes always in a dynamic topology. Due to nodes mobility neighboring nodes might have moved out of cluster range during next reclustering period and CH may not find enough nodes in every round to form a cluster and in such cases some earlier works have assumed that stand alone nodes can transmit directly to sink. Cluster size is dynamically varied within a pre determined range inside tracks. Clusters are formed in two hop coverage region of CH. Though two hop cluster area slightly increases energy consumption in intra communication, but reduces number of direct communication from non cluster member called standalone node and sink. This takes care of balancing energy at cluster level .

This work is carried out with dynamic cluster size within tracks and clustering in two hop range, CH election parameters are nodes remaining energy and mobility. Further for inter cluster communication preferential relay node selection irrespective of tracks is used. This selects nodes within common region of two neighboring clusters to act as relay node, if no such nodes are found then data is transmitted by selecting CHs in the path. This reduces load on CHs and balances load, energy consumption among nodes and reduces number of hops. we propose unequal clustering with dynamically variable cluster size in tracks and preferential relay node selection to balance energy usage among members and CHs for lifetime improvement of MWSN. Challenges while using mobile sensor nodes are dynamic topology , continuous reclustering, issues in terms of connectivity and cluster coverage and inter cluster communication paths are dynamic due to node mobility. Mobility changes the following in every round during clustering,

1. Number of clusters formed in tracks,
2. Size of clusters in tracks.

The objectives and contributions of the work are :

1. Form unequal clusters among tracks to balance energy consumed for inter and intra cluster communication.
2. To avoid single node clusters, cluster size is not fixed can vary dynamically within tracks, saves both intra and inter cluster energy .
3. Reduce number of hops for inter cluster communication by varying sensor range by the virtue of nodes position in sensor field.

Further this paper is organized as follows. In Section II a brief discussion about work done in this area is presented. Section III, lists the assumptions related with sensor field. A tailor made unequal clustering with dynamically variable cluster size within tracks protocol is discussed in section IV. Next evaluation of the work with discussion on obtained results in section V is presented . Finally in section VI work is concluded.

2. RELATED WORK

Most of earlier works in “unequal size clustering” area considers that cluster size and its distance to sink are inversely proportional to one another. Near sink small ones and far away large clusters are formed. One of the earliest work on “unequal clusters” is [4] ,here nodes are static, CH is assumed to be rich in resource and are always in center of cluster. this assumption is not applicable for MWSNs. As an improvement [10] elects cluster head by using a random number set by each node ,if this value of any node crosses a threshold value then it is a candidate for CH election. [11] Further improves cluster head selection process by using neighboring nodes average residual energy instead of only one nodes residual energy. Weight function is computed considering distance and remaining energy to determine competition range for improving lifetime .

[l] proposes an approach of zone based clustering head selection algorithm. Sensor field is divided into tracks and zones. clusters are formed among nodes in one zone. Initially one node is picked as CH. For CH rotation another node having highest remaining energy is also selected. [15] “EPUC” all clusters in one track are of same size, data transmitted to BS by relay through CHs. Proposes a condition for inter- CH distance, which is adaptively adjusted helps in load balancing among CHs. [9] proposes a protocol that considers node mobility. sensor field is bifurcated as zones. Maintains routes to sink by updating node information, hence leading to low new route formation overheads.

[8] proposes a protocol for WSN where sensor nodes are location unaware. Hence location identification is given importance and node location identification is performed by sink using power controlled capability directional antenna. Sensor area divided into concentric rings with sink at center. Clusters formation starts from second ring onwards, *i.e* in first ring no clusters formed all nodes in this ring act as relay nodes to balancing energy consumption. [5] this work clusters within circular tracks. tracks are divided into triangular sectors. One main CH and many auxiliary CHs are formed. all CH form an chain within sector, auxiliary-CHs collect and transmit to the major-CH, then major-CH to sink, not applicable for MWSNs.

[6] presents an approach for energy consumption reduction by clustering approach. CH selection is done based on the number of neighboring nodes within one hop distance present at that instant of time. As number of neighboring nodes present keeps changing due to mobility, CH rotation is performed efficiently as neighboring node list is updated frequently. [7]proposes a protocol to handle audio, video continuous data streams. To deliver continuous data in dynamically changing topology due to mobility of sensor nodes is carried using cross-cluster handover mechanism and delay is reduced by path redirection scheme. [13] an improved distributed unequal clusters are formed considering remaining energy, number of nodes in cluster area and distance to BS. Re cluster process happens within cluster, reducing energy consumed if central clustering was performed.

[12]Most of the WSN clustering protocols use single hop communication for communicating inside the cluster, but due to random mobility if cluster area is declared as one hop many nodes may not be included in any cluster. Hence in this work intra communication performed using both single and two hop to reduce number stand alone nodes or single node clusters

3. ASSUMPTIONS

3.1. Preliminary assumptions of nodes and sensor field

Assumed Sensing area is flat. Sensor are homogenous, position aware and mobile. Nodes follow Random bounded mobility and Pause Time model. After moving to new location nodes pause for a small time. One static sink with unlimited energy placed within the range of track-1. The words base station and sink are interchangeable. Sensor field is divided into tracks and tracks are further divided into zones. Nodes are capable of measuring their own residual energy after intra and inter communication, and energy spent on mobility in every round. Nodes when present in different tracks will have different range for inter cluster communication.

4. OVERVIEW OF UNEQUAL CLUSTERING WITH DYNAMICALLY VARIABLE CLUSTER SIZE WITHIN TRACKS

This work is an energy balanced and efficient scheme. All nodes are assumed to be homogenous. Each round is broadly classified into clustering phase and inter communication phase. Initially all nodes in three tracks broadcast their residual energy compares its energy with neighboring nodes energy *i.e* nodes within one hop region. If its own energy is less than any of neighboring nodes it withdraws itself from CH election process else declares as CH and completes election process.CH broadcasts an joining message ,nodes within two hop region willing to join acknowledges and clusters are formed. CHs collect sensed data from member nodes and transmits it to sink in communication phase by multi hop Path. The next node in path is selected in a way to cover a maximum distance in every hop. To cover maximum distance in every hop, node coverage area varies from track to track Nodes range depends on the track they are present in a particular round. Hence range varies on the virtue of nodes' position in the field. Different tracks are assigned with different node range while participating in inter cluster communication. Range is directly proportional to distance from sink. The above steps are repeated till sufficient nodes are present in network to carry out inter cluster communication.

