Proclivity of Mobility and Energy based Clustering schemes towards Load-balancing schemes in Wireless Ad-hoc Networks

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Abstract—
In the field of mobile ad hoc networks (MANETs), clustering plays an important role in achieving the basic levels of system performance, such as throughput and delay, in the presence of both large number of communicating mobile terminals and any sort of mobility. A large variety of approaches for ad hoc clustering have been presented, whereby different approaches typically focus on different performance metrics. In our work, we study an energy and mobility aware clustering approach along with another load-balancing clustering approach. Whereby, we devise a term called Effective Residual Energy (E.R.E) that shows the inclination of both these approaches towards each other. We show that how our scheme adapts to the load-balancing features of CBRP without explicit location-based data and instead it directly takes the node's range into consideration. Thereby, our proposed clustering scheme takes into consideration energy, mobility and load-balancing features all at the same time.
Keywords
Proclivity of Clustering Schemes with energy conservation, Effective Residual Energy (E.R.E), Head Evaluation Parameter (H.E.P).

1. Introduction

The IEEE 802.11 standard defines two operational modes for WLANs: infrastructure-based and infrastructure less or ad hoc. Network interface cards can be set to work in either of these modes but not in both simultaneously. In these cases, a more efficient solution can be provided by the infrastructure less or ad hoc mode i.e. mobile ad-hoc network (MANET). When operating in this mode, stations are said to form an Independent Basic Service Set (IBSS) or, more simply, an ad hoc network. Any station that is within the transmission range of any other, after a synchronization phase, can start communicating. No Access Point (AP) is required, but if one of the stations operating in the ad hoc mode also has a connection to the wired network, stations forming the ad hoc network have a wireless access to the Internet. Some of the constraints in MANETs are - limited bandwidth, low battery power of nodes and frequent link breaks due to mobility of the nodes. These constraints should be taken into consideration while maintaining the connectivity among the nodes.

The main constraint of sensor nodes is their very finite battery energy, while limiting the lifetime. For this reason, the protocol running on sensor networks must efficiently reduce the node energy consumed in order to achieve a longer network lifetime [7]. Different clustering schemes that have been proposed focus on particular parameters such as degree, mobility (speed), range (location) and energy of the nodes.
This paper proposes a new idea based on Effective Residual Energy (E.R.E) using which the clustering scheme not only encompasses the mobility and energy factors but also load-balancing features, thereby making the scheme more efficient in ad hoc network maintenance.

2. Study of clustering metrics

The clustering schemes can be classified according to their objectives. This criterion divides the clustering schemes for MANET into six categories as follows [6]:

- DS-based clustering,
- Low-maintenance clustering,
- Mobility-aware clustering,
- Energy-efficient,
- Load-balancing clustering and
- Combined metrics based clustering schemes.

Among these mobility aware clustering schemes is based on utilizing mobile nodes' mobility behavior for cluster construction and maintenance and assigning mobile nodes with low relative speed to the same cluster to tighten the connection in such a cluster.
Energy-efficient clustering is based on avoiding unnecessary energy consumption or balancing energy consumption for mobile nodes in order to prolong the lifetime of mobile terminals and a network.
Load-balancing clustering is based on distributing the workload of a network more evenly into clusters by

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limiting the number of mobile nodes in each cluster in a defined range.
Lastly, combined-metrics-based clustering based on considering multiple metrics in cluster configuration, including node degree, mobility, battery energy, cluster size, etc., and adjusting their weighing factors for different application scenarios.
In our combined-metrics based clustering scheme we take into account factors such as node degree, residual energy capacity, moving speed, and range. This category aims at electing the most optimal clusterhead in a local area, and does not give preference to mobile nodes with certain attributes, such as lowest ID or highest node degree. One advantage of this clustering scheme is that it can flexibly adjust the weighting factors for each metric to adjust to different scenarios [6].This keeps a balance between different factors associated with the selection of cluster head in CBRP.

