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Life time improvement with hybrid clustering in Mobile Sensor Networks

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Abstract— In mobile sensor networks (MSN) handling dynamically changing topology in clustered MSNs is an important challenge as it affects the cluster formation. If re cluster triggering is performed at predetermined time or rounds without considering nodes position and stability of original cluster structure, leads to unnecessary energy usage in a dynamic topology. Life time of MSN can be extended by efficient re cluster triggering techniques. In this work cluster head (CH) rotation and re cluster triggering carried out either locally or globally based on changing position of CH and backup-CH (BU-CH) or residual energy. CH, one BU-CH are identified in every cluster, CH hands over its role to BU-CH without altering cluster structure in case it moves out of cluster boundary. In the absence of both within core boundaries then either local or global re clustering triggered. Reclustering and CH rotation are triggered when CH or BU-CH nodes surpass their boundaries and not by predetermined time or rounds as in most works. This work is a hybrid, distributed, topology driven clustering technique with minimum overheads, reduced reclustering in turn prolongs network lifetime.

Keywords— MSN, Re cluster triggering, Hybrid re clustering, Global and local reclustering, Energy efficient

I. INTRODUCTION

Mobile sensor networks (MSN) are built with mobile nodes or mobile sink. Sensors are deployed in sensor field to monitor certain parameters. Sensors resources - battery, buffer, memory and range are limited. Randomly deployed nodes collect data from sensor field and communicate it to sink situated outside or inside sensor field for processing. Nodes are capable of communicating among themselves and also with sink. In most applications battery replacement is near to impossible either due to mobility or harsh environment [1].

Clustering techniques in routing protocols play a crucial role in increasing cluster stability and network lifetime. Hence algorithms are designed keeping energy conservation as main aim in all processes, from sensing to transmitting it to sink. If every node is allowed to transmit directly to sink, lot of energy is spent [2]. Clustering is one popular technique in which nodes are grouped based on some common sensor parameters, with a head node CH. Cluster members transmit data to CH instead of sink, CH further transmits it directly or in multi hop path to sink. Hence CHs' energy depletion is large when compared to member nodes and die early. Therefore, energy balancing among members and CH is achieved by rotation of roles.

In most static networks one time clustering performed in first round and only CH rotation is to be planned. Whereas MSNs requires re clustering very often as sensor change location resulting in topology change. As sensor move with low speed topology change is minimal. In such a case if reclustering is triggered on time or round basis, results in inefficient resource management. Hence optimal time to trigger reclustering is to be determined taking into account sensors' new location and CH residual energy. It is found beneficial if re clustering is triggered based on topology change in MSN. Often re cluster triggering in MSN is caused due to CH moving out of cluster region, even when all other members are within cluster region. In such case instead of triggering re clustering another suitable node within the cluster region can take over CH role and postpone reclustering. This work aims to re-cluster when CH or BU-CH, or both desert clusters due to their mobility. When compared to static networks CH rotation and re clustering is often in MSNs. As network topology is dynamic it is a difficult task to rotate CH and maintain cluster structure as nodes surpass cluster boundary often causing instability in cluster structure and links. Decision to rotate CH and trigger reclustering procedure plays an important role in energy conservation. These decisions can be either local at cluster level limited to only cluster of interest, or at sink level restructuring entire network. For former case decision is based on local information with minimum control packet overhead but resource management may be not balanced well. In case of global triggering network resource management is efficient but incurs large amount of information and control packet overhead.

CH rotation is performed to balance energy expenditure and usually performed in two ways- Energy based rotation and time based rotation. In former predetermined energy threshold is used to trigger CH role among members when its residual energy falls below threshold. In latter CH rotation done periodically or for data rounds [3]. Local reclustering is within initial cluster without altering its structure, with minimum energy consumption and control packet overhead, but cluster distribution not always optimal. Global re clustering forms new clusters throughout the network efficient clusters are formed with large number of control packets overhead consuming more energy, in turn reducing network lifetime. Both methods are not sufficient for dynamic topology if used separately. Hence in this work a compromise is struck between the two techniques and used together considering not only residual energy of CHs but also changing neighbors. This work aims to re-cluster when CH or BU-CH, or both surpass their boundaries in clusters due to their mobility and global re clustering is postponed by locally shifting CHs role to another potential node called BU-CH present with in cluster.

