Tree Structured Group ID-Based Routing Method for Mobile Ad Hoc Networks

Hiroaki Yagi, Eitaro Kohno, and Yoshiaki Kakuda
Graduate School of Information Sciences, Hiroshima City University
Email: {yagi@nsw.info., kouno@, kakuda@}hiroshima-cu.ac.jp

***Abstract*—In ad hoc networks, wireless links can be disconnected by both the wireless instability and the node mobility. To tackle the wireless instability problem, multipath routing methods have been proposed. The multipath source initiated tree-based routing ID routing method (SRIDR) employs a tree-structured node ID that is assigned from a specific source node. While SRIDR is effective in compensating for disruptions due to wireless instability, it is not effective when the nodes are mobile. To counter disruptions due to mobile nodes, nodes have to reconstruct paths. Tree structured IDs can be assigned by each node in a self-organized manner. In this paper, we proposed a new tree-structured group ID-based routing method for mobile ad hoc networks. We have confirmed that our proposed method can maintain a high data delivery ratio even if the nodes are mobile.**

Keywords-Tree structured group ID; Mobile ad hoc networks; Bottom-up ID re-assignment.

I. INTRODUCTION

Ad hoc networks are self-organized networks, which consist of wireless terminals with routing and forwarding functions. In ad hoc networks, links between nodes can be disconnected due to both the instability of wireless connections and the node's mobility. These disruptions decrease the data delivery ratio. In previous research, we proposed the first source node initiated tree structured ID-based multipath routing method, referred to as the source initiated tree-based routing ID routing (SRIDR) [1] [2] in this paper. While SRIDR is an effective method to compensate for the instability of wireless connections, it is poor at compensating for disconnections due to node mobility.

SRIDR's ID assignment process employs the dynamic address routing (DART) [3] process. While this process is useful for static ad hoc networks, this process is problematic for mobile ad hoc networks. In mobile ad hoc networks, SRIDR's ID assignment process lead to the reassignment of all nodes in a network.

Jain et al. [4] proposed for assigning node ID in heterogeneous systems of wired access networks with mobile terminals. It provides a reassignment system for mobile terminals' IDs. It utilizes the same ID assignment process as the one described in [5]. [4] also utilizes the more effective ”bottom up” method presented in [6] [7].

In this paper, we propose a new group ID-based multipath routing method that is an extension of SRIDR. Our proposed method employs group-based ID and “bottom-up” ID reassignment processes to improve the data delivery ratio of (mobile) ad hoc networks. We implemented our proposed method on a network simulator and confirmed the effectiveness of our proposed method.

The rest of the paper is organized as follows: in Section II, we discuss the background of our research. In Section III, we describe our proposed method. In Section IV, we show the results of our simulation experiments. We conclude the paper in Section V.

II. BACKGROUND

SRIDR is a multipath routing method for establishing multiple detouring paths that keeps a communication path connected even if some nodes fail in their data packet forwarding. SRIDR employs tree-structured node IDs in order to suppress the control packet count. A node ID is a unique identifier that shows the relationship between two or more nodes. Each node is assigned its node ID from the first source node [1] [2] [3], named the start node. In this paper, this assignment procedure is referred to as the “top down ID assignment procedure.” In SRIDR, a node constructs its routing table using node IDs or subnet IDs. A node forwards data packets using the constructed routing table. A subnet ID shows a group of nodes which share the same node ID prefix. SRIDR has the following characteristics:

- Top down assignment of node IDs
- The utilization of routing tables to construct detour paths for data packets

In SRIDR, a node ID is assigned by a top down assignment process from the most significant bit of the node ID. Fig. 1 shows a network with nodes that have assigned node IDs. In SRIDR, the first source node (S) becomes the start node, which initiates the ID assignment process. The start node has the node ID (000) and it assigns a new node ID to adjacent nodes. Node C is an adjacent node of node S in Fig. 1. As an example, let us imagine node C is the first node in the network to make an ID request. In this case, node S assigns the node ID (100) to node C. Then node A, also an adjacent node of node S makes an ID request. So node S assigns the node ID (010) to node A. When a node is assigned its node ID, it can assign node IDs to adjacent nodes. Subsequently, in Fig. 1, node A assigns node B the node ID (011) and node C assigns node D the node ID (110). This is how nodes are assigned their node IDs. Nodes with assigned IDs exchange routing entries and make a routing table that constructs multiple paths. A node utilizes this routing table to find detouring paths for data packets. Thus, SRIDR can compensate for wireless instability by using detouring paths. In mobile ad hoc networks, node ID based detouring paths are

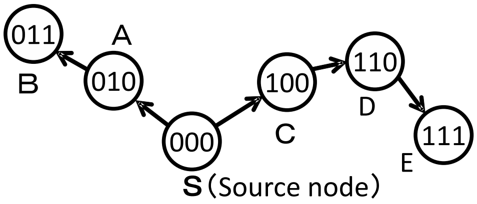


Figure 1: “Top-down” node ID assignment procedure.

usually invalid for SRIDR because node IDs might differ in more than one bit and therefore cannot connect and forward data. To counter this, node IDs must be reassigned. However, if every node is reassigned, the resulting influx of control packets will reduce the data packet delivery ratio. In addition, when a reassignment request occurs too frequently on a specific node, the node cannot have a stable node ID and therefore cannot forward data appropriately. For this reason, we have proposed the following method.