3. Related work

The earlier works proposed in this area comprise of: LEACH (Low energy Adaptive Clustering Hierarchy) which was a self-organizing and adaptive clustering protocol that used randomization to distribute the energy load evenly among the sensor nodes [8]. PEGASIS (power-efficient gathering in sensor information systems) [9], [10] was an improvement over LEACH but there is no centralized cluster formation mechanism thus each node had to spend additional energy for performing data aggregation to achieve hierarchical distribution of energy. CODA was introduced to relieve this imbalance of energy. However, the work of CODA relied on global information of node position, and thus it was not scalable. In HEED, author introduced a variable known as cluster radius which defined the transmission power to be used for intra-cluster broadcast [11]. ACE clusters the network in a constant number of iterations using the node degree as the main parameter. Soro et. al. [12] proposed an unequal clustering size model for network organization, which can lead to more uniform energy dissipation among cluster head nodes, thus increasing network lifetime.
The idea behind the energy efficient topology control algorithm is that it allows nodes in the network to communicate in its neighborhood to form small groups of nodes which are called clusters. In CBRP, the cluster head election is based on the ID of the nodes and the node with the lowest ID among its neighbors is selected as cluster head [2]. Because of mobility of nodes in ad hoc network this is probable that elected cluster head to be too mobile. Therefore, the lowest ID nodes will be consuming extra battery power for performing functionalities of a cluster head. This will lead to election of inactive or poor energy node as cluster head. The selected lower energy nodes will result in performance degradation in the network and more energy will be consumed indirectly as a result of frequent change of cluster head. Novel cluster based routing protocol for wireless sensor networks introduces a concept in which the operation of CBRP is divided into rounds and each round contains two phases, set-up phase and steady-state phase. In the set-up phase, each node broadcasts the Node_Residual_Msg within radio range r, which contains residual energy of node. Each node receives the Node_Residual_Msg from all neighbors in its radio range and updates the neighborhood table and generates CHSV (Cluster Head Selection Value) based on which the choice of the optimal cluster head is made[3].The advantage of this scheme was that it alternated the role of cluster head which balanced energy consumption among cluster members. It used distance and residual energy of the nodes to elect the optimum cluster head that saved more energy in nodes. Thus it combined the concept of energy-efficient clustering and load-balancing clustering schemes.
Motivation behind introducing degree, energy and mobility aware clustering scheme is to find an alternative efficient way for clustering in MANET that improves the performance of the ad-hoc network and reduces the frequency of change of cluster heads.
The recent work in energy efficient clustering is the concept of DEMAC that introduces an efficient technique of cluster head selection by computing a priority factor (F-factor) in terms of degree, energy and mobility of the participating nodes. With this scheme, a node with the highest F-value will be named cluster head. But DEMAC does not take the load balancing factor (using distance based scheme) into consideration which makes it contrast to the concept given in Novel clustering schemes.
This paper is an extension of DEMAC which uses effective residual energy for cluster head selection such that such that it becomes a combined-metrics based clustering scheme. The proposed work shows the proclivity of the mobility and energy based clustering schemes towards the load-balancing schemes in ad-hoc network.

4. Proposed methodology

The proposed methodology for energy conservation utilizes cluster based routing protocol as the base protocol for the purpose of comparative study. The protocol divides the nodes of the ad hoc network into a number of overlapping or disjoint 2-hop-diameter clusters in a distributed manner. A cluster head is elected for each cluster to maintain cluster membership information. Inter-cluster routes are discovered dynamically using the cluster membership information kept at each cluster head. By clustering nodes into groups, the protocol efficiently minimizes the flooding traffic during route discovery and speeds up this process as well. Furthermore, the protocol takes into consideration the existence of uni-directional links and uses these links for both intra-cluster and inter-cluster routing.

The goal of Cluster Formation is to impose some kind of structure or hierarchy in the otherwise completely disorganized ad hoc network. Each node transmits some packets named “Hello message” to announce its presence to its neighbor nodes. Upon receiving a hello message, each node updates its neighbor table[2]. The basic idea proposed is to compute the head evaluation parameter (HEP) using the effective residual energy and incorporate this information in the “hello message” to be send to the neighboring nodes. This methodology makes this scheme less complex at the same time choice of optimum cluster head is made taking into account both mobility and location of the node for energy conservation.

A. Effective Residual Energy

The residual energy is the energy in store that a node has which is actively participating or was once active in an ad-hoc network. This remaining energy of the node is used for its further activities in the network. Therefore the conservation of residual energy is very important for the reliability, stability, maintainability and scalability of infrastructure less ad-hoc networks.

The idea proposed in this paper is to calculate the effective residual energy (ERE) of each active node in terms of its residual energy, the degree and its range. The degree of a node defines the number of neighbor nodes to which it is connected using bi-directional links. The transmission range may differ from node to node depending upon its type (laptop, PDAs etc). The ERE is given by the formula:

$$ERE = \frac{Residual\ Energy \times Degree}{Range} \tag{1}$$

This effective residual energy incorporates two important factors of degree and range that makes it an efficient parameter to be used for the choice of a node that has optimal properties to become the cluster head in given clustering scenario.

Of course, greater the degree of the node the more probable it is to become the cluster head but in a 2-hop cluster based routing scenario, size and density of the cluster also plays a very significant role as they directly affect the residual energy of the participating nodes thus effecting their performance in the network. Large clusters result in depletion of the energy of the cluster head at a greater rate. As a result frequent choice of new cluster head is to be done which increases the over-head of the network.

B. Head Evaluation Parameter

This effective residual energy calculated provides a perfect blend of load-balancing and energy-based clustering schemes for clustering in mobile ad-hoc network. Using the ERE we calculate the Head Evaluation Parameter (H.E.P) to establish a selection criteria for the clusterhead.

