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Performance Evaluation of Energy Efficient Communication Protocol for Mobile Ad Hoc Networks

Toshihiko Sasama, Kentaro Kishida, Kazunori Sugahara, and Hiroshi Masuyama

Abstract**—**A mobile ad hoc network is a network of mobile nodes without any notion of centralized administration. In such a network, each mobile node behaves not only as a host which runs applications but also as a router to forward packets on behalf of others. Clustering has been applied to routing protocols to achieve efficient communications. A CH network expresses the connected relationship among cluster-heads. This paper discusses the methods for constructing a CH network, and produces the following results: (1) The required running costs of 3 traditional methods for constructing a CH network are not so different from each other in the static circumstance, or in the dynamic circumstance. Their running costs in the static circumstance do not differ from their costs in the dynamic circumstance. Meanwhile, although the routing costs required for the above 3 methods are not so different in the static circumstance, the costs are considerably different from each other in the dynamic circumstance. Their routing costs in the static circumstance are also very different from their costs in the dynamic circumstance, and the former is one tenths of the latter. The routing cost in the dynamic circumstance is mostly the cost for re-routing. (2) On the strength of the above results, we discuss new 2 methods regarding whether they are tolerable or not in the dynamic circumstance, that is, whether the times of re-routing are small or not. These new methods are revised methods that are based on the traditional methods. We recommended the method which produces the smallest routing cost in the dynamic circumstance, therefore producing the smallest total cost.

Keywords**—**cluster, mobile ad hoc network, re-routing cost, simulation

I. Introduction

A mobile ad hoc network (MANET) has properties which are fundamentally different from the traditionally wired networks regarding communication, mobility, and resource constraints. This makes the design of distributed algorithms much more complex than the designs of traditional distributed systems. However, resource constraints, for example low bandwidth, limited power supply, or low process capability, are some of the prominent features of mobile environments [1]. In addition, the mobility of MANET nodes is handled by ad hoc routing protocol. These MANET nodes can be used in high-cost situations to create a centralized infrastructure. Recently, the integration of MANET nodes into the Internet has been the focus of many research efforts in order to provide MANET nodes with Internet connectivity [2]. Organizing a network into a hierarchical structure could make management systems, such as routing, more efficient. In these MANETs, clustering is one of the most important approaches to energy efficient and cost efficient communications. Clustering is an algorithm in which the network is divided into non-overlapping sub networks, referred to as clusters where every node of each sub network is at the most k-hops from a distinguished station called the cluster-head (CH). Clustering is a hierarchical structure, and as such is suitable for a relatively large numbers of nodes [3]-[7].

Clustering is conducted by first selecting Cluster-heads. Non-cluster-heads choose clusters to join and then become members. Though there are several kinds of clustering algorithms, we took the lowest ID algorithm [8] which is widely used. In this algorithm, all nodes are each assigned a unique ID, first. An example of such networks is shown in Fig.1 where solid lines show node pairs which are able to communicate directly. A node that has the lowest ID among neighbors which have not joined any clusters will declare itself the cluster-head. Other nodes will select one of the neighboring cluster-heads to join and become members. This process is repeated until every node has joined a cluster. Fig.1 shows an example of a network clustered by dotted circles.

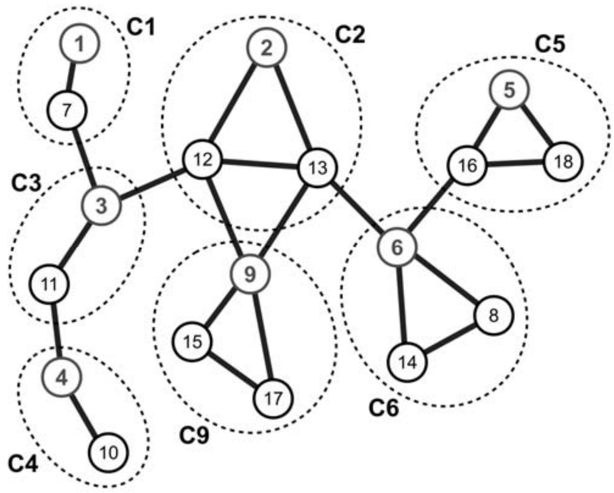

Fig. 1 A network with 7 cluster-heads

T. Sasama, K.Sugahara and H. Masuyama are with Graduate School of Engineering, Tottori University. K. Kishida is with ME student in Graduate School of Engineering, Tottori University.