The network layout used for proposed work is as shown in Figure 1. Sensor area is divided into three tracks as track-1 track-2 and track-3 represented as T1, T2 and T3 respectively.T1 is further divided into four zones, T2 into three zones and T3 into two zones. The track size and zone size increases as we move away from sink, to form big clusters in far regions and small clusters in regions near to sink. In Figure. 2, Totally 113 mobile nodes are deployed in different tracks and zones. TI nodes are in red colour, T2 nodes are in blue colour and T3 nodes are in green colour. The red circle within blue square near T1 is one stationary sink.

4.1. Clustering

This work mainly contributes to clustering as below

1. Elects CHs from nodes present within one hop region,
2. CH election based on nodes prediction residual energy vector- energy remaining at the end of present round.
3. variable cluster size in tracks,
4. Communication within cluster single or two hop.

Prediction residual energy vector is used to elect CH from one hop nodes. This vector predicts residual energy considering distance between nodes of one hop distance that would be remaining after intra cluster communication, considering nodes' remaining energy at the end of previous round.

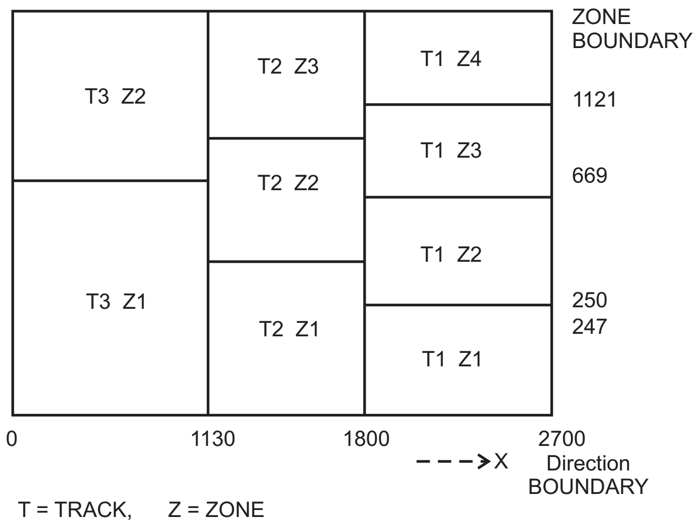


Figure 1: Tracks and zones boundary

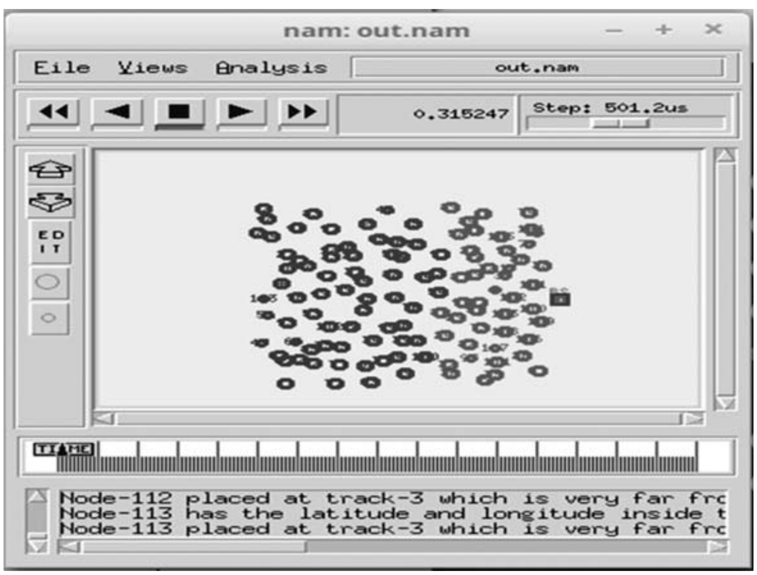


Figure 2: Sensors deployment in tracks

In first round as all nodes will have same energy to initiate election process nodes are allowed to deplete a small amount of energy which differs from node to node ,this is done only in first round. In subsequent rounds remaining energy at the end of previous round is used for energy prediction. A CH is elected among nodes present within one hop distance in same track, considering residual energy of nodes . One node is elected as CH with high remaining energy than any of other nodes in its neighbour hood. If energy that is remaining at the end of previous round is directly used for CH election, then real energy used up for transmission may be different. As at the end of the round CH might have spent more energy and its residual energy may come down below minimum threshold level and become dead node which will be unable to perform its duties. Hence in this work remaining energy calculations for intra cluster communication are done before CH election and actually transmission. Power spent on data transfer depends on packet size, hop and distance for which it is transmitted. Each node calculates its energy to be spent if it is elected as a CH and broadcasts predicted remaining energy at the beginning of every round, nodes become silent if their own predicted remaining energy is less than its neighbours else assumes itself a winner . As calculations are performed before action, nodes whose remaining energy is close to minimum are avoided from being elected as CH enhancing nodes life time. Nodes within two hop region are given a chance to join the cluster by cluster-join message . Nodes which receive this can join the cluster by giving acknowledgment .The size of clusters formed is not uniform throughout the track but keeps changing as per the availability of nodes in vicinity of CH. The cluster size in tracks are , track-1, clusters' maximum size 3, track-2 ,clusters' maximum size 6, track-3, clusters' maximum size 9.

In Figure 3, track-1 cluster-7 is of size 3,with nodes 26,61,106. Node 26 is the CH..In Figure 4, track-2 cluster-4 has only five nodes. That is nodes 7,19,31,44 and 63 have formed a cluster with node- 44 as CH. The maximum cluster size for track-2 is 6.But as CH was able to get acknowledgement only from 5 nodes within two hop distance this cluster has only 5 nodes which is less than the maximum limit 6.Therefore cluster size in track can be 1,2,3.In track-2 it can be 1,2,3,4,5,6 and in track-3 it can be 1,2,3,4,5,6,7,8,9. In Figure 5, track-3 cluster-1 nodes are 1,4,14,18,21,27,28,33,40 a total of 9 nodes have formed cluster. In this way clusters of varying sizes but less than maximum size of that track are formed.

4.2. Inter cluster communication

This is the communication between CHs and sink using multi hop communication. Next hop node selected is the farthest node present in the direction to sink. Node range while participating in inter cluster communication for track-1 = 300 mts, track-2 = 400 mts and track-3 = 500 mts. Nodes which are common for neighboring clusters are given first preference in selection of next hop node as they cover greater distance, if no such nodes are found CHs are selected .