Motivation: When compared to static network CH rotation and reclustering is required often in MSNs due to dynamic topology. But as sensors move with very low speed in MSNs when compared to Ad hoc network, resulting minimal topology changes with respect to time. Hence frequency of CH rotation and reclustering in MSN is not as demanding as in Ad hoc networks. Therefore, network resource utilization can be minimized by reducing number of re clustering i.e. by triggering it only when topology demands and not on regular basis. This work is unique as both CH rotation and triggering reclustering are performed following topology changes caused due to mobility and not only energy as in static networks.

Organization of the paper: Rest of the paper is organized as follows: In section II some global and local cluster related algorithms are reviewed. Section III proposes a hybrid clustering is discussed. Section IV consists of hybrid cluster results and related discussion. The work is concluded and future research direction on this work is presented in section V.

II. Related Work:

Lot of research is carried out to improve energy efficiency in clustered WSNs and MWSNs. These can be classified broadly as distributed/local and centralized /global methods. Following are some work on this area: By rotating CHs role when its residual energy reduces below a dynamic value calculated by algorithm considering changing topology, thereby nodes with less residual energy are not allowed to participate in communication. Hence network lifetime is improved [4]. Number of Clusters to be formed is decided by BS globally. CHs are elected based on position and residual energy. BS in advance calculates the number of rounds for which CH can continue, hence reduce energy usage on CH rotation and control packet overhead incurred in replacement, improving network lifetime [5].To improve network life many clustering algorithms are proposed LEACH is one such in which CH rotation and data collection is performed periodically on how many times a node has been a CH. Reclustering is triggered locally within clusters limits with minimum overhead[6]. In energy driven clustering algorithms, the CHs roles are rotated when the residual energy of CH is less than a threshold value. This method can be used in the global re-clustering as well as in local re-clustering. Large overheads can be eliminated resulting in prolonged network lifetime [7]. In local re clustering cluster area does not change, global reclustering change cluster area considering dynamic topology in any particular round [8]. Global re-clustering is not necessary when a CH has sufficient residual energy to perform its duties hence reduces clustering overhead and improves energy efficiency [9]. Researchers are aiming at achieving best clustering by tuning the weakness of existing algorithm or combining two or more existing methods. Combined clustering techniques yields better performance than individual antecessors [10]. The following are some works using combination of local and global re clustering, in mobility pattern dependent re clustering algorithm, global re clustering is triggered based on the estimated local reclustering times of different clusters following mobility pattern. This work estimates time for local reclustering of individual cluster, further these are used to estimate global triggering time based on sensors new position due to mobility [11]. Global methods require knowledge of all nodes to make decision with high information exchange, where as local information of only neighbour clusters is used in local methods with minimum information exchange. A hybrid category uses both methods to overcome disadvantage one another [12]. In a globally distributed clustering technique each node decides its local role in cluster on information known to sink by performing topological analysis to know about the nodes around it using global information and finds the CH based on its location [13]. When nodes are mobile it is advantageous to use both global and local re-clustering. Here in first two rounds CHs are selected by sink using centralized algorithm. In subsequent rounds new CHs are selected by previous rounds CHs i.e locally. Short come of this is hybrid clustering used only for first two rounds for rest rounds its performance is similar to distributed scheme[14].Networks' lifetime can be improved by reducing the frequency of global reclustering by locally rotating CH role based on its residual energy. This results lifetime improvement by reducing energy consumption spent on frequent re clustering all the clusters[15].

Network Model:

Simplified network model and some assumptions made are,

- N sensor nodes are deployed in an M x M square field.
- All nodes have mobility and only BS is stationary after deployment.
- Sensor nodes are homogenous.
- Sensor nodes are location aware and have unique ID.
- Nodes use power control to adjust the amount of transmitting power.
- BS situated out the sensor field, has enough energy, and its location is known to nodes.
- A node with highest weight is selected as CH, residual energy, mobility and density are the parameters used for selection.

