EVALUATION OF K-/LATTICE-CLUSTERING ALGORITHMS FOR RANDOM WIRELESS MULTI-HOP NETWORKS

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Abstract: A k-clustering protocol is an algorithm in which the wireless network is divided into non-overlapping sub networks, referred to as clusters, and where every node of a sub network is at most k hops from a distinguished station called the cluster-head. A lattice-clustering protocol is an algorithm in which a given area is divided by lattices and randomly distributed hosts in a lattice are one hop from the cluster-head. In this paper, we evaluated the energy eficiencies for the broadcasts designed in both k-clustering and lattice-clustering protocols. The evaluation showed that the k-clustering protocol is characterized by the smallest broadcasting power of each node, and a lattice-clustering protocol constitutes a characteristic feature of the most minimal total energy consumption. The main source of greater energy consumption in k-clustering protocol is a large number of transmissions between adjacent node pairs.

1 INTRODUCTION

Ad hoc networks consist of wireless hosts that communicate without the need of any fixed infrastructure. These Ad hoc networks are well suited to specific and often extreme situations, such as disaster-relief, law-enforcement, and fire-detection where each host works as a sensor node, or simply for collaborative computation in some short-term public events. A k-clustering protocol is an algorithm in which the wireless network is divided into non-overlapping sub networks, referred to as clusters, and where every node of a sub network is at most k hops from a distinguished station called the cluster-head. A lattice-clustering protocol is an algorithm in which a given area is divided by lattices and randomly distributed hosts in a lattice are one hop from the cluster-head. Clustering is commonly used in ad hoc networks in order to limit the amounts of both energy consumed for communication and information stored for routing at individual nodes. The clustering approach is used to offer scalability and is efficient in a dense network. Several clustering algorithms have been proposed for each different advantage. The basic idea of (Wu and Dai, 2004) is to reduce the network density through clustering using a short transmission range. Then neighboring cluster heads which are 2 or 3 hops away are connected using a long transmission range, that is, without using any gateway selection process. K-clustering, one of the main clustering protocol, requires no special broadcasting power by heads, thus, a surface can be clustered by nodes with a uniform power. This advantage means that each node requires and consumes a lesser amount of energy than that of the 2-level clustering and the 1-level flat approach. Since, in broadcasting, all nodes are employed in receiving a message, it is important to discuss total energy consumption. We assume the situation that a node broadcasts to all other randomly distributed (n-1) nodes which can use synchronous radio transmissions in each of their transmitting ranges. In this situation, we evaluate the energy efficiencies for the broadcasts designed in both k-clustering and lattice-clustering. The remainder of this paper is organized as follows: In Section 2, we introduced the k-clustering algorithm. The lattice-clustering algorithm is introduced in Section 3. Section 4 shows our simulation experiences and results. Finally, our conclusions are expressed in Section 5.

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2 K-CLUSTERING ALGORITM

2.1 Algorithm

A k-clustering protocol is an algorithm in which every node locates at most k hops from its belonging cluster-head. Each node knows its own position and its ID (or IP address), but it is assumed that each node has no topological information. The transmission radius of every node is set to the same. Then, for a given number n of nodes deploying randomly and uniformly on a surface of size s, there exist the optical values of both this transmission radius r and the clustering value k which lead to the condition where every node knows cluster in which its belongs and every gate way knows the list of its adjacent clusters. Gate way is a node whose communication range contains nodes belonging to other clusters. This study has been performed by (Ravelomanana, 2005), he gave the theorem that, for any fixed constant l , there exists a constant C(l) such that if r is set to

$$r = \frac{\sqrt{(1+l)|S|logn}}{\pi n} \quad (1)$$

every node may have received all the identities of each of its neighbors. In this paper, we use the above r when l is 0, and the same k as in (Ravelomanana, 2005).k=an integer log(log n) discarded under the decimal point.

[Algorithm]

1. Find a node with the smallest ID. Label a cluster head to the node.
2. Let every node, located at most k hops from the newest cluster head but not yet a member of other clusters, be a member belonging to the newest cluster head. Remove IDs from the cluster head and the member nodes.
3. Repeat processes 1 and 2 until every node belongs to a cluster.
4. Label a gateway to the node if a node belonging to another cluster locates in the transmission radius of the node.