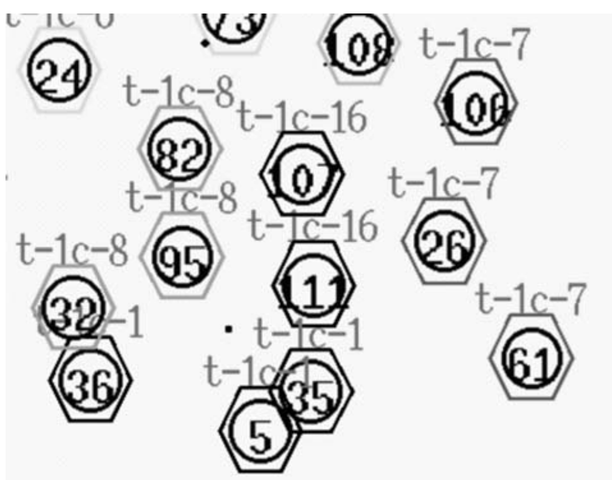


Figure 3: Track-1 cluster-7,nodes 26,61,106

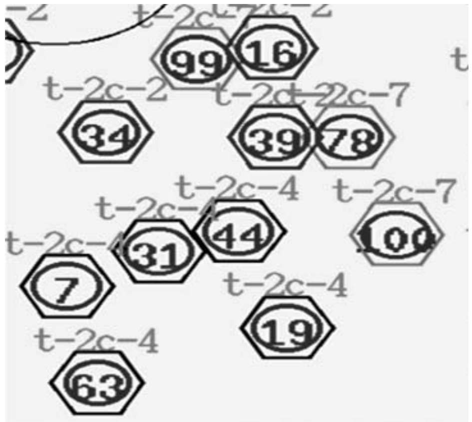


Figure 4: Track-2 cluster-4,nodes 7,19,31,44,63

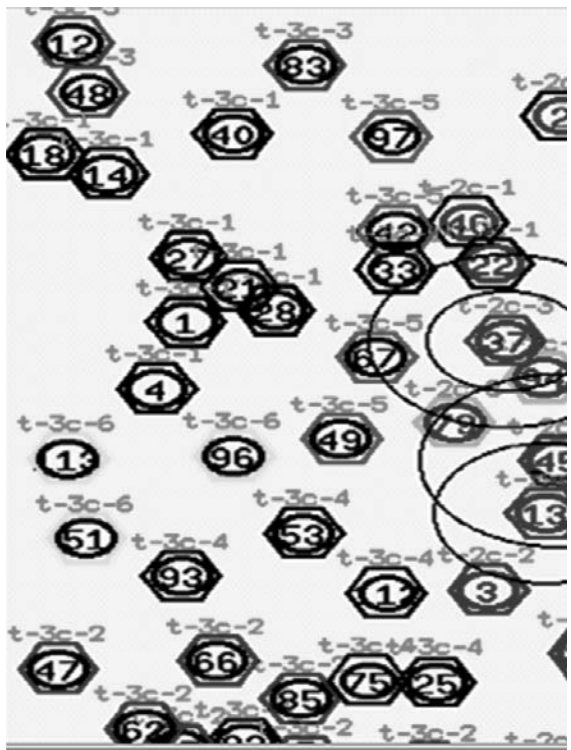


Figure 5: Track-3 cluster-1, nodes1,4,14,18,21,27,28,33,40

Figure 6 give the path details of clusters and energy used for inter cluster communication. The number of hops required is less to transmit data for same distance in comparison with communication using only CHs ,hence data travels for more distance in every hop in tracks.

Distance between any two nodes is calculated using Euclidian equation

$$d(x, y), (a, b) = \sqrt{(x-a)^2 + (y-b)^2} \quad (1)$$

d = distance between two node ,

(x, y) = coordinates of node- n_1,

(a, b) = coordinates of node- n_2

5. RESULTS AND DISCUSSIONS

NS2 simulation tools are used to test and evaluate the work. The setup values for simulation of the of Unequal Clustering With Dynamically Variable Cluster Size Within tracks are summarized in table 1. Mobile nodes use random mobility with a pause between mobility. Nodes can hear one another if present within a separation of 250 meters. Minimum space between nodes is 10mts. Topology changes once in 10 msec. This work concentrates on balancing energy consumption in the network, by conserving energy during intra cluster communication and reducing number of hops. If less energy used by nodes to perform different tasks network life is improved.

The performance of proposed work is evaluated for :

1. **Number of CH:** Gives the distribution of nodes in rounds in random topology.
2. **Network residual energy:** Total remaining energy of network at the end of respective round.
3. **Network lifetime:** Represents the time when first node in the network dies. This is evaluated by increasing the power dissipation of nodes for transmitting data /mts.