III. WORKING

Working of this algorithm can be divided into two phase 1. Clustering 2. Data collection and communication.

A. CLUSTERING PHASE:

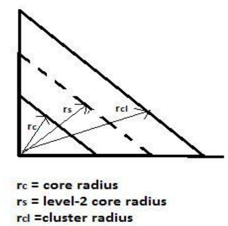
Sensor nodes are randomly deployed in area to be monitored Fig 2, gets synchronized with sink and start communicating with it. Initially sink forms clusters within grids Eq(1) and selects CHs with high residual energy, low mobility ,minimum density and almost at mid of cluster Eq(4) , among nodes present within one cluster boundary. As deployment is random, sink may not always find enough nodes to create clusters within grids. If nodes in any cluster region is less than minimum cluster size, then nodes in adjacent cluster region are combined and clusters are formed Eq(2). These clusters continue data collection till sufficient number of members are present or CH and BU-CH location are within core cluster boundary rc and rs respectively

Fig 1. If Members/CH/ BU-CH move out of cluster boundary or CH energy is less than minimum threshold, then cluster structure is hampered in turn data collection effected. In such case new members are to be added to existing cluster, hence either local or global re clustering triggered based on condition. If network topology change is minimum and not effecting data communication, local re clustering triggered. During local reclustering only role switching between CH and BU-CH take place within cluster without changing its structure. If topology change is large and effects data collection, then global reclustering triggered and totally new clusters are formed. Re cluster triggering condition plays a vital role in energy consumption. They have to be carefully adjusted else unnecessary triggering causes overheads and wastes resource. Fig 4, Conditions for re cluster triggering are as follows.

i) local reclustering: a) CH-surpassing core area b) BU-CH- surpassing level-2 core area c) Reduced CHs' residual energy d) Reduced member count.

a)CH-surpassing core area : CH moving out core area (rc or r1)- Fig 4.d, CH broadcasts its departure hands over its role to BU-CH, cluster continues with old members without altering cluster structure and cluster boundary.

b)CH and BU-CH moving out of core area(rc)- Fig 4.b: A BU-CH is identified within level two core area (rs or r2) with highest residual energy and low mobility, if member count >=threshold then CH hands over its role .



SECOND LEVEL CORE RADIUS = R_{SLC}= (R_S- R_C)

Fig.1 Triggering regions

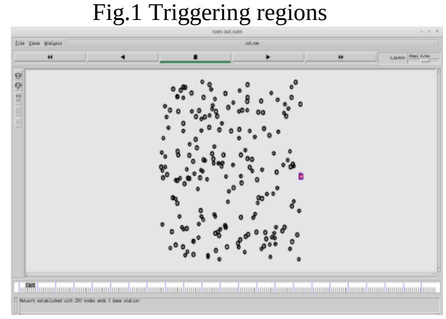


Fig 2 Nodes deployment

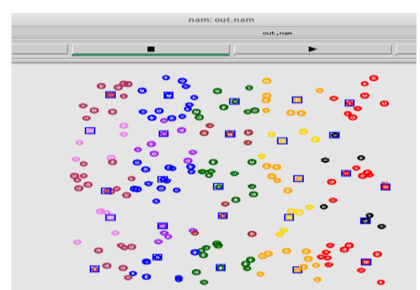


Fig.3 Cluster distribution

c) CH residual energy less than Threshold-Fig 4.a, Local re clustering triggered when a preset number of member nodes are still in the range of parent cluster and BU-CH is within its boundary BU-CH takes up the role of CH.

d) Member count less than threshold Fig 4.c CH and BU-CH within core area

(rc)-only that cluster is re clustered by joining new members.