In this paper, we discuss, in the next section, three traditional methods for the construction of a CH network. We prepared new two algorithms and examine their const performances in the following sections with the reasoning that good cost performances of these CH networks respecting the amount of packet transmissions in static circumstances do not hold in dynamic circumstances.

II. Preliminary

Connectivity among cluster-heads is required for most applications such as message broadcasting. Under the condition that the power supply is identical for all nodes, cluster-heads do not directly connect with other cluster-heads that are at least 2 hops away. This means that cluster-heads should include a multi-hop packet relay design, that is, some non-cluster-heads should be selected as gateway nodes to perform message forwarding between cluster-heads. The distance between the cluster-heads of two neighbor clusters is generally 2 or 3 hops. The traditional methods of constructing a CH network are characterized by the calculation of the amount of area to construct; the largest 2k+1 hops-, the middle 2.5 hops-, and the smallest A-NCR-methods, as follows;

2.1 2k+1 hop coverage[8]

One way is to select border nodes as gateways for connecting the cluster-heads. A border node is a member with neighbors in other clusters.

Finding gateway nodes to connect all cluster-heads within each other's 3-hop neighborhood is another widely used method.

2.2 2.5 hop coverage[9]

Each cluster-head covers all cluster-heads within 2 hops and some cluster-heads that are 3 hops away.

2.3 A-NCR[10]

The adjacent-based neighbor cluster-head selection rule (A-NCR) is an extension and generalization of the "2.5" hops covering theorem, used for neighbor cluster-head selection in the first phase. In A-NCR, a small set of neighbor cluster-heads (within 2k+1 hops) can be found by each cluster-head while ensuring the global connectivity of cluster-heads. At the most, 2k+1 hops-broadcasting is needed. The parameter k is tunable, and usually at 1. This is because in ad hoc networks, network topology changes frequently. Therefore the small k may help to construct a combinatorial stable system, where the propagation of all topology updates is sufficiently fast enough to reflect the topology change.

In the above methods, A-NCR method is most cost effective for the construction of the CH network because it uses the smallest computing area. Since a path found through the smallest computing area creates the possibility of finding a longer routing path in a real network, this subsequently may lead to a higher running cost, which places receiving the data transmission under real circumstances at a disadvantage. Fig.2 shows each CH network constructed based on the above 3 methods.

2.4 Routing

One-to-one communication is possible in CH networks. In one-to-one communications, the source node sends a request to the cluster-head of its cluster, of which the source node is a member. In the CH network, the cluster-head broadcasts route searching packets which contain the ID of the destination node. When the cluster-head with the destination node contained in its own cluster receives the broadcast, it then sends back a route decision acknowledgement packet to the source node along the route history. Thus, the source node is able to find the route.