III. PROPOSED METHOD

A. Overview

In this paper, we propose a new group ID assignment method in order to deal with the reduction of the data delivery ratio due to node mobility in the tree-structured group ID. In our proposed method, nodes share the same ID and constructs groups to minimize the frequency of assignment requests. We propose reassigning group IDs in a self-organized manner, referred to as the “bottom-up” reassignment process. The “bottom-up” reassignment process is localized to the parent-child relationship of the mobile nodes. This reassignment process can suppress the escalation of control packets. Our proposed method has the following characteristics:

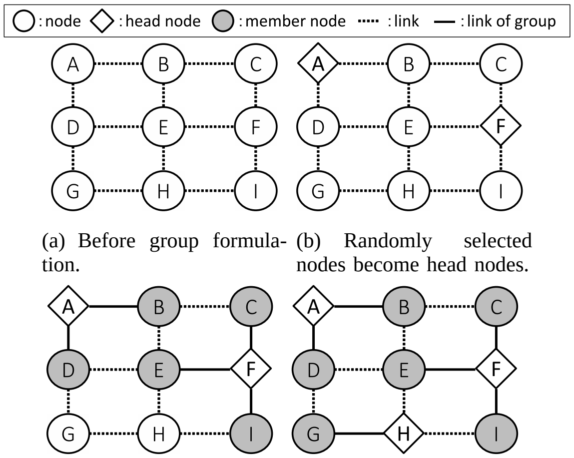
1) Group formulation
2) “Bottom-up” group ID assignment
3) Group ID reassignment

In our proposed method, nodes first form a group. After that, each group is assigned its initial group ID. Adjacent groups exchange information to form a tree structure of group IDs. When the links between two or more groups are disconnected, our method reassigns group IDs. We describe our proposed method below.

B. Group formulation

In our proposed method, multiple nodes that have the same node ID form a group. Nodes in a group are categorized as either a head node or member nodes. The formulation of groups is as follows:

1) Randomly selected nodes in the network become head nodes.
2) The adjacent nodes to the head nodes become member nodes.
3) If a node is not a head or a member node, it performs the above-mentioned procedures (1 and 2) until all nodes become either head or member nodes.



(a) Before group formulation. (b) Randomly selected nodes become head nodes.

(c) The adjacent nodes to head nodes become member nodes. (d) Group formulation completed.

Figure 2: Group formulation procedure.

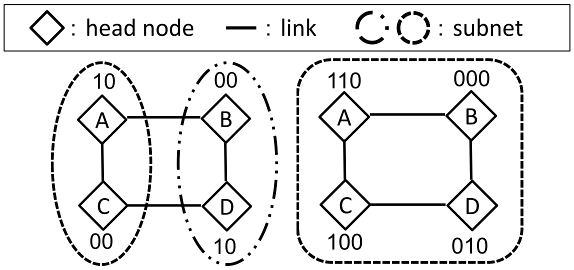
Fig. 2 shows the group formulation procedure. Fig. 2(a) shows an example topology of a network. In Fig. 2(b), nodes A and F are randomly selected to become head nodes. Subsequently, the nodes adjacent to A and F become member nodes. This is shown in Fig. 2(c). The solid black line denotes this relationship. In Fig. 2(c), nodes B and D become member nodes of node A. Node C, E, and I become member nodes of node F. These procedures are repeated and the network forms groups such as Fig. 2(d).

C. “Bottom-up” group ID assignment

When the network forms groups, the head nodes start group ID assignment procedures. In contrast with the “top down” ID assignment process, the “bottom-up” ID assignment process assigns group IDs from the least significant bit. When the head node in a group is assigned its group ID, the member nodes share the same group ID as the head node. In the procedure of assigning group IDs between two head nodes, one head node establishes itself as a parent head node and the other as a child head node. At this time, parent and child head nodes and their member nodes form a subnet. A subnet is a small group of nodes which shares the same prefix as the larger group ID. After that, each group starts to construct a group ID tree using the following procedures:

1) Every head node has the initial group ID, (0).
2) Each head node searches its adjacent head node to construct a subnet.
3) The constructed subnet searches for its adjacent head nodes or subnets to construct a new larger subnet.
4) Two subnets/head nodes construct a new larger subnet by adding 0 or 1 at the beginning of the assigned group ID.
5) Procedures 2-4 are performed repeatedly during the predetermined time.