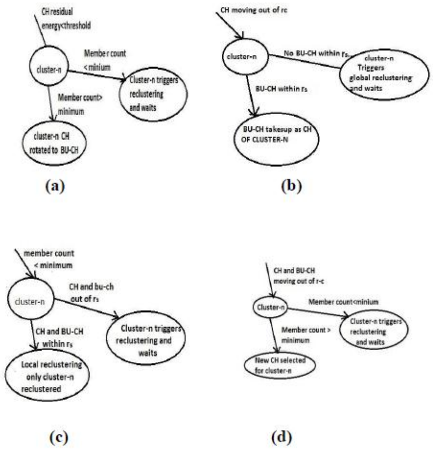


Fig.4 Re cluster triggering conditions

ii) Global reclustering: CH is moving out of) and no BU-CH within second level core (rs). Then CH is unable to find BU-CH to handover its role hence triggers re clustering request. Intimates member nodes and transmits the data which it has collected.

B. DATA COLLECTION AND COMMUNICATION.

Nodes transmit sensed data to their CHs , Further each CH transmit its cluster data to BS by multi hop communication route, this is dynamically determined and may consists of CHs and member nodes. In absence of nodes in neighborhood directly communicates.

CH and BU-CH selection:

The sensor field 'S', is divided into virtual grids with fixed boundaries,

Where $1 \leqslant x \leqslant 25$. (1)

Nodes within these grids are clustered,'Si' represents the cluster set

Where $1 \leqslant i \leqslant 25$ and $3 \leqslant j \leqslant 13$. (2)

The mobile sensors are randomly deployed in sensor field and represented as

$$\sum_{i=1} |s_i| = 199 \quad (3)$$

One CH is selected among members with highest residual energy, minimum mobility and least density, the cluster set is represented as,

where $1 \leqslant x \leqslant 25$ and each (4)

One BU-CH is selected based on residual energy, mobility and density among remaining members in region of second level core radius rslc,

rslc= (rs- rc) (5)

where rslc= second level core radius, rs = level 2 core radius, rc =core radius

The BU-CH set is represented as,

, where $1 \leqslant x \leqslant 25$ and each (6)

All other nodes in sensor field are called members 'M', represented as

$$M = \{m_{1,} m_{2,} m_{3,} \ldots\ldots\ldots\ldots m_i\} \quad (7)$$

Total members (Tm) in any cluster (cli) range excluding CH and BU-CH

$$\text{Tm} = |m_i| = |s_i| - 2 \quad (8)$$

Energy consumption calculations

PCS (l, d) = (Eele + Eamp) l × dn (9)

PCR (l) = Eele × l (10)

Where, Eele energy consumed by receiver or transmitter circuitry, Eamp energy spent at transmitter amplifier, l message length, n range 1.8 to 6 based on surrounding environment. Power consumed for sending (PCS) and Power consumed for receiving (PCR) is energy spent for transmitting and receiving by sensor for message of l bit over a distance of d respectively and computed by eq (9) and eq (10).

IV Results and Discussion

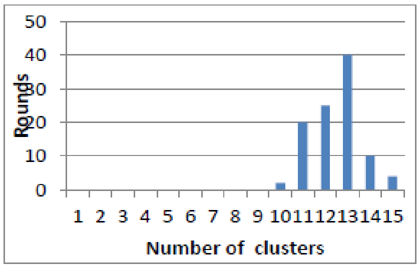
A. Simulation setup: Sensor field of 500 X500 with 199 randomly deployed mobile nodes, and one sink is considered. It is assumed that sensors have 20 mts broadcasting radius. First optimal values of rc and rs are determined to minimize re cluster triggering. Further it was investigated to determine the impact of the proposed algorithm on network lifetime. Energy consumption for intra and inter cluster communication per round were calculated and the performance of algorithm in terms of residual energy and network life was evaluated via simulation on NS2 with table-1 setup.

