A BROADCASTING ALGORITHM USING ADJUSTABLE TRANSMISSION RANGES IN MOBILE AD HOC NETWORKS

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Abstract: Reducing energy consumption is one of the major subjects in designing a good broadcasting algorithm for mobile ad hoc networks. This paper discussed 2 approaches to communication algorithms; 2-level clustering mesh approach and 1-level flat mesh approach, and proposes one of them which makes it appear that the total amount of expended energy becomes lesser. (Wu and Dai, 2004) previously proposed 2 approaches; 2-level clustering approach and 1-level flat approach. In mobile ad hoc networks mobile hosts move frequently, and these moves may cause a change in communicating relationships. In designing a minimum energy routing protocol for these mobile ad hoc networks with this inherent property, the use of a virtual backbone has become popular. This study (Wu and Dai, 2004) is based on the virtual backbone conception. Our 2 proposed approaches change the clustering performed in (Wu and Dai, 2004) into mesh so that energy consumption becomes smaller. The efficiency of the 1 level flat mesh approach is confirmed through our simulation study.

1 INTRODUCTION

Mobile ad hoc networks (simply MANET) consist of wireless mobile hosts that communicate without the need of any fixed infrastructure. Broadcasting is a process in which the same massage is delivered to every node. An overhead in MANET comes from this broadcasting or blind flooding which is a process to determine a necessary route in ordinary one-to-one routing protocols in MANET. Broadcasting or flooding may generate excessive redundant message derivation. This redundant message derivation causes not only a broadcast storm problem (Tseng, Ni, Chen and Sheu, 2002) but also serious redundant energy consumption. An efficient broadcasting route is a conventional Steiner tree which leads to NP-hard. Although MANET has no physical backbone infrastructure, a virtual backbone can be formed by nodes in a connected dominating set (CDS) of unit-disk graph (Wu and Dai, 2004) of a given MANET. More concisely, a virtual backbone is an exclusive communication path framed among imaginary partitioned groups.
The concept of this virtual backbone is powerful for saving communication energy. Fig.1 (a) and (b) shows the two broadcast processes; one using the concept of a virtual backbone and the other without, respectively. By way of the arrows depicted in the 6 frames of each graph, all necessary one-to-one communications necessary to perform a broadcast from source node s is described. Fig.1 shows that the broadcasting process using the concept of a virtual backbone requires fewer arrows, this means less energy consumption.

Virtual Multicast Backbone (VMB) structures are commonly used in current multicast protocols. Instead of the conventional Steiner tree model, the optimal shared VMB in ad hoc networks is modeled as a Minimum Steiner Dominating Set in Unit-Disk Graphs (Ya-feng, 2004) which leads also to NP-hard.

Energy-efficient broadcasting has been widely studied. Several protocols have been proposed to

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manage energy consumption by adjusting transmission ranges. For a comprehensive survey on various aspects of broadcasting in MANET, refer to (Stojmenovic and Wu, 2004). In this paper, we use the static and source-independent approach for CDS construction since it is more genetic. It is also assumed that no location information is provided, as was similarly mentioned in (Wu and Dai, 2004).

The remainder of this paper is organized as follows: In Section 2, we introduce some preliminary knowledge required to understand 2 new protocols. The 2 level clustering mesh approach and 1 level flat mesh approach are introduced in Section 3. Section 4 shows our simulation experiences and results. Finally, we will conclude in Section 5.

2 PRELIMINARIES

Instead of a physical backbone infrastructure, MANET can form a CDS, as mentioned before. (Wu and Li, 1999) proposed the "marking process" which is a self-pruning process to construct a CDS: *Each node is marked if it has two unconnected neighbors, otherwise it is unmarked.* The marked nodes form a CDS, which can be further reduced by applying pruning rules (Dai and Wu, 2003).

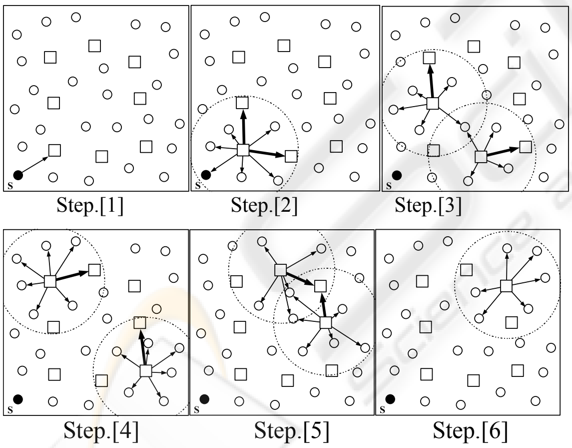
Pruning rule k: A marked node can unmark itself if its neighbor set is covered by a set of connected nodes with higher priorities.