Fig. 3 shows the procedures of group ID assignment. For convenience, Fig. 3 shows only head nodes. Each head node has an initial group ID, (0), and constructs a new subnet by combining with other head nodes. Suppose that head nodes A



(a) Conbine between head nodes.
(b) Conbine between subnets.

Figure 3: Group ID assignment procedure.

and C combine. If , for example, node C is the first to request combining, node A becomes the parent head node, and assigns a 1 in front of its assigned group ID, (0). Then node C becomes the child head node and it assigns a 0 in front of the assigned group ID, (0). As a result, the group IDs of nodes A and C become (10) and (00), respectively. In the same manner, head nodes B and D form a new subnet and become child and parent head nodes as shown in Fig. 3(a).

Next, we assume that subnets A-C and B-D will combine and construct a new subnet. When head node A becomes the parent head node, head nodes in subnet A-C add a 1 at the beginning of their existing group IDs (10) and (00). In addition, head nodes in subnet B-D add a 0 at the beginning of their existing group IDs (00) and (10). Consequently, head nodes A, B, C, and D acquire their group IDs (110), (000), (100), and (010), respectively.

D. Group ID reassignment

When a child head node or its member node detects a disruption in the link to its parent head node, the child head node or member node starts the group ID reassignment procedure. While the parent head node also detects a disruption in the link with the child head node or member node, it does not perform the group ID reassignment procedure, maintaining a higher packet delivery ratio. The following is the group ID reassignment procedure in our proposed method:

1) A child head node or a member node detects a disruption in the link to its parent head node.
2) If a child head node or a member node locates another head node, it reassigns its group ID to join the new head node. This completes the group ID reassignment procedure.
3) If a child head node or a member node cannot locate another head node, it starts the group ID reassignment procedure with the member nodes in its group.
4) After procedure 3, the "bottom-up" group ID assignment procedure will start and the child head node's group will join the group ID tree of an adjacent group.

Fig. 4 shows the result of this group ID assignment procedure. In Fig. 4, X indicates a "don't care bit" that is a 1 or a 0. "1XX" shows the subnet that includes head nodes A and C, and member nodes E and G. These nodes shares the same prefix "1" at the beginning of their group ID/node IDs. Similarly, "0XX" shows the subnet that includes head nodes B and D, and member nodes F and H. These nodes share the same prefix "0" at the beginning of their group ID/node IDs. "XXX" indicates the whole network. It is special a subnet.

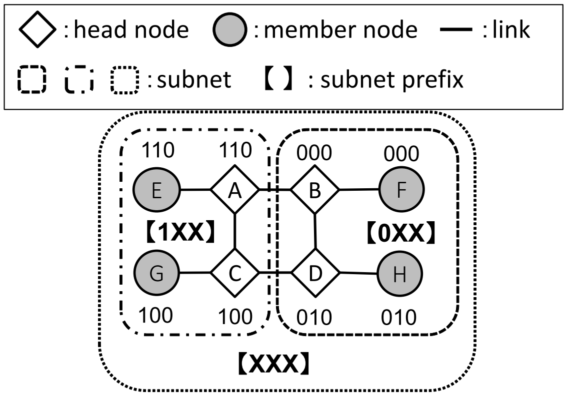


Figure 4: Result of group ID assignment procedure.

E. Data packet forwarding

As in SRIDR, our proposed method forwards data packets in the following way:

1) A node compares its group ID with the destination node's group ID, and calculates the subnet to which the destination node belongs.
2) The node refers its own routing table and determines the next hop node using the subnet information.
3) The node forwards the data packet to the next hop node.
4) Our proposed method repeats procedures 1-3 until the destination node receives the data packet.

IV. SIMULATION EXPERIMENTS

A. Overview

We have conducted simulation experiments of our proposed method on a network simulator, QualNet ver.5.0 [8], to evaluate its effectiveness. We have measured the data packet delivery ratio and the control packet count. We compared our proposed method to SRIDR and a tree structured bottom-up node ID-based routing method without group IDs.

B. Simulation Environment

TABLE I: Parameters for experiments.