Table 1: Details of Simulation Setup

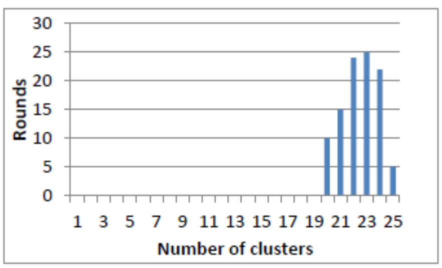
Parameters	Values
Network area	500 X 500
Number of nodes	199
Sink	1
Packet size -Data -Req/Ack	 512 bytes 2 bytes
Mobility	10 mts/mint
E_{ele}	50 nJ/bit
E_{amp}	100 pJ/bit/m^2

B. CLUSTER DISTRIBUTION:

Clusters are well distributed in sensor field results in well balanced energy balance as their boundaries are fixed Fig 3. Cluster size is varying and member count varies within threshold values from cluster to cluster. Cluster size depends on number of nodes present within cluster boundary at that instant of time as nodes change their position. The performance of proposed work is compared with [15], in which nodes are stationary and only residual energy of CH is considered for re cluster triggering.



(a) [15]



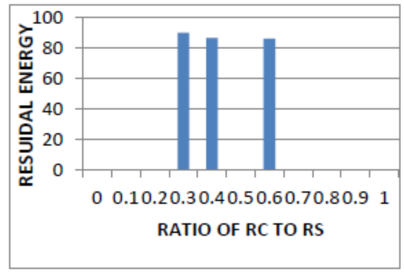
(b) Proposed

Fig 5. Cluster distribution in rounds

Algorithm stability is calculated by the number of clusters formed in each round. In fig 5. Clusters formed in proposed work and [15] are compared selecting randomly 30 simulated rounds. Fig 5.a. Around 10 to 15 CHs are formed in 40 rounds for a maximum of 15 CHs. In Fig 5.b the max CHs that can be formed is 25, and CHs are found to have range 20 to 25.

Though sensors are mobile in proposed work, CHs formed are well distributed throughout the network- Fig 3, as clusters are formed within virtual grids. This yields good energy balance among the sensors.

C. optimal rc and rs values: Core radius and second level radius influences network life, as CHs and BU-CHs are selected within these radii respectively. By maintaining rc constant and varying rs it is found that greater the value of rs, chances of finding a BU-CHs increases reducing re cluster triggering in turn improving overall residual energy and network life. Smaller the ratio of rcto rs better is the performance. Number of re cluster requests also decreases as ratio rc to rs decreases hence improving residual energy - Fig 6.



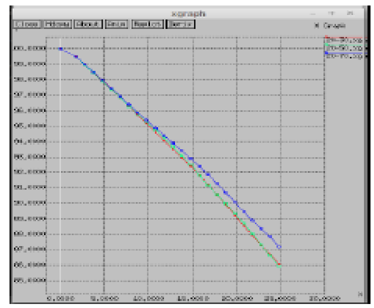


Fig 6. Variable radius-2(rs)

Effect of radius2 (rs): keeping core radius(rc) constant, level-2 core radius(rs) is increased, from Fig 6. Energy consumed is less as area for finding a BU-CH is more which decreases reclustering requests from clusters and improves residual energy.

Re cluster triggering threshold: In [15] if any one cluster is unable to find a suitable node to take up its role global triggering is performed. In proposed work such cluster / clusters can take up local reclustering to find new CH locally and continue if total number of re clustering requests in the network is less than pre-set threshold.

Re cluster request: In [15] if any one cluster is unable to find a suitable node to take up its role global triggering is performed. In proposed work such cluster / clusters can take up local reclustering to find new CH and continue if total number of re clustering requests in the network is less than pre set threshold. In this work performance of network is evaluated using two parameters i) Radius-rslc ii) triggering threshold.

i) Radius- rslc : Due to mobility CHs' , BU-CHs' and sensors' change their position hence cluster structure. If CH has moved out of rc, it can no longer continue as CH and has to hand over to BU-CH. If no BU-CH is present within second level core radius = rslc= (r s- rc), re cluster request is raised by that CH before it deserts the cluster. Network under goes a global re clustering if total requests in network is greater than a set threshold, else locally new CH is selected. Greater the radius rs, less re cluster requests are raised improving network performance, Fig 8.

Re cluster triggering threshold: From fig. 7, it is seen that if threshold value is less then more global re clustering performed consuming more energy, when compared to large reclustering threshold value. Striking a compromise between the two parameters, Fig 9 higher the second level core radius and triggering threshold better is networks' performance in terms of energy.