The clustering approach is commonly used to offer scalability and is efficient in a dense network. Basically, the network is partitioned into a set of clusters, with one cluster-head in each cluster.

Cluster-heads form a DS which is a subset of nodes in the network where every node is either in the subset or a neighbor of a node in the subset. No two cluster-heads are connected. Each cluster-head connects to all its members (non-cluster-heads) in most k hops, which originates from the k-level clustering approach. The classical clustering cluster formation works are stated in (Wu and Dai, 2004):

(1) A node v is a cluster-head if it has the highest priority in its 1-hop neighborhood including v. (2) A cluster-head and its neighbors form a cluster and these nodes are covered. (3) Repeat (1) and (2) on all uncovered nodes.

Two new approaches to construct a backbone will be proposed and discussed in this paper. These approaches originate from two approaches; 2-level clustering and 1-level flat approaches. In the lower level of 2-level clustering, the network is covered by the set of cluster-heads under a short transmission

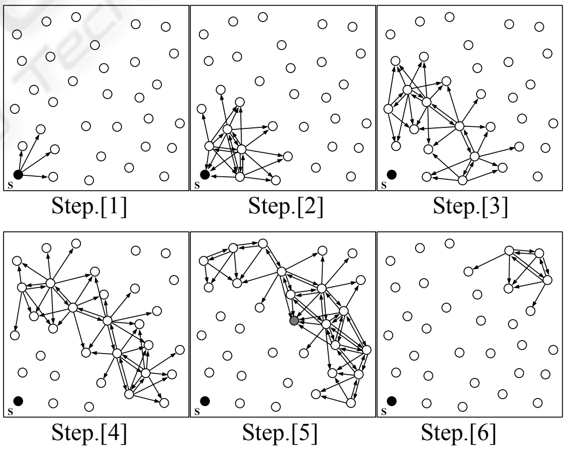


Step[1] : A source node uploads.

Step[2] : The □ node transfers the data to every node and other □ nodes in a range.

Step[3] – [6] : Similarly, the □ node transfers the data.

Figure 1(a): A broadcast process using the concept of virtual backbone.



Step[1] : A source node transfer the data to every node in a range.

Step[2] : Receiving nodes transfer the data to every node in a range.

Step[3] – [6] : Similarly, receiving nodes transfer the data.

Figure 1(b): A broadcast process using none of the concepts of a virtual backbone.

(● : Source node, ○ : Node, □ : The node which communicates between the groups,
Circle in broken line[ ] : Group, → : Data transfer, ➡ : Data transfer between groups)

range. In the upper level, all cluster-heads are covered by the set of marked cluster-heads under a long transmission range. Conversely, the 1-level flat approach constructs a flat backbone, where the network is directly covered by the set of marked cluster-heads having a long transmission range.

2.1 2-level Clustering Approach

As mentioned above, this approach uses different transmission ranges at different levels to connect not only non-cluster-heads and cluster-heads but also to connect cluster-heads where gateway nodes are required to make selections.

Marking process on cluster-heads and marked cluster-heads:

1. *Select a node with the highest priority among nodes which belong to none of the cluster heads and let it be a cluster-head. Every node in the cluster-head's range of (1/3)r belongs to the cluster-head.*
2. *Continue process 1 until every node is a cluster-head or belongs to any one of the existent cluster-heads.*
3. *Select a cluster-head which has the most cluster-heads laid in its range of r and at least one of them does not lay in every other cluster-head. Let this be the first marked cluster-head.*
4. *Select a cluster-head which has the most cluster-heads laid in its range of r and lays itself within the range of any other marked cluster-heads of r.*
5. *Continue process 4 until all such cluster-heads are gone.*

Broadcast process:

1. *A source node uploads its own data to the cluster-head.*
2. *The cluster transfers the data to a marked cluster-head located within the range of r.*
3. *The marked cluster-head transfers the data to every cluster-head and marked cluster-head within the range of r.*
4. *Receiving marked cluster-heads change into transferors for the data if the data is new. Conversely, receiving cluster-heads automatically broadcast data within their own range.*
5. *The process 4 terminates when every node receives data sent by the source.*

Figure 2 (a) shows a broadcasting process based on this approach.

