M-060

モバイル・アドホック・ネットワークにおけるクラスタ接続法による転送量の比較評価
Comparative Evaluation of Traffics using Cluster Connecting Methods in Mobile Ad Hoc Networks

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1. Introduction

A mobile ad hoc network (MANET) has properties which are fundamentally different from the traditionally wired networks regarding communication, mobility, and resource constraints. That makes the design of distributed algorithms much more complex than the designs of traditional distributed systems. However, resource constraint, for example low bandwidth, limited power supply, or low process capability, is one 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 may make the management systems such as routing efficient. Clustering is a hierarchical structure, and as such is suitable for a relatively large numbers of nodes.

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 take the lowest ID algorithm [3] which is widely used. In this algorithm, 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 the lowest ID algorithm.

In this paper, we will define, in the next section, three methods for the construction of a CH (cluster-heads) network in which clusters are connected. In Section 3, we will evaluate the cost performances of these CH networks respective of the amount of packet transmissions.

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2. Preliminary

Connectivity among cluster-heads is required for most applications such as message broadcasting. On condition that is identical for all nodes are power supply, 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 2 or 3 hops. There are three ways (Fig. 2) to define a cluster-head V's neighbor cluster-head set C(v), which are as follows:

2.1 2k+1 Hops Coverage

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

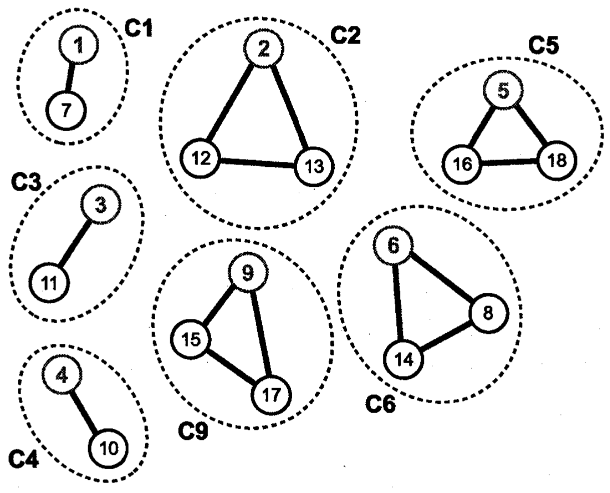

Fig. 1. An example of a network clustered by the lowest ID algorithm (clusters; C1-C6 and C9).

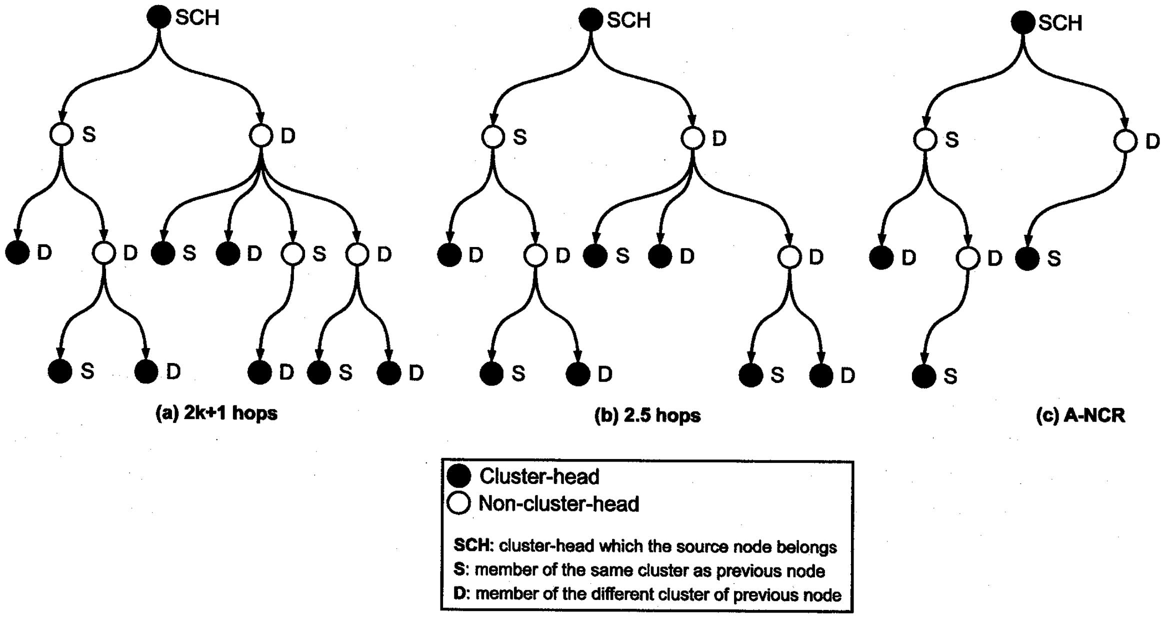

Fig. 2. Coverage diagrams of three different methods.

