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A hierarchical routing algorithm for MANET based on multi-agent learning

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Abstract—Mobile Ad-hoc Networks (MANETs) can construct impromptu networks by wireless mobile nodes without fixed infrastructure. A routing algorithm for MANETs based on multi-agent cost learning has been proposed. In this algorithm, multiple agents learn the costs of the communication paths by calculating weighted values, and select the effective paths based on the costs. This algorithm is robust for the movements of wireless mobile nodes. In order to develop this algorithm into larger-scale environments, this paper proposes a hierarchical routing algorithm for MANETs. The proposed algorithm constructs hierarchical networks based on address information, and does not require cluster-head nodes. In the simulation experiments, the effectiveness of the proposed algorithm can be confirmed by evaluating the delivery rate and control packet counts.

1. Introduction

Mobile Ad-hoc Networks (MANETs) can construct impromptu networks by wireless mobile nodes without fixed infrastructure[1]. Therefore, routing protocol for MANETs requires adaptability for dynamic network topology by node mobility. Types of routing Algorithm for MANETs are classified into "Proactive" type that each node sends routing information at fixed time intervals, and "Reactive" type that each path is searched just before each node sends data packets. "Proactive" type is suitable for high node density networks and high frequency communications. "Reactive" type is suitable for high mobility networks

AntHocNet[2] has a property of "Proactive" type and "Reactive" type. A routing algorithm for MANETs based on multi-agent cost learning[3] is more effective than AntHocNet in dynamic networks. But, this method can use one routing information to one destination. And, it can't use routing information when it failed to search the path.

Therefore, this paper proposes a hierarchical routing algorithm for MANETs. The proposed method can use routing information to destination node even when it failed to search the path, by using hierarchical routing tables. In the simulation experiments, the effectiveness of the proposed algorithm can be confirmed by evaluating the delivery rate and control packet counts.

2. Routing algorithm for MANETs based on multi-agent cost learning

A routing algorithm for MANETs based on multi-agent cost learning has been proposed[3]. In this algorithm, multiple agents learn the cost of the communication paths, in order not to select the same intermediate nodes, and search unknown paths based on the costs. In this algorithm, the i th node has a routing table T_i, whose example is shown in Table 1. In this table, W denotes a weighted value learned

Table 1: Routing Table T_i

Node i	Neighbor node j	Neighbor node k
Destination d_1	$W_{ij}^{d_1}$	W_{ik}^{d1}
Destination d_2	$W_{ij}^{d_2}$	W_{ik}^{d2}

by calculating costs between nodes. For example, $W_{ij}^{d_1}$ is the weighted value in the case where the i th node sends data packets to the destination node d_1 via the j th neighbor node. The i the node sends hello message for the neighbor node management. As the i the node detects a neighbor node j, the weighted value W_{ij} is registered to the table T_i. If the other nodes have been already registered in T_i, the value of W_{ij} is set to the average value of W in T_i. Otherwise, the value of W_{ij} is set 1 as the initial value.

By the following three stages, each node sends data packets to the destination node.

1. Forward Agent
2. Backward Agent
3. Data Packet Forwarding.

2.1. Forward Agent

Let us consider that a source node sends data packets to a destination node. First, the source node sends plural forward agent by broadcast transmission. As each intermediate node that receives one of forward agents sends it to a neighbor node selected by Eq.(1).

$$P_{ij} = \frac{W_{ij}^{-\alpha}}{\sum_{n \in N_i} W_{in}^{-\alpha}} \tag{1}$$

where P_{ij} is probability that i th node selects the j th node as the next hop node. α is priority for weights. The i th node updates W_{ij} by Eq.(2) after the i th node sent the forward agent.

$$W_{ij} \leftarrow W_{ij} + Cost_{ij} \tag{2}$$

If an intermediate node that received forward agent has a destination node in the neighbor nodes, the intermediate sends to the destination node as the next hop node. The forward agent constructs an address list of all nodes which it passes through. In addition, only a forward agent firstly arriving at the destination node is accepted, and the other forward agents are rejected.

2.2. Backward Agent

When a forward agent firstly arrived at the destination node, the destination node sends backward agent. A backward agent follows the address list constructed by the forward agent in reverse. An intermediate node that receives the backward agent sends it to the next hop node based on the address list. Then, the intermediate node updates the weighted value W.

$$W_{ij} \leftarrow W_{ij} \times (1 - \rho) \tag{3}$$

where ρ is a reduction rate.

2.3. Data Packet Forwarding

The source node that receives backward agent sends data packets. Each intermediate node to the destination node selects the next hop node by Eq.(4).

$$s = \begin{cases} Eq.(1) & if \varepsilon \leq \varepsilon_0 \\ \arg\max\limits_{n \in N_i} W_{in}^{-\alpha} & otherwise \end{cases} \tag{4}$$

where ε is the random value in the range of $[0, 1)$. ε_0 is the threshold of the probability in the range of $0 \leq \varepsilon_0 \leq 1$, and decides relative importance of exploitation and exploration. Then, the data packets are delivered to the destination node.