5. Comparative analysis

In this paper, we provide a comparative analysis of how different clustering schemes such as CHSV (Based on load-balancing parameter) and DEMAC (based on energy and mobility parameter) make vivid choice of cluster head for the same scenario and how the utilization of the proposed concept of effective residual energy removes the contrast and generates a general formula that satisfies the result of both the above given schemes.

***Scenario1**: Choice of Cluster Head using Novel Cluster Head Selection Value Scheme*

In figure 1, a network topology is shown which has nodes 1~6 that are within the transmission range of each other. Each node has a specified residual energy and is at a specified distance from each other. Applying the formula given by novel clustering scheme and evaluating the CHSV value of every node to find the cluster head:

$$CHSV = \frac{RE(i)}{\sum all\ neighbours\ j\ of\ i(Dis(j)^2 + TP + K)}$$
(2)

TABLE1

PARAMETER DESCRIPTION

Parameter	Description
RE(i)	Residual energy of node (i)
Dis(j)	Distance from node i to node j
TP	Transfer Power for 1 bit
K	Number of bits to be sent from node i to node j

ADJACENCY TABLE FOR THE GIVEN TOPOLOGY

N	1	2	3	4	5	6
1		0.6	0.8	0.9	1.0	1.3
2	0.6		0.7	1.5	0.4	1.0
3	0.8	0.7		2.0	0.5	1.9
4	1.5	1.9	2.0		1.2	1.0
5	1.0	0.4	0.5	1.2		0.7
6	1.3	1.0	1.9	1.0	0.7	

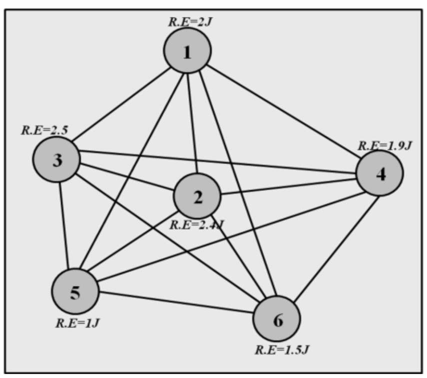

Fig 1. Topology used for scenarios

TABLE 2

According to Novel's formula the CHSV values calculated are as follows (for ease of calculation TP=1 & K=1):

TABLE 3 CHSV VALUES

CHSV(1)	0.44
CHSV(2)	0.704
CHSV(3)	0.278
CHSV(4)	0.200
CHSV(5)	0.259
CHSV(6)	0.193

Since the CHSV (2) value is the greatest, node 2 is selected as the cluster head using this scheme.

***Scenario 2**: Choice of Cluster Head Using The DEMAC Scheme*

Using the same topology as shown in Fig1. and considering a constant speed (5 m/s) of the participating nodes we now apply the formula proposed by DEMAC:

$$F = \frac{residual\ energy\ (RE) \times Degree}{2^{\alpha \times Speed}}$$
(3)

We now calculate the priority factor (F-factor) for the given node 1~6 and select the node with the highest F-factor as the cluster head.

TABLE 4 PRIORITY FACTOR VALUES

F(1)	0.0000122
F(2)	0.0000146
F(3)	0.0000153
F(4)	0.0000116
F(5)	0.0000061
F(6)	0.0000092

Thus node 3 is selected as the cluster head using this scheme.

***Scenario 3**: Choice of Cluster Head using the Concept of Effective Residual Energy*

We now calculate the H.E.P by utilizing ERE in place of residual energy in Scenario 2, for the given nodes 1~6 and select the node with the highest H.E.P value as the cluster head.

TABLE 5

HEAD EVALUATION PARAMETER (HEP) VALUES

HEP(1)	0.000009
HEP(2)	0.000010
HEP(3)	0.000008
HEP(4)	0.000006
HEP(5)	0.000005
HEP(6)	0.000005

From the given table we conclude that node 2 is selected as the cluster head using this scheme. This shows that

ERE makes the mobility based scheme inclined towards the load balancing scheme.

6. Conclusion

Earlier comparative works have proved that CBRP under the scheme of CHSV considered distance and residual energies of nodes and elected optimum cluster heads that saved more energy in nodes. It also alternated the role of cluster heads to balance energy consumption among cluster members. This scheme was more computation oriented as it involved explicitly obtaining the location of each of the neighbors. However, the second scheme studied by us was that of DEMAC and it concentrated on a formula based approach for degree, energy and mobility aware clustering. The formulated approach proposed by us lays stress on the computation of E.R.E rather than directly use R.E. The incorporation of range factor in DEMAC's formula takes into consideration the location factor (given in CHSV scheme) but with reduced computational overheads. So, our clustering scheme shows an inclination towards both the factors and thus provides a midway between the studied schemes for optimal clusterhead selection.

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