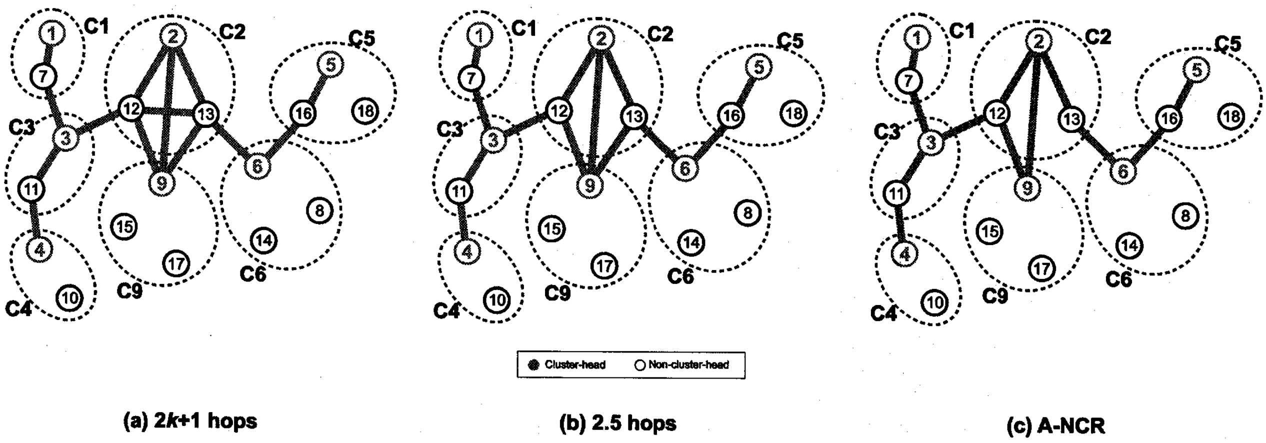

Fig. 3. Each CH network is constructed based on three different methods.

with neighbors in other clusters. Finding gateway nodes to connect all the cluster-heads within each other's 3 hops neighborhood is another widely used method.

2.2 2.5 Hops Coverage

In [4], J. Wu and W. Lou developed the "2.5" hops coverage theorem. Each cluster-head covers all cluster-heads in 2 hops and some cluster-heads that are conditional 3 hops away.

2.3 A-NCR

In [5], S. Yang et al. defined the adjacent-based neighbor cluster-head selection rule (A-NCR) which 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

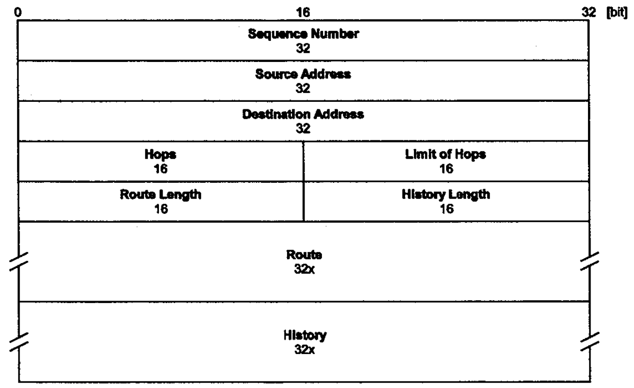

Fig. 4. Structure of a route-searching packet.

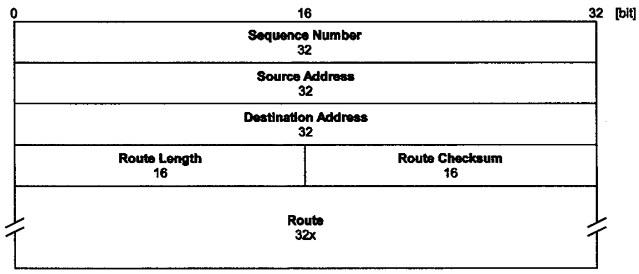

Fig. 5. Structure of a route-decision-acknowledgement packet.