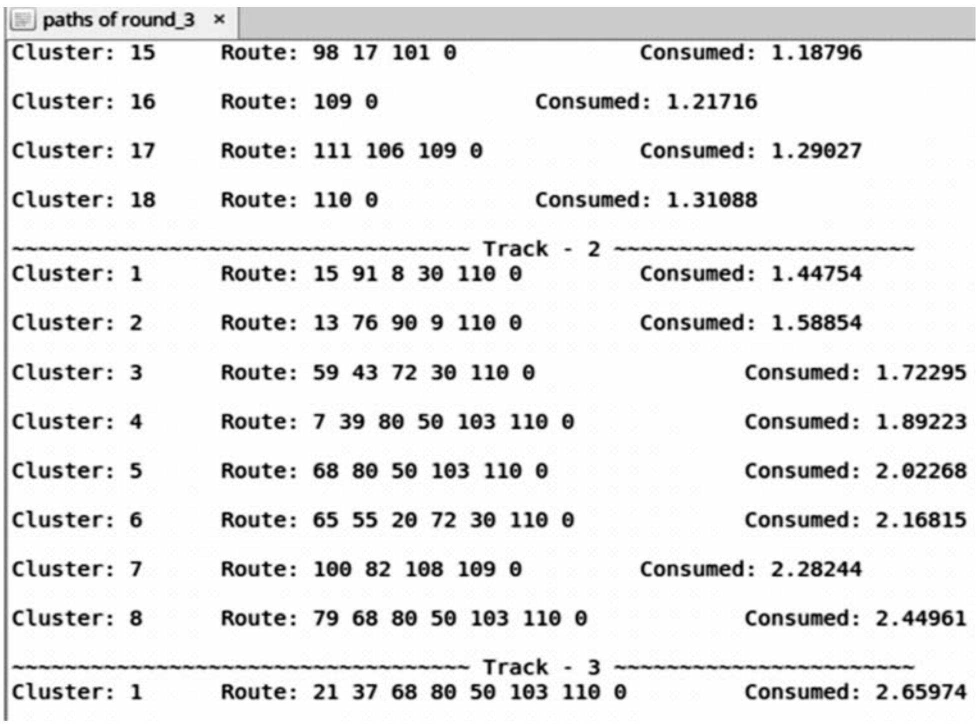
5.1. Number Of CH

1. **Varying Number Of Rounds:** In figure 7,8,9 it is found that number of clusters formed in different tracks are in the same range for different rounds. This indicates that number of clusters formed in every round is almost constant even in a dynamic topology.
2. **Varying sensor range and cluster size:** Sensor range in track-1 is R1, similarly R2 and R3 for track 2 and 3. Set A and set- B are two combination of range used for simulation purpose, as shown in table-2. By varying maximum cluster size in tracks, energy expenditure on inter cluster communication is studied and the results are plotted. Three combination of cluster size are considered for simulation as shown in table- 3. Evaluation of Table 2,3 values, for set-A and set-*b* is carried out separately and results are plotted in figure 10,11, X-axis represents cluster size and Y-axis represents total energy spent by all clusters in individual tracks for transmitting their collected data to sink. Energy spent in track-1 is represented in blue, in track-2 by red and in track-3 by green. Simulation is carried out for three combination of maximum cluster size (CS) for each track as in table-3. In Figure 10,11 , from energy expenditure of inter cluster communication ,It is evident that set-A with CS = 3,6,9 consumes least inter cluster energy. Therefore all simulation trials of this work are carried out using set-A and CS = 3,6,9 setting.

Table 1
Simulation setup

Parameters	*Values*
Number of nodes	113
Simulation area	2700*2500 mts
Sensor node deployment	Random deployment
Number of sink	1
Mobility for nodes	Random mobility
Power consumption in node for mobility/meter	0.001 J/mts
Power consumption for sending and receiving the data/byte/meter	0.0001 J/mts
Transmission technology	wireless RF
Initial energy of sensor nodes	100 J
Operating Frequency	914 MHz

Parameters	*Values*
Data rate	2Mbps
Data size	512 bytes
Propagation model	Two ray ground
Antenna used	Omni directional antenna
Transport protocol	UDP
Application	CBR
Transmission range of each node	250 mts
Time for each round	10msec