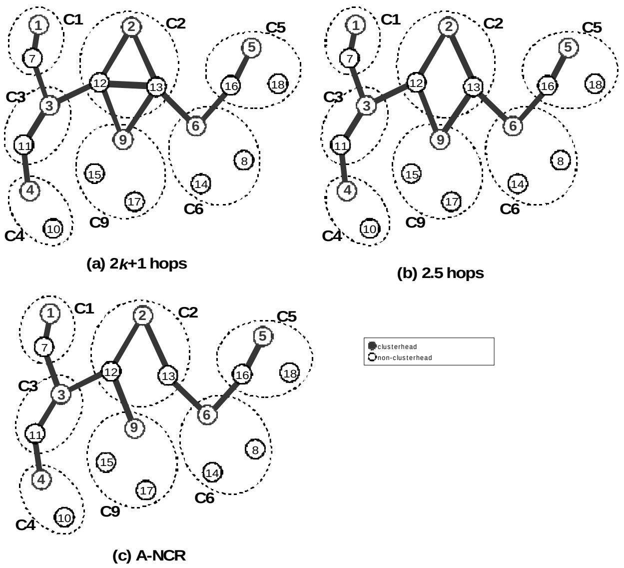

Fig. 2 Each CH network is constructed based on 3 different methods

2.5 Static and dynamic evaluations in the traditional CH networks

In order to make our motivation clear, we show the routing cost and running cost required for a data packet as was found by the above three methods in the circumstances where every node is static and dynamical, respectively. We evaluated the cost required for the route computation with the following equation; Routing cost = (the packet size of a route searching packet)×(the total number of hops required in the routing decision)+(the packet size of a route decision acknowledgement packet) ×(the total number of hops in the decided route)

On the other hand, we used the following formula for the evaluation of running costs; Running cost = (the packet size of a data packet)×(the total number of hops in the decided route)

Fig.3 and Fig.4 show the routing cost and the running cost versus the number of nodes, respectively. These data show there is no great difference in the running cost between the static and dynamic circumstances, but there is a difference of 10 times in the routing cost. The reason is that mobile movements cause the frequent cutting off of routes, so re-routing demands occur frequently.

From the above discussion, improved methods do not required for many re-routing demands. If this requirement is satisfied, we may cut down the routing cost.

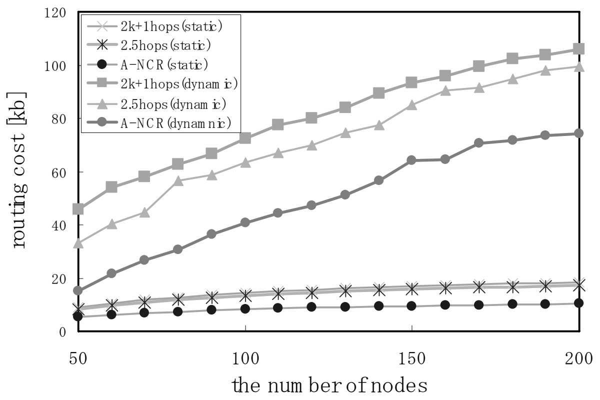

Fig. 3 Routing cost versus the number of nodes in the two circumstances

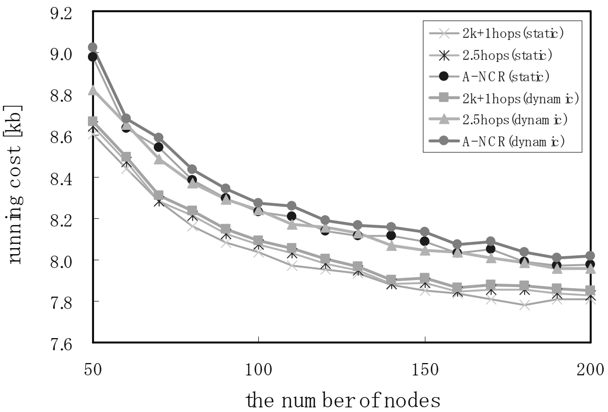

Fig. 4 Running cost versus the number of nodes in the two circumstances

III. New Methods to build a CH network

In this section, we define new 2 algorithms to build up a CH network and evaluate their required costs in the following section.

3.1 New method A

Each node holds the routing table for a certain period after a new CH network is built, and uses it as a looking object to build a back up route [11] when the original route is cut off. The extreme node on the living line tries to find the shortest path to the destination node using the routing table. If the extreme node cannot find the shortest path, then the node behind it next tries to find the shortest path. If the living path to the destination node (= the shortest path) cannot be found, this process is repeated until it reaches the cluster head. Unfortunately, if the living path cannot be found until the cluster head is reached, then a rerouting is performed in the new CH network. This method requires many communications, but does not require a larger computation area. Fig.5 demonstrates an example of new method A.