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.

Fig. 3 shows each CH network constructed based on the above three kinds of methods.

2.4 Routing

A 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 which the source node is a member. In the CH network, the cluster-head broadcasts route-searching packets which contain the preassigned 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 which is recorded in the route-searching packet. Thus, the source node is able to find the route.

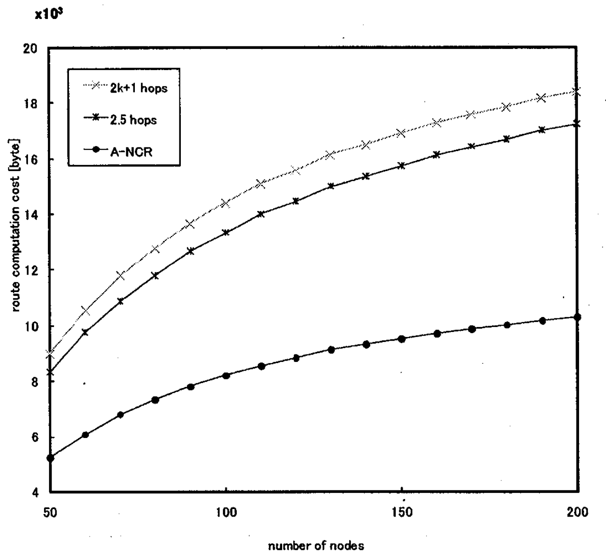

Fig. 6. Route computation cost.

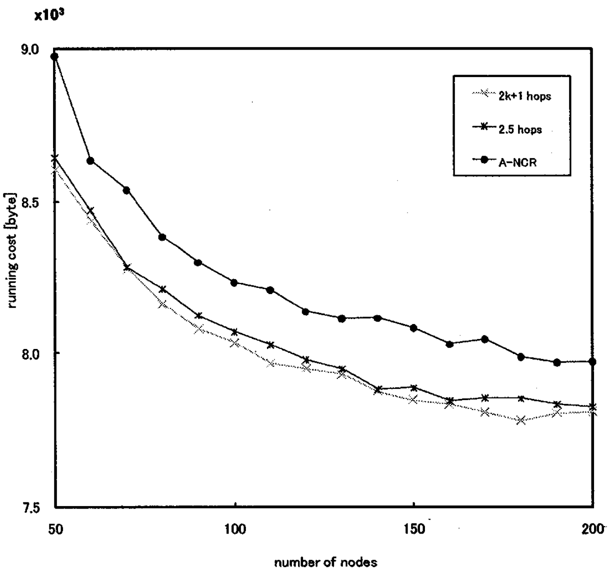

Fig. 7. Running cost.

3. Simulation Experiences and Results

In this section, we evaluate the cost performances of these CH networks respective of the amount of packet transmissions. That is to say, we evaluate the running costs for transmitting data on each routing path as was found by the above three methods.

