Location-based Flooding Area Restriction for Mobile-assisted Ad Hoc Networks

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***Abstract*—In mobile ad hoc networks, radio interference and mobility of nodes may degrade the packet arrival rate due to the dynamic topological change. Then, traditional reactive routing protocols may cause huge network resource consumption due to the route request flooding for discovering the destination. To solve the above issue, flooding area restriction methods can reduce the unnecessary control messages to narrow the flooding area based on the location information. However, each node must share location information before sending route requests via control messages. Besides, it is also difficult to share the correct location information of nodes due to the mobility of nodes. This paper proposes a flooding area restriction method to reduce the unnecessary control messages to determine the flooding area by sharing the location information via a mobile network. In addition, computer simulations reveal the effectiveness of the proposed method in comparison with a traditional routing protocol.**

***Index Terms*—ad hoc network, location information, mobile network, flooding area**

I. Introduction

Mobile ad hoc network makes an autonomous distributed network by using wireless nodes as relay nodes via multi-hop communication between nodes. For realizing the autonomous network, the dynamic routing protocol is an important factor to realize the ad hoc network because of the dynamic topological changes [1], [2].

As ad hoc routing protocols, general reactive routing protocols [3]–[6] establish a route by exchanging control messages between nodes when a communication request occurs. However, they consume network resources since many nodes broadcast numerous control messages for discovering the destination.

To solve the above issue, flooding area restriction methods [7], [8] restricts the flooding area of control messages to a specified area based on the location information. Therefore, they can reduce unnecessary control messages to restrict the flooding area. However, nodes keep the location information, which is propagated by using the route request. Hence, they may fail to set an appropriate flooding area since the location information may become obsolete due to the mobility of nodes. In addition, when a source does not have location information of destination, they cannot reduce the control messages since the source initiates route request flooding without any flooding area restrictions.

This paper proposes a flooding area restriction method which specifies the flooding area based on the location information of nodes which is shared via a mobile network.

II. Related Work

In Kashiwabara et. al. [7], this method reduces route request messages to restrict a route request flooding area based on location information. In this method, the route request includes the location information of the source, destination, and the sender when a node sends a route request. Therefore, receivers can obtain location information. Hence, they hold them to restrict the flooding area for a specified period.

First, when a communication request occurs, the source checks whether it has the location information of destination or not. If it does not have the location information of destination, it initiates the route request flooding without flooding area restrictions. If it has the location information of destination, it writes the information into the route request, and then initiates the route request flooding. When a node receives the route request with location information, it checks whether it is within the flooding area or not. If so, it relays the route request. If not, it ignores and discards the route request. As a result, this method can reduce control messages and suppress network resource consumptions.

However, this method requires to sufficiently exchange route requests to update the location information since the location information becomes obsolete due to the mobility of nodes. Namely, it may not set the correct flooding area in real environments.

In Sasaoka et. al. [8], this method also reduces route request to restrict a route request flooding area based on location information and node density. First, each node periodically sends a hello message, and the receiver counts them during transmission intervals of the hello messages. When a communication request occurs, a source sends a route request which includes the source's location and a flag. Note that the flag is set or unset depending on whether the node density of the neighbor area is dense or sparse.

On receiving the route request with the flag, if the distance to the source is equal to or more than the predetermined threshold, the receiver checks the number of neighbors. Otherwise, the receiver ignores the route request. On receiving the route request without the flag, the receiver relays the route request without any restrictions like as a traditional route request flooding. If the number of neighbors is larger than a threshold, the receiver relays the route request with setting the own location and the flag. If the number of neighbors is the same as or smaller than the threshold, the receiver relays the route request without setting the flag. As a result, this method suppresses the route request flooding in dense areas based on the location information and number of neighbors.

However, when high mobility environments, this method may cause the difference between the actual information and obtained information for both the location and number of neighbors. As a result, this method may misunderstand the state of local surroundings, and therefore, it increases the unnecessary route requests, or it excessively suppresses the route requests.

III. Proposed Method

A. Concept

This paper proposes a flooding area restriction method based on location information with using mobile networks. In traditional protocols, each node needs to obtain the location information to propagate them by control messages via local networks. However, the information becomes obsolete, and therefore they degrade the performance under fast-changing environments.

To solve the issue, the proposed method manages and uses the location information by a server accessed via mobile networks. Figure 1 shows an example of the proposed method. We design the location server based on a location-based communication framework [9]. First, each node sends a control message which includes own address and location information to the server via mobile network in a fixed interval. The server keeps and manages each node's location in the ad hoc network. After that, the server determines the forwarding area of each ad hoc network based on the location information when a node requests to establish a route. Although the proposed method can apply to various routing protocols, to simplify to explain the proposed method, we adopt a traditional reactive routing protocol called ad hoc on-demand distance vector (AODV) [3] for the explanation.