Simulator	QualNet ver.5.0 [8]
Number of nodes	50
Field size (m^2)	1100 × 1100
Number of source and destination pairs	1, 5
Data packet size (Byte)	512
Data packet interval (sec)	0.25
Radio area (m)	250
MAC layer protocol	IEEE802.11b
Max. bandwidth (Mbps)	2
Simulation time (sec)	2000
Node distribution	RANDOM
Max. node speed (m/s)	5
Node mobility model	Random waypoint model [9]

Table I shows the parameters for the simulation experiments. We set the field size to accommodate an average of

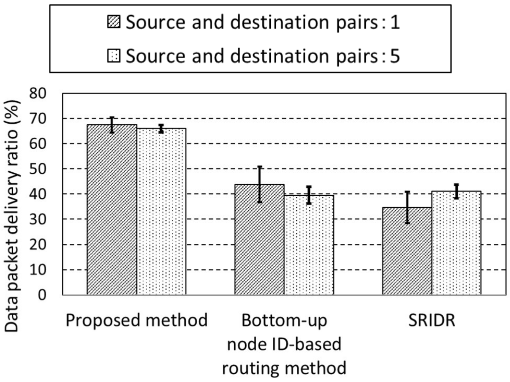


Figure 5: The data packet delivery ratio.

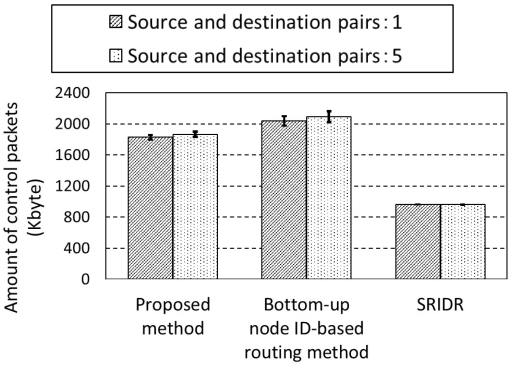


Figure 6: The amount of control packets.

eight adjacent nodes. In addition, nodes are randomly deployed and there is one source and destination pair (In Figs. 5 and 6 we denoted as “Source and destination pairs:1 ”) or five source and destination pairs (In Figs. 5 and 6 we denoted as “Source and destination pairs:5 ”).

C. Methodology

When a run of the simulation experiment starts, each node starts group formulation procedures and performs bottom-up group ID assignment procedures. 20 seconds after the start of the simulation run, the first source node starts transmitting the data packets. With the configuration of five source and destination pairs, 10 seconds after that, the second source node starts transmitting data packets. Thereafter the other source nodes start to transmit data packets one after another every 10 seconds. When a node detects a disruption, SRIDR sends data packets using detouring paths. In contrast, our proposed method and the tree structured bottom-up node ID-based routing method performs their group ID/node ID reassignment processes instead.

D. Result

Figs. 5 and 6 show the results of the data packet delivery ratio and the control packet count with respect to our proposed method, SRIDR, and the tree structured bottom-up node ID-based routing method, respectively. The vertical axes show the results of the data packet delivery ratio and the control packet count, respectively. The horizontal axes are the routing methods. Each result is the average of 50 simulation runs. The error bars show 95 percent confidence intervals.

To measure the amount of control packets, we created an output file in a simulator. In the simulator, when a control packet was transmitted, the simulator added a line to the output file indicating the data size of the control packet. When the simulation experiment was concluded, we calculated the total amount of control packets.

Control packets varied in size from 8 to 28 (Byte/packet). However, control packet containing node routing tables varied with a larger range.

E. Discussion

Fig. 5 shows our proposed method has the highest data packet delivery ratio among the methods. This shows that our proposed method is the most effective. Additionally, the data packet delivery ratio of SRIDR and that of the tree structured bottom-up node ID-based routing method are almost the same. In the tree structured bottom-up node ID-based routing method, there is a high frequency of reassignment procedures which slows down data packet delivery ratio to about the same as SRIDR. Therefore, the data packet delivery ratio is the same as SRIDR.

Fig. 6 shows that the control packet count of SRIDR is the smallest and the control packet count of our proposed method is slightly smaller than that of the tree structured bottom-up node ID-based routing method. In SRIDR, since the node ID reassignment procedures were not performed, the control packet count of SRIDR is smaller than that of our proposed method. While the control packet count of our proposed method was larger than SRIDR, the frequency of group ID reassignment was low. In our proposed method, links between groups were increased by forming groups, leads to a smaller control packet count than that of the tree structured bottom-up node ID-based routing method.

V. CONCLUSION AND FUTURE WORK

In this paper, we proposed a new tree structured group ID-based routing method to tackle the disruptions caused by the node mobility. We implemented our proposed method on a network simulator and performed the experiment to compare and evaluate the results. Our proposed method showed a high data delivery ratio and lower control packet count than that of the tree structured bottom-up node ID-based routing method.

As future work, we planned to measure characteristics over time of our proposed method. We have to improve our method taking into account the connectivity of groups.

ACKNOWLEDGMENT

This research is supported by JSPS KAKENHI Grant Number (B) (No.24300028), and (C) (No.25330109). This research is also supported by the Ministry of Internal Affairs and Communications under Strategic Information and Communications R&D Promotion Programme (SCOPE) Grant No.131408006, and by The Telecommunications Advancement Foundation (TAF), Japan.

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