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paths of round_3 ×
Cluster: 15     Route: 98 17 101 0            Consumed: 1.18796
Cluster: 16     Route: 109 0          Consumed: 1.21716
Cluster: 17     Route: 111 106 109 0          Consumed: 1.29027
Cluster: 18     Route: 110 0          Consumed: 1.31088
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Track - 2 ~~~~~~~~~~~~~~~~~~~~~~~
Cluster: 1      Route: 15 91 8 30 110 0       Consumed: 1.44754
Cluster: 2      Route: 13 76 90 9 110 0       Consumed: 1.58854
Cluster: 3      Route: 59 43 72 30 110 0              Consumed: 1.72295
Cluster: 4      Route: 7 39 80 50 103 110 0           Consumed: 1.89223
Cluster: 5      Route: 68 80 50 103 110 0             Consumed: 2.02268
Cluster: 6      Route: 65 55 20 72 30 110 0           Consumed: 2.16815
Cluster: 7      Route: 100 82 108 109 0       Consumed: 2.28244
Cluster: 8      Route: 79 68 80 50 103 110 0          Consumed: 2.44961
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Track - 3 ~~~~~~~~~~~~~~~~~~~~~~~
Cluster: 1      Route: 21 37 68 80 50 103 110 0       Consumed: 2.65974
```

Figure 6: Path details in tracks

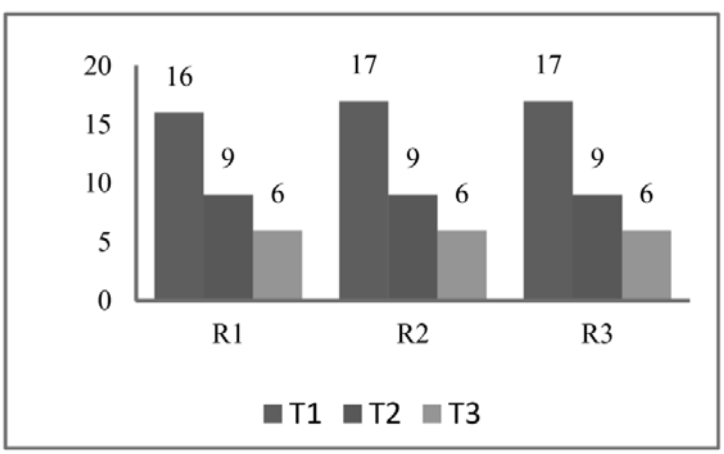

Figure 7: CH formed in 3 rounds

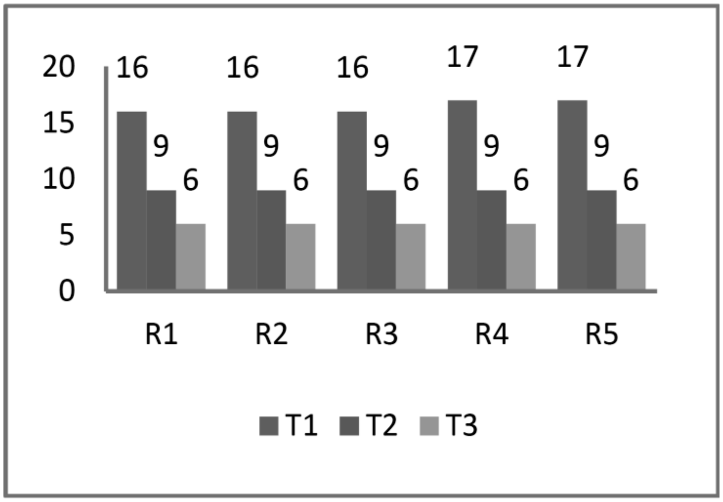

Figure 8: CH formed in 5 rounds

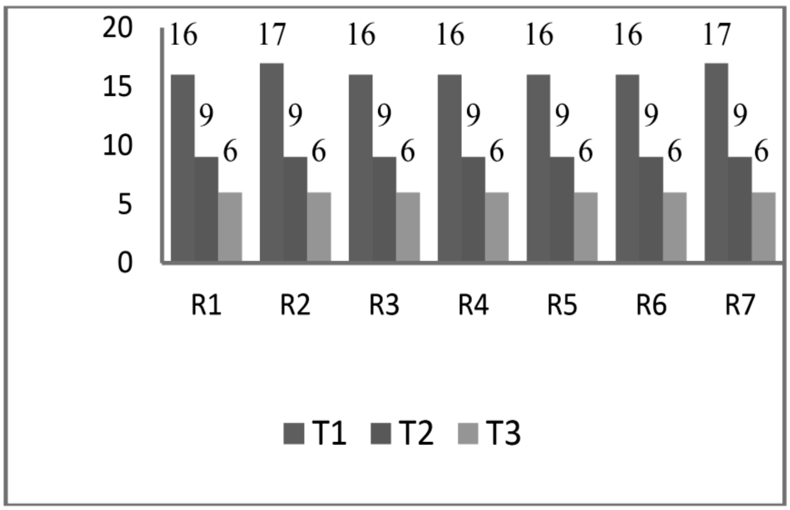

Figure 9: CH formed in 7 rounds

Table 2
Sensor range

Sensor Node Range	*R-1 In mts*	*R-2 In mts*	*R-3 In mts*
Set-A	300	400	500
Set-B	250	400	500

Table 3
Cluster size

	Track-1	Track-2	Track-3
Maximum Cluster Size (CS)	2	6	8
	3	6	8
	3	6	9

3. **Comparison of cluster size and clusters formed:** This is performed to determine the maximum cluster size to be used in different tracks. Inter cluster energy consumption depends on number of clusters formed. Figure 12, 13 gives relationship between maximum cluster size and number of clusters formed in round-1 with settings as per table-2 and table-3 respectively. X-axis represents cluster size (CS) and *y*-axis represents number of CHs or number of