2.2 1-level Flat Approach

Though the two marking processes for cluster-heads and marked cluster-heads are the same as in the above approach, using a uniform transmission range can prevent redundant energy consumption.

Marking process on cluster-heads and marked cluster-heads:

1. *Select a node with the highest priority among nodes which belongs to no cluster head and let it be a cluster-head. Every node in the cluster-head's range of (1/4)r belongs to the cluster-head.*
2. *Continue process 1 until every node is a cluster-head or belongs to any other cluster-head.*
3. *Select a cluster-head which has the most cluster-heads laid within its range of r and at least one of them does not lay in every other cluster-head. Let it be the first marked cluster-head.*
4. *Select a cluster-head which has the most cluster-heads laid within its range of r and one which lays itself within the range of r of any other marked cluster-heads.*
5. *Continue process 4 until such a cluster-heads are gone.*

Broadcast process:

1. *A source node uploads its own data directly to the marked cluster-head.*
2. *The marked cluster-head broadcasts the data to every node (other marked cluster-heads, cluster-heads, and nodes) located within its range of r.*
3. *The process 4 terminates when every node receives data sent by the source.*

Fig.2(b) shows a broadcasting process based on this approach.

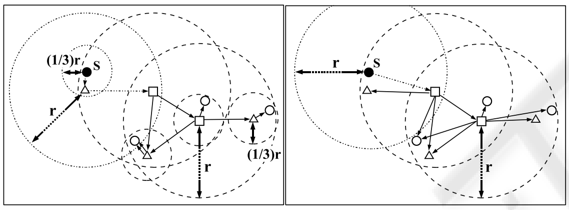
3 2-LEVEL CLUSTERING MESH APPROACH AND 1-LEVEL FLAT MESH APPROACH

A mesh-clustering protocol is introduced to the above two approaches. A given domain is divided by N×N lattices. In the following marking process, let R=r1 in the 2-level mesh approach and let R=r2 in the 1-level mesh approach where r1 and r2 are shown in Fig.3.

Marking process on cluster-heads and marked cluster-heads:

1. *Select the most central node in each lattice and let it be the cluster-head in the lattice and let randomly distributed nodes in the lattice be subordinate nodes of the cluster-head in the lattice.*
2. *Select a cluster-head which has the most cluster-heads laid in its range of r and at least one of them does not lay in every other cluster-head. Let it be the first marked cluster-head.*
3. *Select a cluster-head which has the most cluster-heads laid within its range of r and lays itself within the range r of any other marked cluster-heads.*
4. *Continue process 3 until such cluster-heads are gone.*

Fig.4 (a) shows marked cluster-heads and cluster-heads nominated based on this process and for reference, and Fig.4 (b) shows them based on the previous 2-level clustering approach.



(a)2-level clustering approach (b)1-level flat approach

Figure 2: Examples of broadcast processes based on two approaches.

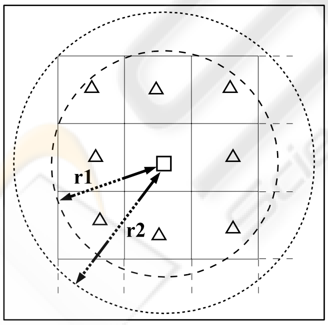


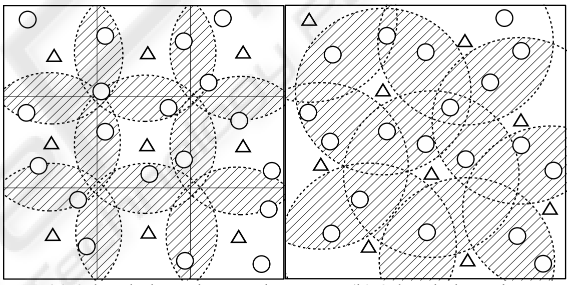
Figure 3: Two ranges in 2-level clustering and 1-level flat mesh approaches.

Broadcast process: *2-level and 1-level mesh approaches adopt the same broadcast processes as those of the 2-level clustering approach and the 1-level flat approach, respectively.*

Fig.5 (a) and (b) show a broadcasting process based on these approaches.