3. Proposed Method

The proposed method brings a hierarchical property to the conventional method. The conventional method requires that at least one forward agent arrives to a destination node in order to learn the path. Also, the source node and the intermediate nodes can't reuse routing information for the other destination nodes. The proposed method appends hierarchical routing to the conventional method to solve the problems.

The proposed method has two routing network layers, high network layers and a low network layer. Each high network layer has plural nodes whose address consists of the same lower bits. The low network layer sends data packets between high layer nodes. The proposed method uses the following three routing tables.

- Destination group table

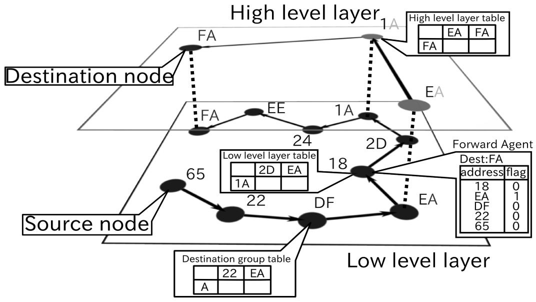

Figure 1: Routing example

- High level layer table.
- Low level layer table

The destination group table is used in routing when a neighbor node belonging to the same group as the destination node is searched. In the high level layer, there are the nodes belonging to the same group. The high level layer table is used in routing when the next hop node in the high level layer is searched. The low level layer table is used in routing to the next high level layer node. The high level layer nodes are classified by the forward agent and backward agent.

3.1. Routing

Figure 1 shows an example of routing. The source node has address 0x65 and the destination node has address 0xFA. Lower 4 bits are used as the group indexes. That is, the group indexes of the source node and the destination node are 5 and A, respectively.

At first, by using the destination group table, the source node (0x65) sends a forward agent to a neighbor node belonging to the same group as the destination node. In Fig.1, A is the destination group, and the node having address 0xEA is the sub-destination. By using the low level layer table, the forward agent is sent from the source node to the sub-destination node.

As the forward agent arrived at the sub-destination node, by using the high level layer table, it is sent from the sub-destination node to the next hop node in the high level layer node. In Fig.1, the node having address 0xEA selects the node having address 0x1A as the next hop node in the high level layer. By using the low level layer table, the forward agent is sent from the sub-destination. Repeating in this manner, the forward agent arrives at the destination node.

Next, the backward agent is sent from the destination node to the source node. the backward agent follows the address list by the forward agent to reverse and also updates the routing table. As the backward agent is sent to the next node, the unused address list entry is removed. In this moment, if flag in the current address list entry is unset, a node update "low level layer table". If it is set, a node updates ”high level layer table”. If there are no flag in all address list entries, a node updates ”Destination group table”.

3.2. Collecting same group addresses

In order to realize the high level layer routing, it is required to grasp the high level layer network topology from the address of each node. Each node collects the address information of the nodes belonging to the same group from the address lists of forward agents and backward agents. If the unknown address is found from an address list, the address is collected as one of the high level layer nodes. Each a backward agent is sent from a destination node via some intermediate nodes, and have the address and hop counts of these nodes. Then, the address information and the hop counts of these nodes are registered in the routing table. Collecting the information, each node grasps the high level layer network topology, and constructs each routing table.

3.3. Sub backward agent

From a source node, plural forward agents are sent to a destination node. One of them firstly arriving at the destination node changes into a backward agent. In the conventional method, the paths through which the other forward agents pass are not learned. Therefore, in the proposed method, if a forward agent passes through a path between high level layer nodes and the corresponding backward agent does not pass through the path, a sub backward agent is sent between the high level layer nodes and learns the path. The timing to send the sub backward agent is decided by the elapsed time when the forward agent starts from the high level layer node.

4. Simulation Experiments

We examine the performances of the proposed method on the following environments, and perform the experiments, by comparing with the conventional method [3].

4.1. Experiment 1

At first, we perform the experiments for the environment in which all nodes are fixed. Table 2 shows the parameters in the experiments. In this experiments, transmission delay

Table 2: Experiment Parameters

Field	$2400m \times 800m$, $4800m \times 1600m$
Number of nodes	96 , 384
α	2.0
ρ	0.99
ϵ_0	0.9
Radio range	$250m$
Hop limit	100
Number of trials	2000

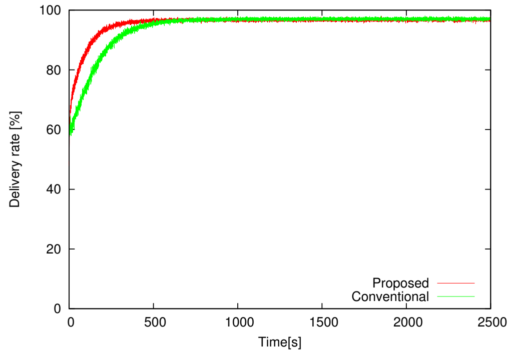

Figure 2: Delivery rate on $2400m \times 800m$

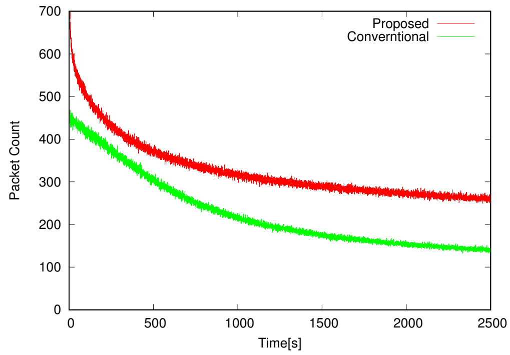

Figure 3: Packet count on $2400m \times 800m$

and transmission data size is not considered. For each 0.25 second, a randomly selected source node sends data packets to a randomly selected destination node. We measure delivery rate rate and control packet counts. The lower 3 bits in the address of each node is used as group indexes.