An example of k=2: Fig. 1 shows an example of 2-clustering where node ci (i=1-7) mean cluster heads.

2.2 Broadcasting in K-clustering

The procedure of broadcasting is as follows:

1. A source node broadcasts its information in its transmitting range.
2. Each node which received the information broadcasts it in the transmitting range.

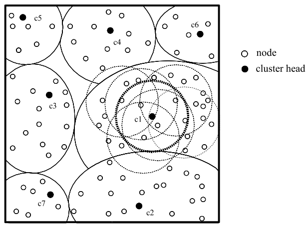

Figure 1: A K=2 clustering where 2 dotted lines ... and ... mean 1 hop and 2 hops regions from each cluster head, respectively.

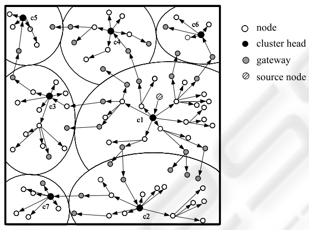

Figure 2: An example of broadcasting in 2-clustering.

3. A cluster head which has received a source node's information broadcasts it to every one of its members at most 2 steps.
4. A source node (gate way) which received the information from a node (gate way) located in the adjacent cluster broadcasts the information within its transmitting range just like a source node in its cluster.

Fig. 2 shows an example of broadcasting in 2-clustering.

3 LATTICE-CLUSTERING ALGORITHM

3.1 Algorithm

A lattice-clustering protocol is an algorithm in which a given domain is divided by NN lattices as shown in Fig.3 and randomly distributed hosts in a lattice are one hop from the cluster-head. This lattice-clustering protocol is divided into 2 kinds: one is where the transmitting range of each cluster-head reaches all 8 adjacent cluster-heads and the other includes only 4 of the closest cluster-heads. They are labeled as Lattice (8) and Lattice (4) in the following section.

[Algorithm]

1. Find the closest node to the center of each lattice-cluster.
2. Label a cluster head to the node.

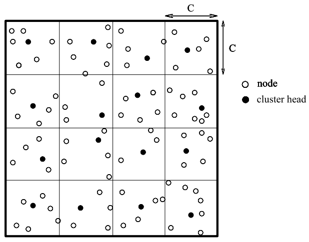

Figure 3: A lattice-clustering of 4 X 4.

3.2 Broadcasting in Lattice-clustering

The procedure of broadcasting is as follows:

1. A source node broadcasts its information in its transmitting range.
2. A cluster head which received source node's information from the adjacent cluster head broadcasts it to every one of its members in its own lattice-cluster.

Fig. 4 shows an example of broadcasting in a 4 X 4 lattice-clustering.

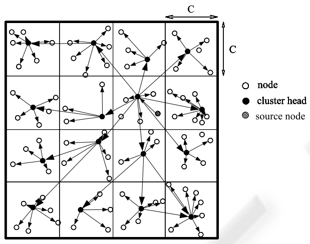

Figure 4: Example of broadcasting in a 4 X 4 lattice-clustering.

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, uniformly and independently, (Wieselthier, 2000). As is customary, the time is assumed to be slotted and in each time slot every node can act either as a transmitter or as a receiver, but not both. In any given time slot, if and only if a node acting as a receiver gets a message, exactly one of its neighbors precisely transmits within the same round. 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.

4.1 Simulation Experience

This section describes the input parameters and output measures for the evaluation of the volume of energy consumption in 2 kinds of clustering. For simulation purposes, we consider a 100x100 square domain where 100, 200,···, 800 and 900 nodes are randomly distributed. In k-clustering, we set the values of clustering k and the transmitting range as the values given in (Ravelomanana, 2005) as mentioned in Section 1. In lattice-clustering, we set a domain divided by 3x3, 4x4 , ···, 15x15, and 16x16. We evaluate the volume of energy consumption for the broadcasting in transmitting range r as r2 (Wieselthier, 2000). Therefore, the broadcasting power Pik required from i to k as shown in (2) and Fig. 5.

$$Pik = Pij + Pjk = r^2 + r^2 = 2r^2 \qquad (2)$$

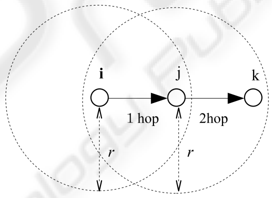

Figure 5: Broadcasting power required from i to k via j.