4 SIMULATION EXPERIENCES AND RESULTS

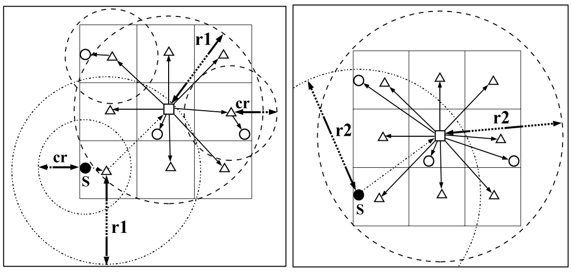
We adopt a commonly encountered model of a network where n homogeneous nodes are randomly thrown in a given region S, both uniformly and independently. If more than two neighbors of a node transmit simultaneously, the node is assumed to receive no message. The neighbors of a node are not permanent within a number of slots, because of unstable network topology.



(a) 2-level clustering mesh approach (b) 2-level clustering approach

Figure 4: Marked and non-marked cluster-heads nominated based on two approaches.

(Shaded part is a duplication of clusters)



(a) 2-level clustering mesh approach (b) 1-level flat mesh approach

Figure 5(a)(b): Examples of broadcast process based on two new approaches.

(● : Source node, ○ : Node, △ : cluster-head, □ : marked cluster-head,
Circled by broken line[┈┈┈] : Transmission range for upload, ···▶ : Data upload,
Circled by dotted line [- - - -] : Transmission range for broadcast, ⟶ : Data broadcast)

4.1 Simulation Experience

This section describes the input parameters and output measures for the evaluation of the volume of energy consumption in 4 kinds of clustering. For the purpose of our simulation, we consider a 100×100 square domain where 1000 nodes are randomly distributed. In mesh approaches, we set the square domain divided by1×1(=N×N), 2×2, …, 9×9, and 10 ×10. We evaluate the volume of energy consumption for the broadcasting in transmitting range r as r^2 (Wieselthier and Nguyan and Ephremides, 2000). We used the same value of r (=24m) as shown by (Wu and Dai, 2004). We also performed experimentation in the case where N is fixed as 3 but the total number of nodes are 100,200, …,1000.

4.2 Results

Fig.6 shows the number of marked cluster-heads for different numbers of divisions. Fig.7 shows the ranges of each cluster-head and marked cluster head for different numbers of divisions. Figs.8 and 9 show the energy consumption for different numbers of divisions and for different numbers of distributed nodes, respectively. These results mean that 1-level mesh approach provides excellent results, especially when 3×3.

4.3 Improved Methods and the Simulation Results

The above results show that the efficiency of 1-level flat mesh approach can be confirmed. However, both this approach and the 2-level clustering mesh approach require an extremely large amount of energy in special nodes (marked cluster-heads), making this a problem. This problem is more evident when the divided square domains become smaller. We further evaluated the volume of energy consumptions required in the case where two ranges in 2-level clustering and 1-level flat mesh approaches are restricted in the smaller sizes as shown in Fig.10. These restrictions make the number of marked cluster-heads larger but the load of each marked cluster-head smaller. Figs.11 (a), (b) and (c) show the energy consumption for different numbers of divisions in the cases of 100, 500, and 1000 nodes, respectively. These results show that the improved 1-level flat mesh approach proves to be superior when the number of divisions becomes larger.

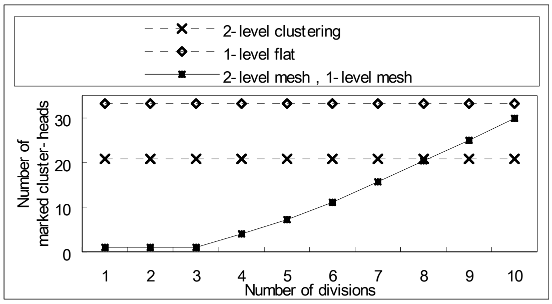


Figure 6: Number of marked cluster-heads for different number of divisions.

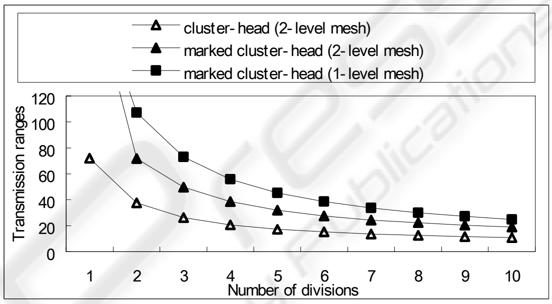


Figure 7: Ranges of each cluster-head and marked cluster head for different numbers of divisions.