Figures 2-5 show the results for delivery rate and control packet counts with different area size.

As shown in Figs. 2 and 4, the delivery rate of the proposed method more quickly increases than that of conventional method. On the other hand, as shown in Figs. 3 and 5, control packet counts of the proposed method is more than those of the conventional method.

4.2. Experiment 2

Next, we perform the experiments for the environment in which all nodes move. Each node moves according to Random Way Point Model [4]. Pause time is 30 sec and max speed is 5 m/sec. The other parameters for the environment is shown are shown in Table 2. In the experiments, area size is fixed to 2400m × 800m.

Figures 6 and 7 show the delivery rate and the control packet counts, respectively.

As shown in Fig. 6, even if each node moves, the delivery rate of the proposed method more quickly increases

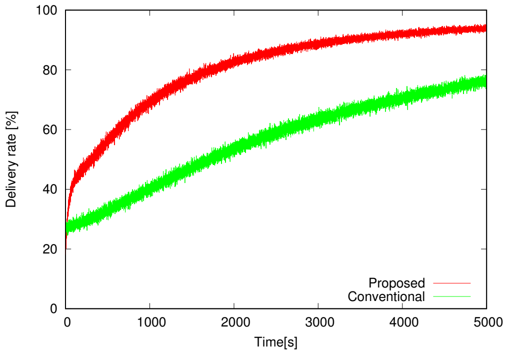

Figure 4: Delivery rate on $4800m \times 1600m$

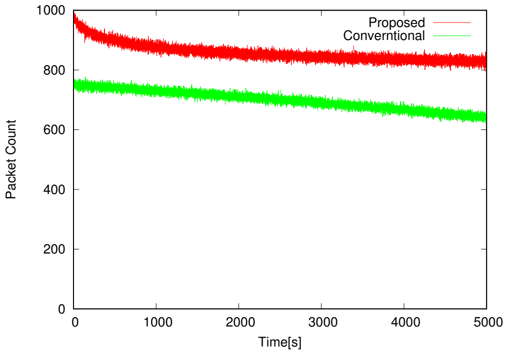

Figure 5: Packet count on $4800m \times 1600m$

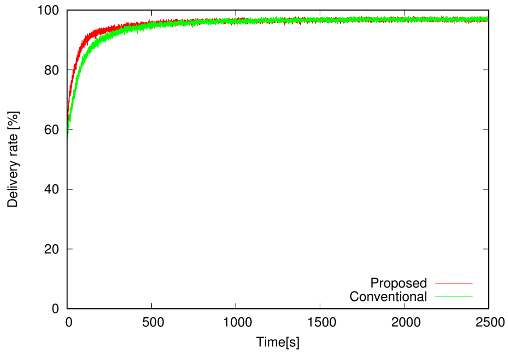

Figure 6: Delivery rate on $2400m \times 800m$

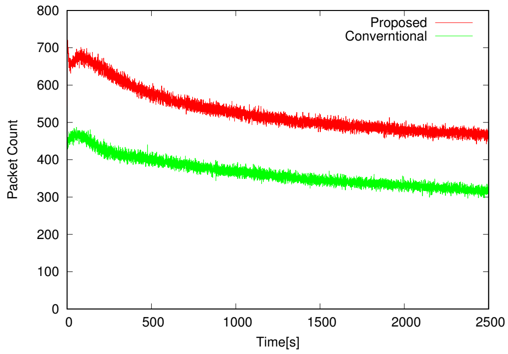

Figure 7: Packet count on $2400m \times 800m$

than that of the conventional method. As the area size becomes larger, this tendency becomes more conspicuous.

Delivery rate of the proposed method more quickly increases than that of the conventional method. And, the control packet counts of the proposed method is more than those of the conventional method. Because, the proposed method can reuse routing information for the other destination node by using the high level layer. Also, the search range can be reduced by using the hierarchical routing, compared with the case of searching all nodes in the network. Those result show that the proposed method is more effective on large scale environments. The proposed method can more immediately communicate on large networks.

5. Conclusion

The proposed method introduces a hierarchical property to the conventional method. According to it, delivery rate more quickly increases than that of the conventional method. On the other hand delivery rate of the conventional method increases very slow on large environments. Therefore, the proposed method is more effective than the conventional to the environments.

Control packet counts of the proposed method are more than those of conventional method. Therefore, we reduce packet counts on the proposed method as future works.

References

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