4.2 Results 1

Fig. 6 depicts the volumes of energy consumptions required in a broadcast for the total number of nodes. Fig. 7 depicts the broadcasting power required in each cluster head for the number of nodes. As shown in Fig. 6, Lattice (4) is best among three clustering algorithms. Fig. 7 shows that k(=2)-clustering saves the broadcasting power to cluster heads the most.

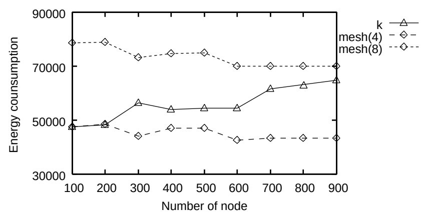

Figure 6: Volumes of energy consumption required in a broadcast.

4.3 Results 2

Further investigation in the following cases can be considered: The k-clustering protocol adopts the direct communication between adjacent cluster heads

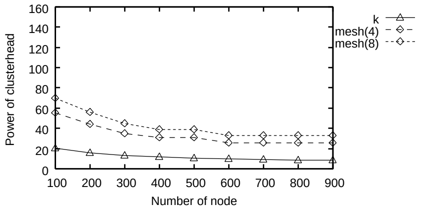

Figure 7: Broadcasting power required in each cluster head.

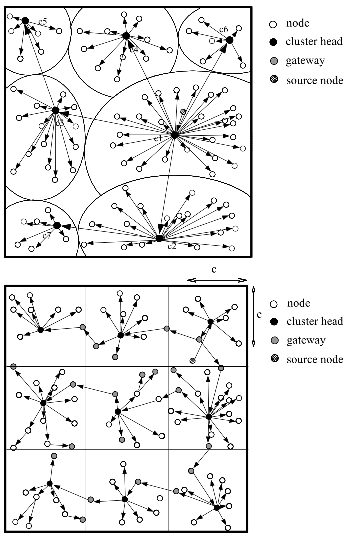

Figure 8: Examples of broadcasting in new K-and lattice-clustering.

(New k-clustering protocol). The lattice-clustering protocol adopts mediate communications between adjacent cluster heads (New lattice-clustering protocol). We briefly summarize the results in the case of these new protocols. In the new lattice-clustering, a given domain is divided by N X N lattices as is in the old lattice-clustering protocol. In order to avoid an increase in the number of gateways, the new protocol must take a certain measure, the details of which are omitted in this paper due to space. The new k-clustering protocol takes the same measure as in the old k-clustering protocol. Fig. 8. shows examples of broadcasting in new k- and lattice- clustering.

We evaluated the total energy consumption, the average broadcasting powers of each head in Fig. 9 and 10, in 5 clustering protocols.

5 CONCLUSIONS

In this paper, we evaluated the energy efficiencies for the broadcasts designed in both k-clustering and lattice-clustering protocols. The evaluation showed that the k-clustering protocol is characterized by the

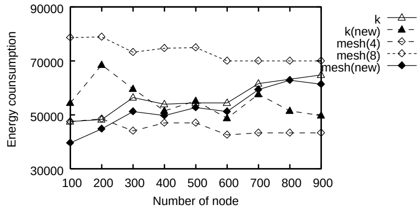

Figure 9: Comparison of the total energy consumption required in 5 clustering protocols.

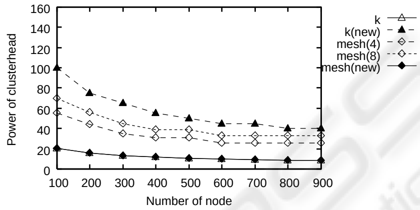

Figure 10: Comparison of broadcasting power required in each cluster head.

smallest broadcasting power of each node, and the Lattice (4)-clustering protocol constitutes a characteristic feature of the smallest total energy consumption. The main source of the energy consumption in k-clustering protocol is a large number of transmissions between adjacent node pairs. Therefore, the obtained results mean that, in the kind of communications such as those in broadcasting, direct communication between cluster heads should be also be taken into the consideration. Further investigations has been performed for the new protocols: The k-clustering protocol adopts direct communication between adjacent cluster heads, and the lattice-clustering protocol adopts mediate communications between adjacent cluster heads.

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