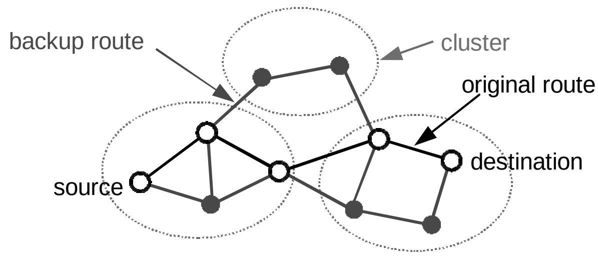

Fig. 5 New method A

3.2 New method B

Each intermediate node and the neighboring nodes on a CH network periodically repair the routing table where new incoming nodes in its communication range and outgoing nodes from its communication range are written in and taken off, respectively. In this method, each intermediate node on a live communication route and its neighboring nodes can always hold plural candidates of a communication route. There is a trade-off between two kinds of communication costs; periodical repair costs and saving costs brought by less times rerouting within a whole network. Fig.6 demonstrates an example of new method B.

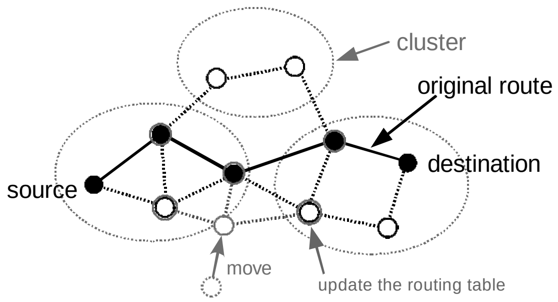

Fig. 6 New method B

IV. Simulation Experiments and Results

In this section, we evaluated the cost performances of these CH networks respective of transmitting data on each routing path as was found by the above three methods.

4.1 Simulation environment

We assumed that each mobile node moves in accordance with the random way point method [12] in the two-dimensional 10km×10km square domain where 50~200 nodes are randomly distributed. The speed of mobile nodes are given by the uniform distribution of 5~80km/h. The moving angle of mobile nodes is also given by the uniform distribution, that is, random. We assumed that all nodes are identical in broadcasting power, that is, each node has 1000m transmitting range.

4.2 Packet specification

We specified the following three kinds of packets; route-searching packet, route- decision- acknowledgement packet, and data packet.

Route-searching packets are used by a cluster head which broadcasts the initial routing for the CH network. This packet is based on UDP/IP [13],[14]; it has a sequence number, a source address, a destination address, a hops-counting number, a limited number of hops, and route information for the adjacent cluster head and route history. Fig.7 illustrates the structure of a route-searching packet. The sizes of route information for the adjacent cluster head and route history are decided by simulation results which say that the size is enough under 4×32 bits.

Route-decision-acknowledgement packets are based on TCP/IP [14],[15], it has and contains a sequence number, a source address, a destination address, and route information from the source address node to the destination address node. Fig.8 shows the structure of a route-decision-acknowledgement packet. The sizes of route-information are decided by simulation results which say that the size is enough under 6×32 bits.