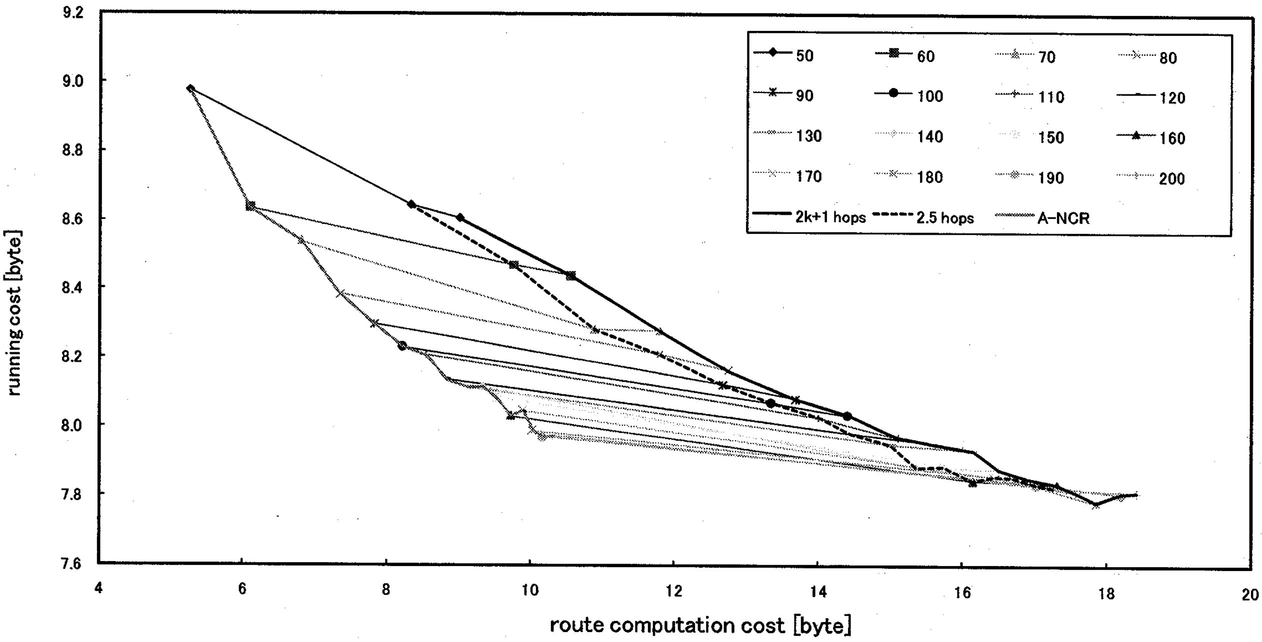

Fig. 8. Correlation between route computation costs and running costs.

3.1 Simulation Environment

For simulation purposes, we consider a 100x100 m square domain where 50-200 nodes are randomly distributed. We assume that all nodes are identical in broadcasting power, that is, each node has 25 m transmitting range.

3.2 Packet Specification

We will specify 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 [6], [7]; it has sequence number, source address, destination address, hops-counting number, limited number of hops, route information for the adjacent cluster-head and route history. Fig. 4 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 4x32 bits.

Route-decision-acknowledgement packets are based on TCP/IP [7], [8], has and contains sequence number, source address, destination address, and route information from the source address node to the destination address node. Fig. 5 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 6x32 bits.

The data packet is based on TCP/IP. That is to say, the size is 1,500 bytes which is the MTU (maximum transmission unit) value in Ethernets.

3.3 Cost Computation

We will evaluate the cost required for the route computation with the following equation;

Route computation 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 can use 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).

3.4 Simulation Results

We will present the route computation cost and running costs in Fig. 6 and Fig. 7, respectively. These illustrate how A-NCR requires the largest running costs.

Fig. 8 shows cost correlation. These data show that, in every number of nodes, the running cost decreases as the route computation cost increases.

4. Conclusions

In this paper, we evaluated the performance of three methods for construction of a CH network respective to the amount of packet transmissions. We demonstrated how 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. It was also made clear that the loss for obtaining this shorter routing path is only several times more complex in regarding to computing time. This result means, that under a realistic lever of node mobility, the effort to reduce a computing area in order to construct a CH network is not effective for total power saving. We are currently interested in the evaluations of the performances of these three methods cases where the propagation of all topology updates is not fast enough to effectively reflect the topology change.

References

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Appendix Figures

The size of route information for the adjacent cluster-head as well as passing history is decided by the following simulation results in Fig. 9 where size is less than 4x32 bits. The size of route information is also decided by the following simulation results in Fig. 10 where the size is less than 6x32 bits.

Fig. 11 shows the total number of hops in the decided route which is required for the calculation of route-computation costs and running costs. Fig. 12 shows the total number of hops in the decided route which is required for the calculation of route-computation costs.