clusters formed. For set-A Figure 12, CS = 2,6,8,more CH formed in track-1, whereas CS = 3,6,8 and 3,6,9 forms same number of CHs in tracks. Both combinations performance is same, but from figure 10 and 11 , CS = 3,6,9 consumes least energy to transmit data from CH to sink ,hence optimal maximum cluster size is 3,6,9 .

5.2. Overall Network Residual Energy

Total remaining energy in network at the end of three, five and seven rounds are plotted in Figure 14. Initial energy before simulation of three rounds is 90.36722J, at end of round-3 remaining energy is 88.9239J . Initial energy for five rounds is 89.72969J, at the end of round-5 remaining energy is 87.9893J.Initial energy for seven rounds is 90.57168J , at the end of round-7 remaining energy is 88.1031J. The algorithm is also tested for static nodes and represented in yellow colour and proposed algorithm in red colour.

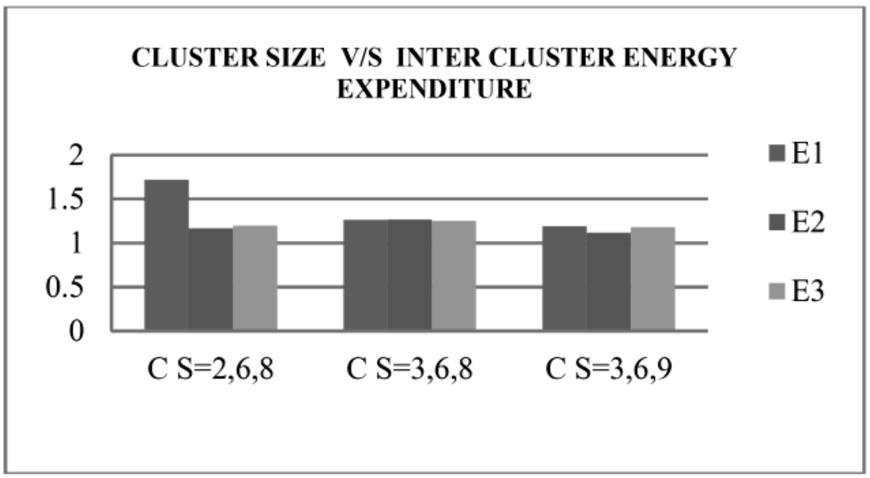

Figure 10: Inter cluster communication energy -Set-A

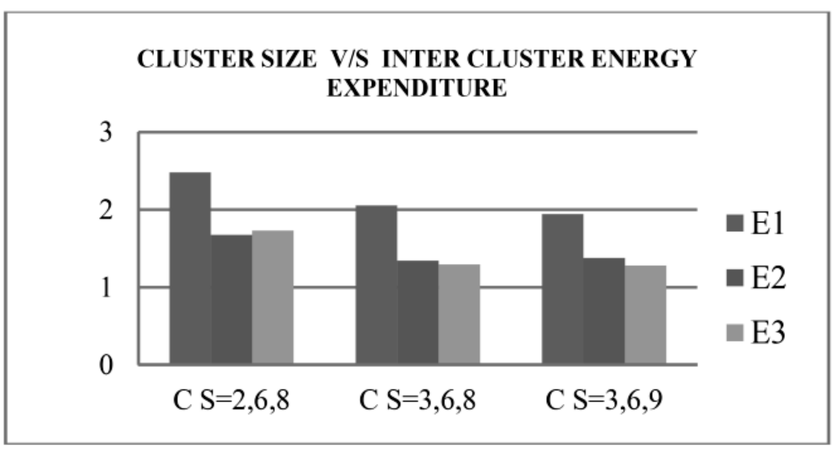

Figure 11: Inter cluster communication energy -Set-B

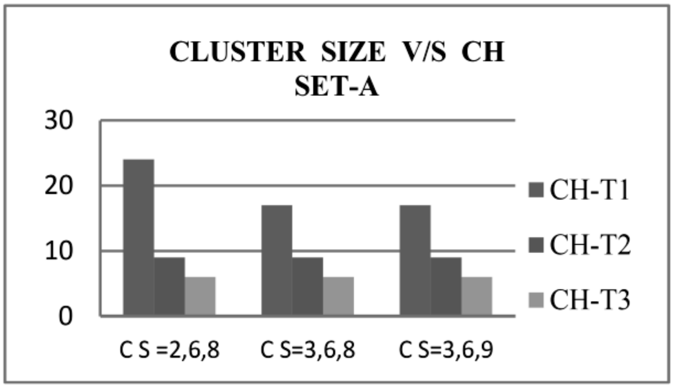

Figure 12: Varying cluster size -set-A

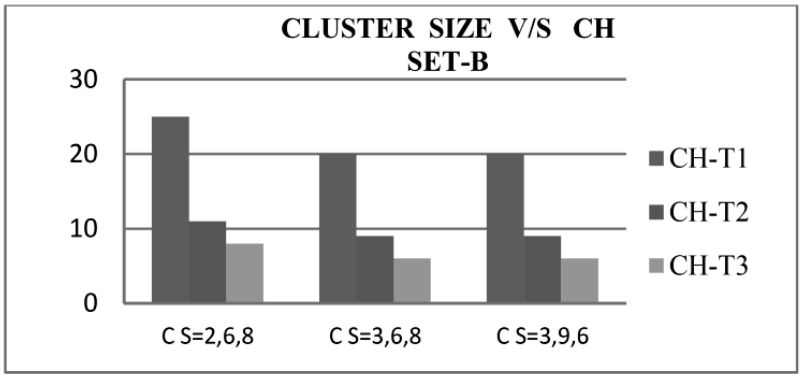

Figure 13: Varying cluster size -set-B

In Figure 14, around 1J of energy is used in first round in all four trials. Whereas less than 1J is used in subsequent rounds. Only in first round extra energy is spent for forming tracks, zones and initial set up, along with energy expenditure on clustering, collecting data at CH and transmitting it to sink which is common to all other rounds .Experiments are conducted for table-2 and table-3 values for three rounds and plotted in figure 15, 16. For three rounds, set-A and CS = 3,6,9 Figure 15 yellow plot is of Unequal Clustering With Dynamically Variable Cluster Size Within tracks and has more overall residual energy when compared to other CS values.