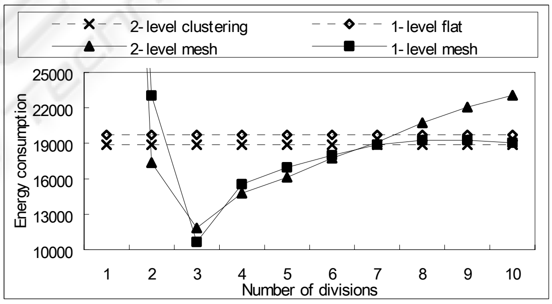


Figure 8: Energy consumption for different numbers of divisions.

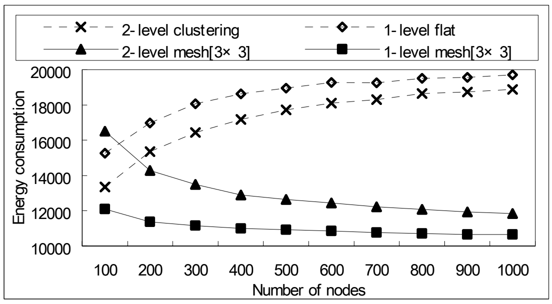
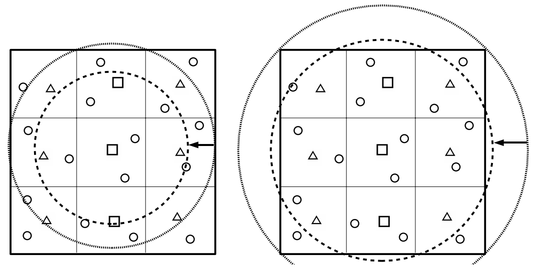


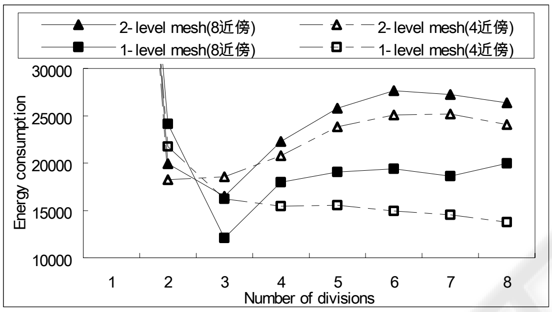
Figure 9: Energy consumption for different numbers of distributed nodes.



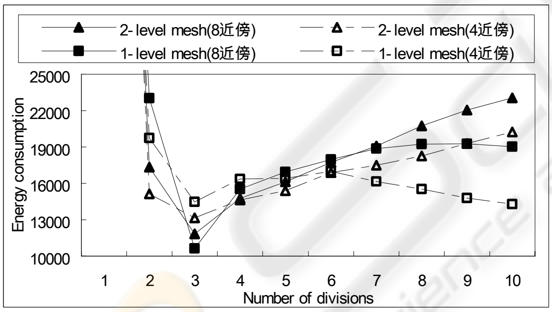
(a)2-level clustering mesh approach (b)1-level flat mesh approach

Figure 10: Restricted range in (a) 2-level clustering mesh and (b) 1-level flat mesh approaches.

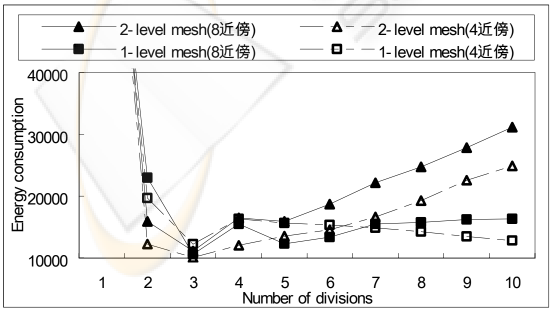
(● : Source node, ○ : Node, △ : cluster-head, □ : marked cluster-head)



(a)The case of 100 nodes.



(b)The case of 500 nodes.



(c)The case of 1000 nodes.

Figure 11: Energy consumption for different numbers of divisions in the cases of (a)100, (b) 500 and (c) 1000 distributed nodes.

5 CONCLUSIONS

Reducing energy consumption is one of the major objectives in designing a good broadcasting algorithm for mobile ad hoc networks. This paper discussed 2 approaches to communication algorithms; 2-level clustering mesh approach and 1-level flat mesh approach, and proposes one of them which makes it appear as though the total amount of expended energy becomes lesser. Our 2 proposed approaches not only use the concept of a virtual backbone but also adopt mesh in clustering so that energy consumption becomes less. The efficiency of 1-level flat mesh approach is confirmed through our simulation study.

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