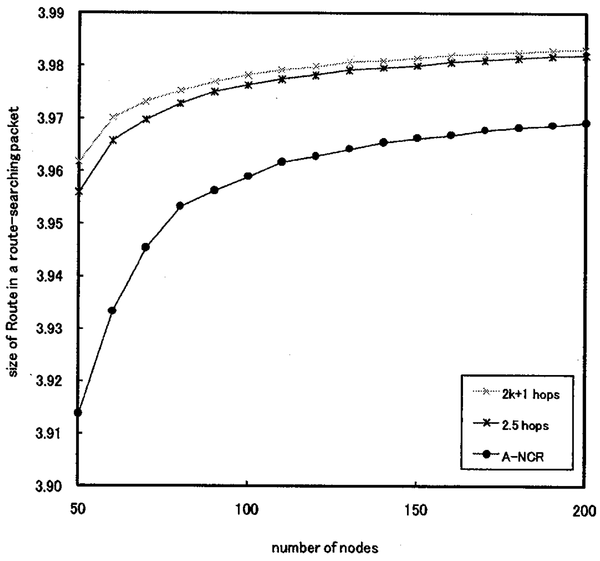

Fig. 9. Size of Route in a route-searching packet.

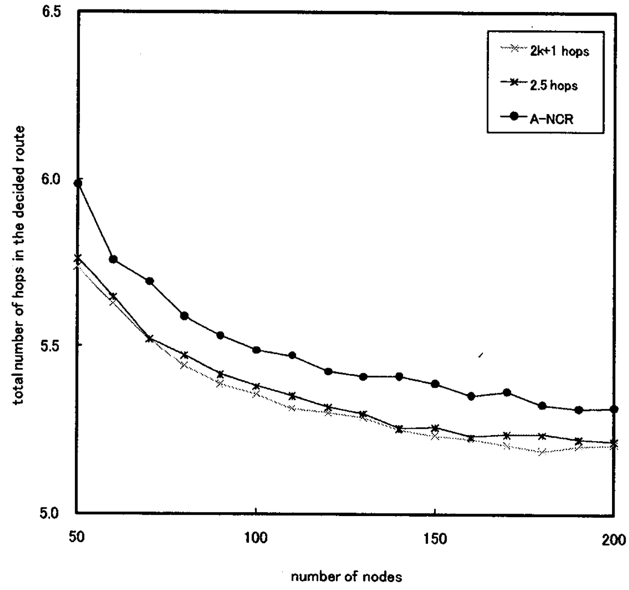

Fig. 11. Total number of hops in the decided route.

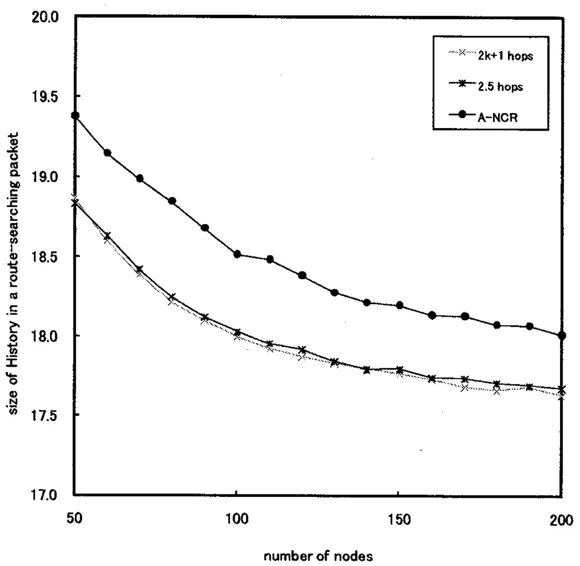

Fig. 10. Size of History in a route-searching packet.

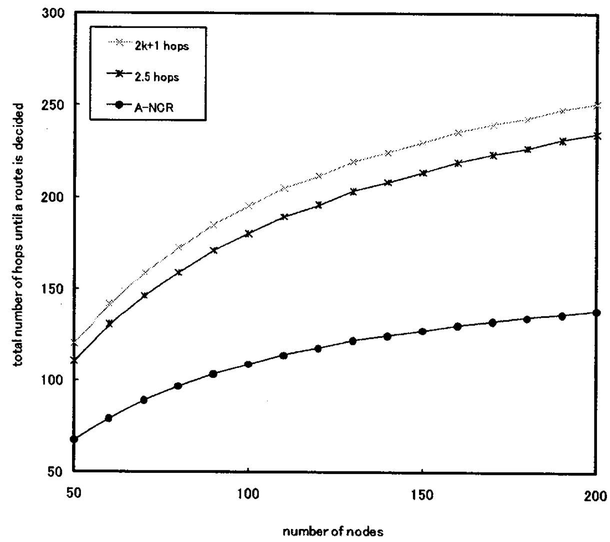

Fig. 12. Total number of hops until a route is decided.