1. **Comparison of one and two hop cluster range :** Cluster coverage area or cluster range plays an important role in energy consumption .In figure 17, number of rounds on *x*-axis and residual energy on *y*-axis. Red plot represents residual energy of this work *i.e* cluster range is two hop. Green plot cluster range is one hop. Two hop clustering saves 0.3047 J of energy for three rounds as single node clusters formation is reduced. . Hence clustering with two range consume less energy when compared to single hop cluster range.

5.3. Comparison Of First Dead Node Time

First dead node acts as an important parameter in deciding networks' life time. This is studied by increasing the power dissipation of nodes for transmitting data/mts(initial assumed value = 0.0001J/mts). In Figure 18, red plot is of proposed work, when power dissipation for transmitting data for a distance of one meter is set to 0.0140J/mts and first node dies. But for one hop cluster range the first node dies when the power dissipation of nodes for transmitting data for a distance for one meter is set to 0.0100J/mts .This indicate that first dead node occurs early in case one hop clusters. Proposed work performance is better than one hop clustering by 0.0040J/mts for one round.

5.4. Inter cluster communication

Data collected at CH is routed to sink in multi hop path. In most of WSNs the hop node selected is a CH for inter cluster communication. The Figure 17 show the path used by CH-4 of track-2. Path is **44->32->82->73->103->110-> 0**. CH node- 44 is in track-2 and other relay nodes participating in communication are from track-1.The source node-44 is CH for cluster-4 of track-2.The next hop node selected is also a CH of cluster-5 in track-1.The rest relay nodes are member nodes. The distance between node- 44 and base station is 1520 mts. CH node-44 is present at a distance of 1520 mts from sink.

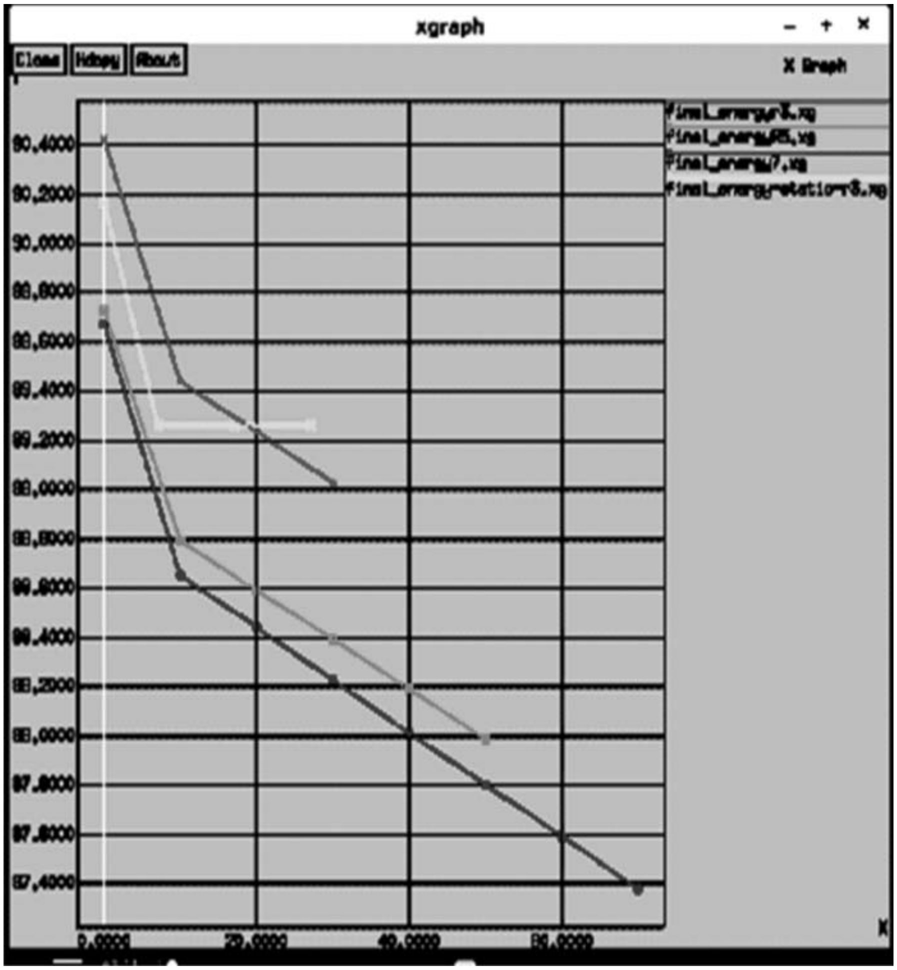

Figure 14: Overall residual energy in rounds