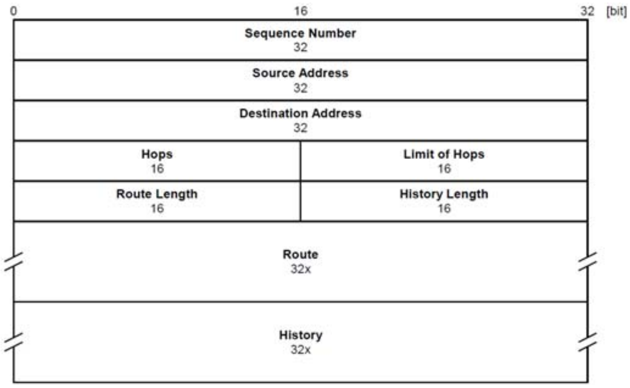

Fig. 7 Structure of a route-searching packet

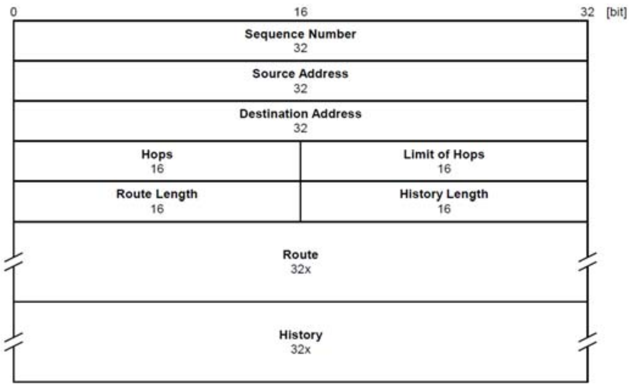

Fig. 8 Structure of a route-decision-acknowledgement packet

The data packet is based on TCP/IP. That is to say, the size is 1500 bytes, which is the MTU value in Ethernets.

4.3 Simulation results

We presented the routing cost required only to rebuild up a route versus mobile speed and total routing cost versus mobile speed in Fig.9 and Fig.10, respectively. These figures illustrate how traditional methods require a larger running cost. These data show that, in every mobile speed, new method A decreases not only re-routing cost but also total routing cost. New method B requires a smaller number of rerouting demands than the traditional method, but requires a bigger total routing cost. This is because of the bigger maintenance cost of the routing table.

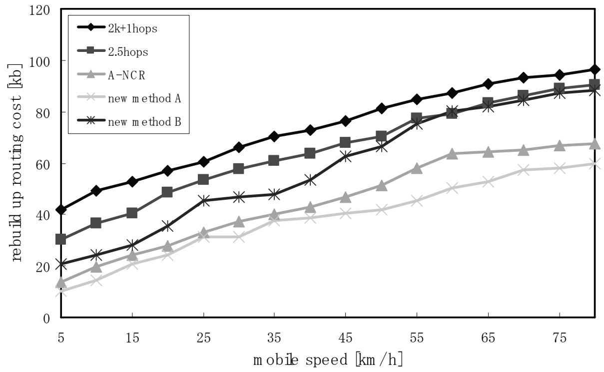

Fig. 9 Re-routing cost for each method

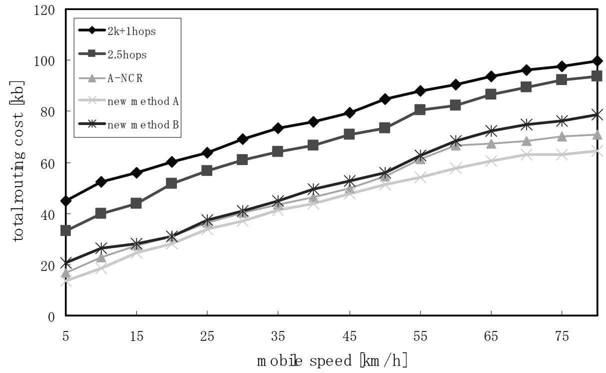

Fig. 10 Total routing cost for each method

V. CONCLUSION

In this paper, we first evaluated the performance of three conventional methods for construction of a CH network respective to the amount of packet transmissions. We can say that the 2k+1 hops-method, which supports the largest computing network and creates the shortest routing path performs the best after a certain amount of time passes. The only disadvantage to obtaining this shorter routing path is that computing time is several times more complex [16]. This result means, that under a realistic level of node mobility, that is, in the dynamic circumstance, the effort to reduce a computing area in order to construct a CH network is not effective for total power saving. So, we tried to evaluate the performances of new methods which may tolerate the cutting off of communication route caused by mobile movements. The evaluation showed that an effective method can produce a 14% savings in power consumption in the dynamic circumstance. This is caused by the reduction of re-routing times. The expansion of a routing table produces shorter communication routes and bigger computation costs which causes a bigger amount of power consumption. On the other hand, the reduction of a routing table produces a lower rate of packet arrivals which means the debasement of communication quality. This is a trade-off in the discovery of the best CH network construction.

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