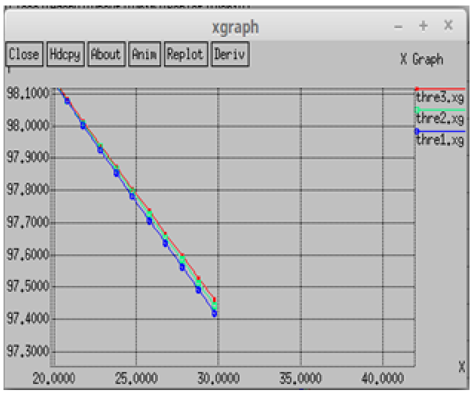


Fig 7. Threshold

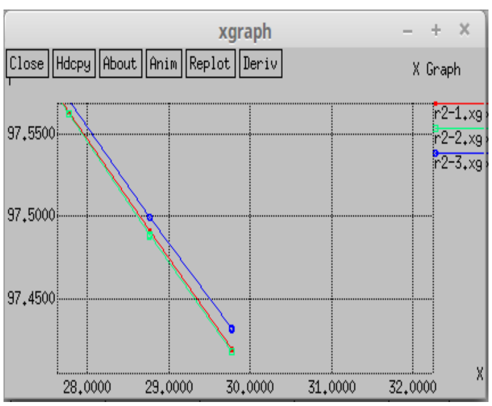


Fig 8. Second level core radius

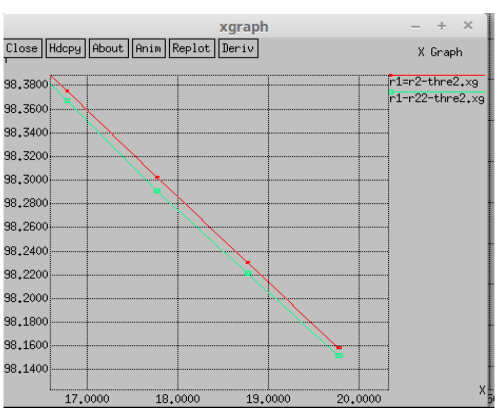


Fig 9. Rs and Threshold

First dead node(FDN): First dead node formation is simulated by increasing the power dissipated for transmitting. FDN formation affects inter cluster communication path and network spends more energy to communicate to sink. From Fig 10, lower the value of rc/ rs FND is delayed, as BU-CH selection area increases reducing re cluster triggering in turn improves network life.

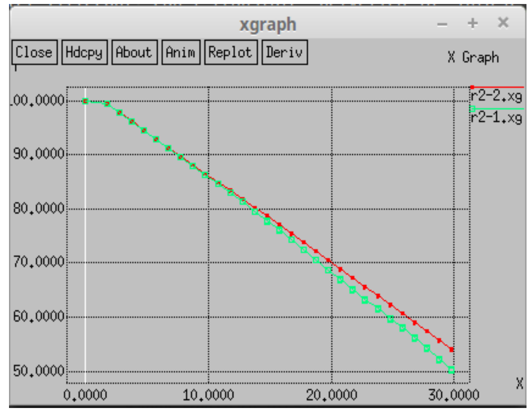


Fig 10. FND v/s Residual energy

V. CONCLUSION AND FUTURE SCOPE

This work is an hybrid re clustering algorithm using a combination of local and global re clustering. Nodes' residual energy, position and density are used while selecting CH and BU-CH. To improve network life re cluster triggering and CH rotation techniques are built using residual energy and position of CH and cluster member count in a dynamic topology. Hence global reclustering is postponed by handing over CHs' role to BU-CH. It is also found that core radius and second level core radius plays an important role in deciding the frequency of global reclustering. Reduced reclustering improves network life time by delaying formation of first dead node.

This work develops mechanism for optimizing re cluster triggering frequency with minimum overheads and enhances network life in a dynamic and randomly deployed MSN. This work considers only nodes mobility and sink is stationary. In some applications sink also need to be mobile to further improve energy efficiency and reduce latency. These factors need to be considered as future scope.

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