In this round node- 44 is present in track-2 hence its range will be 400 mts therefore it selects node-32 the farthest node placed at a distance of 371 mts as next hop node in path and transmits data to it. Node-32 is a CH it is a second option node and gets selected as first option nodes are present at a distance greater than 400 mts. Next relay node is node- 82, this is a member node at a distance of 309 approximately equal to 300 mts, the range of track-1 nodes. Next is node-73 at a distance of 207 ,the distance between node-73 and node-103 is 216 mts ,between 103 and 110 is 205 mts and distance between last relay node-110 to base station is 212 .This path uses 0.1520 J, if the same distance was to be covered by all relay nodes of same range i.e 250 mts, it requires 7 hops .Hence by varying nodes range by virtue of its position one hop is saved for just 6- hop communication path ,on an average if 33 clusters are formed in one round with an average of 6 hop per path, then approximately minimum of 31 hops are saved /round.

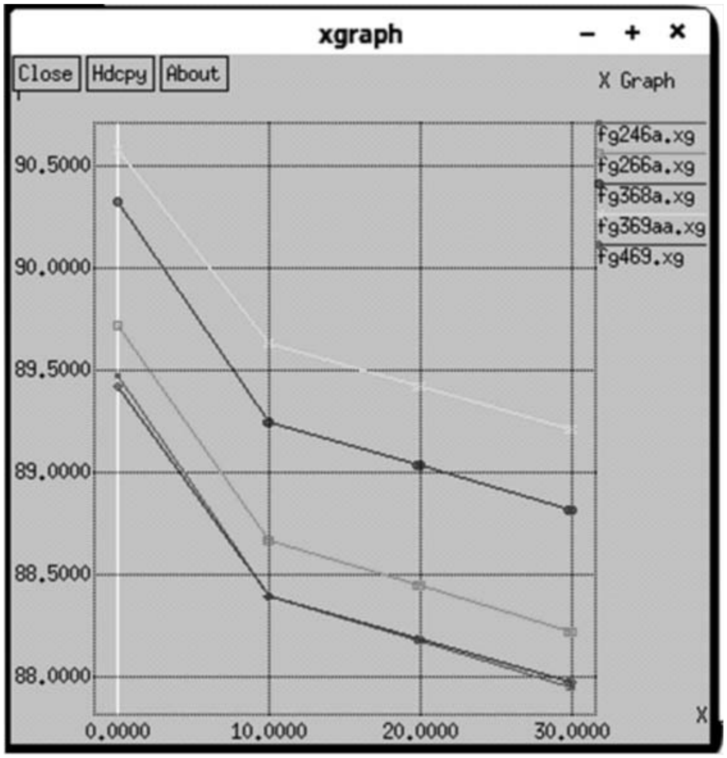

Figure 15: Residual energy v/s cluster size for set-A

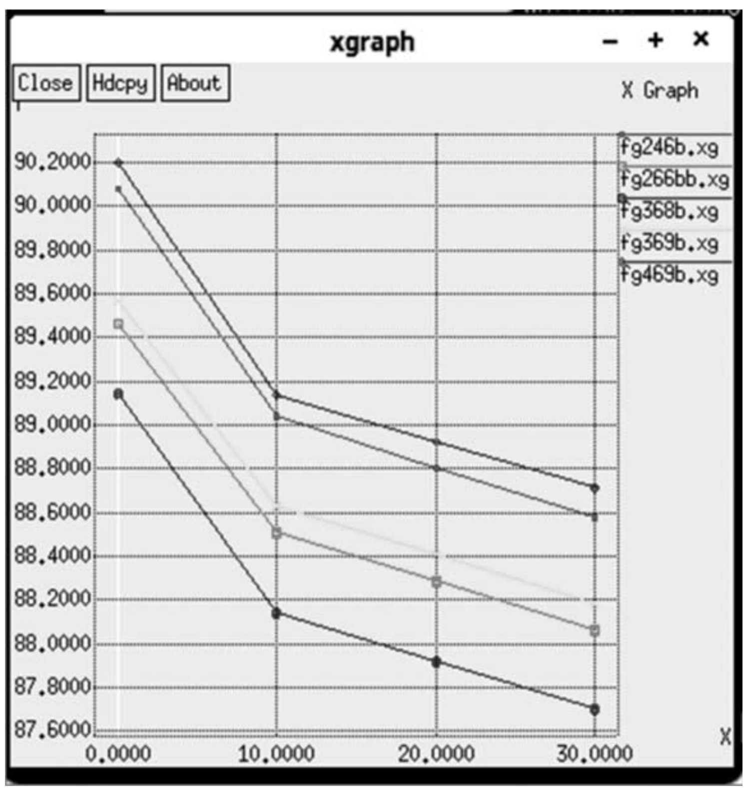

Figure 16: Residual energy v/s cluster size

6. CONCLUSION

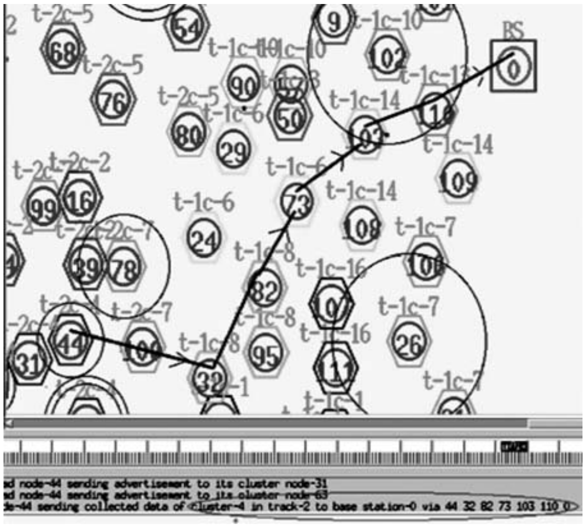

Figure 17: Inter cluster communication

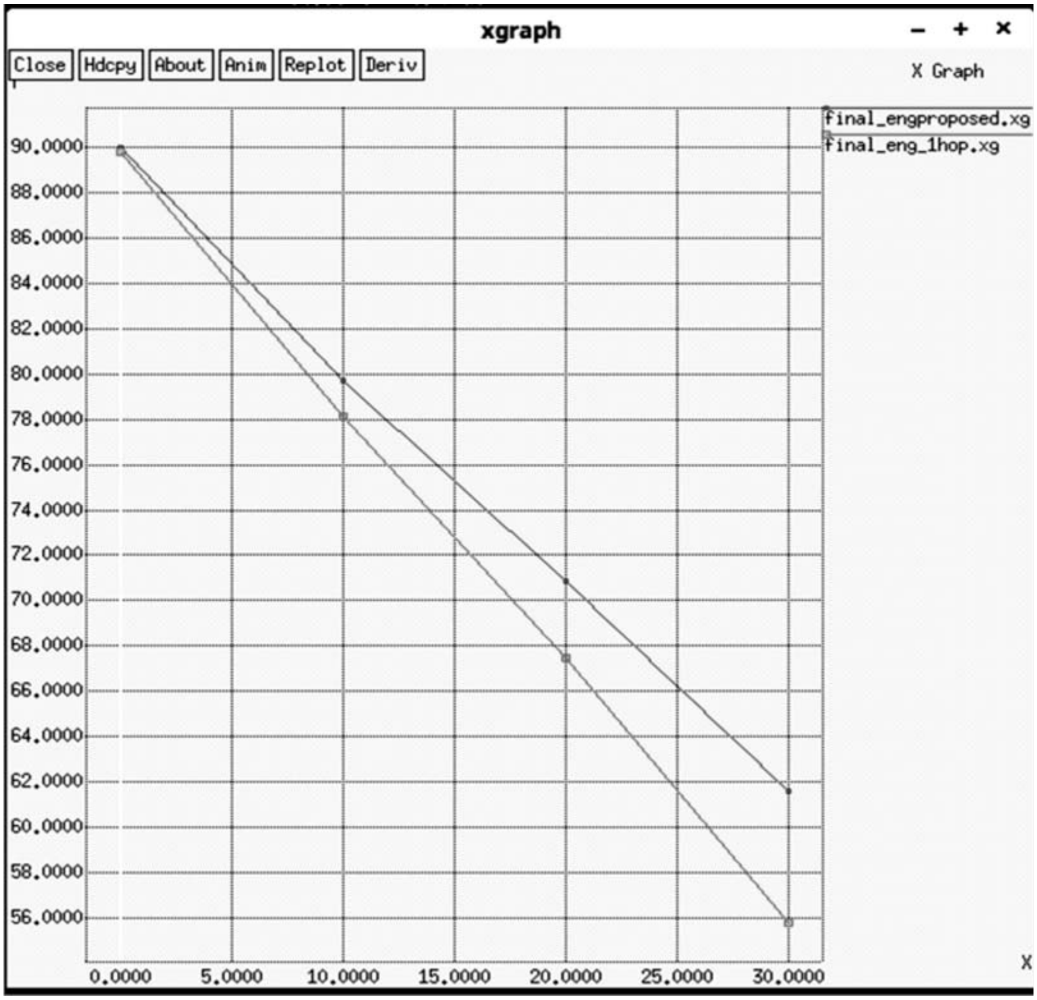

Figure 18: First dead node

Experimental results indicate improvement in proposed Unequal Clustering With Dynamically Variable Cluster Size Within tracks algorithm in terms of residual energy and network life. The performance of this protocol can be studied further by testing on test bed by changing mobility pattern such as continuous mobility . Varying size clusters in tracks reduces the chance of forming single node clusters and balances between energy used for members to CH communication and CH to sink communication. Varying node range in tracks allows nodes to cover a large distance in single hop, reduces number of hops required for Inter cluster communication. Hence improving energy efficiency and network life time.

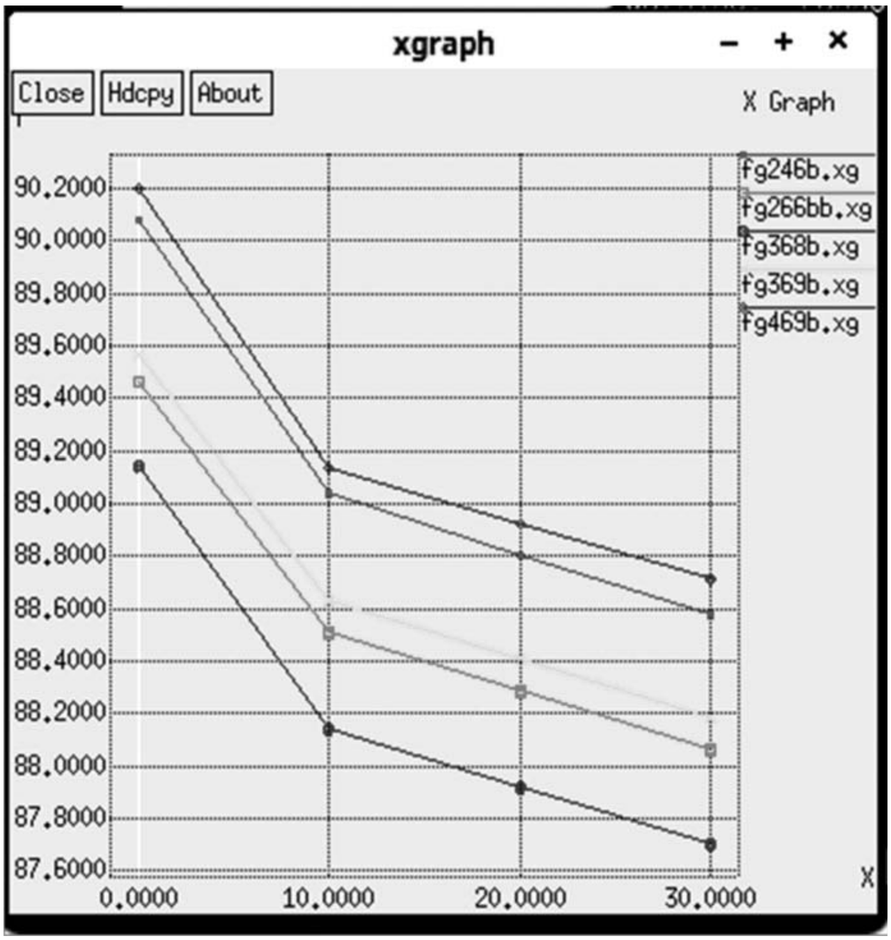

Figure 19: One and two hop cluster

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