B. Procedure

When a communication request occurs, a source sends a control message which includes its address and destination's address to the server via a mobile network. After receiving the control message, the server makes the elliptical flooding area. For the flooding area calculation, the proposed method uses the distance between the source and destination for the axis distance of the elliptical flooding area. The details of the elliptical flooding area calculation are described in Sec. III-C. After the calculation, the server sends a control message to notify the success to the source. If the server does not have the destination's location, it sends a control message to notify the failure to the source.

On receiving the control message from the server, the source initiates the route request flooding towards the destination with or without the area restriction based on the success or failure of making the flooding area. When a node receives the route request with the area restriction, it sends a control message which includes the source address, destination address, and its location to the server via mobile networks. The server checks whether the node is within the flooding area or not. If the node is within the flooding area, it sends the route request. If not, it ignores and discards the route request.

When the destination receives the route request, it sends a route reply towards the source. Here, the routing procedure follows an adopted routing protocol, and therefore the route reply will be relayed based on the traversed path known as the reverse path of the route request since we adopted AODV in this paper. Finally, when the source receives the route reply, it starts to send data.

C. Elliptical Flooding Area Calculation

We introduce the elliptical flooding area calculation based on locations of a source and a destination. Figure 2 shows an

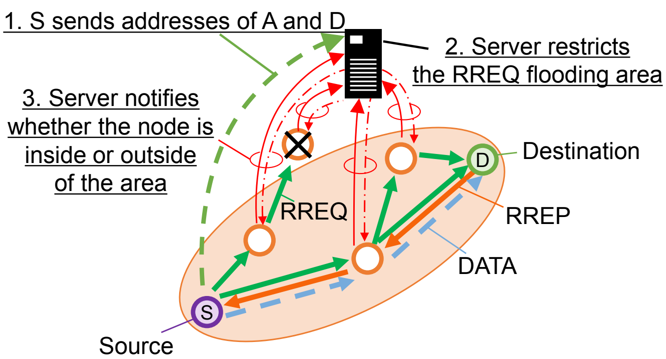

Fig. 1. Example of route construction using the proposed method.

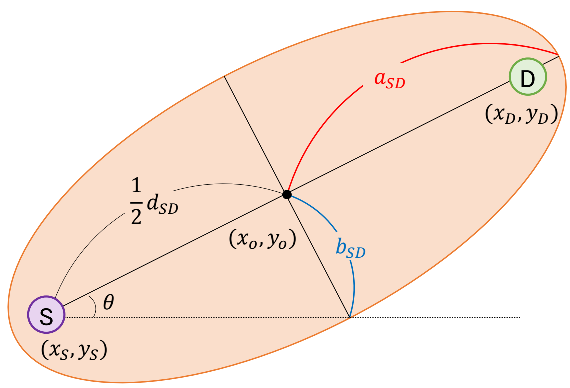

Fig. 2. Elliptical flooding area in the proposed method.

example of the elliptical flooding area in the proposed method.

When the server receives a control message which includes the addresses of the source S and destination D, it calculates the elliptical flooding area whose major axis is the distance between S and D.

First, the server calculates the semi major axis a_{SD} and semi minor axis b_{SD} from the ellipse which has vertices of S and D and the center coordinates of the ellipse (X_O, Y_O) as

$$d_{SD} = \sqrt{(x_S - x_D)^2 + (y_S - y_D)^2}, \quad (1)$$

$$(x_O, y_O) = (\frac{x_D + x_S}{2}, \frac{y_D + y_S}{2}), \quad (2)$$

$$a_{SD} = \alpha \times \frac{d_{SD}}{2}, \qquad b_{SD} = \beta \times \frac{d_{SD}}{2}, \quad (3)$$

here, α and $\beta (0 < \alpha, \beta)$ denote scaling factors. when α and β are set to the large values, the flooding area becomes larger. In addition, when α and β are set to 1, flooding area becomes a circle with the diameter d_{SD}. Next, we define the slope of d_{SD} as θ, and then the server calculates $\sin\theta$ and $\cos\theta$ as

$$\sin\theta = \frac{|y_D - y_S|}{d_{SD}}, \qquad \cos\theta = \frac{|x_D - x_S|}{d_{SD}}. \quad (4)$$

The server stores the elliptical flooding area to decide whether a node is within the flooding area or not.

When a server receives a control message from a node r, it verifies whether the node r is within the flooding area or not based on Eq. (1)–Eq. (4) and the r's coordination (x_r, y_r) as

$$\left(\frac{(x_r - x_O)\cos\theta + (y_r - y_O)\sin\theta}{a_{SD}}\right)^2 + \left(\frac{-(x_r - x_O)\sin\theta + (y_r - y_O)\cos\theta}{b_{SD}}\right)^2 \leq 1. \quad (5)$$

IV. Performance Evaluation

We conducted simulations to evaluate the performance of the proposed method in comparison with AODV. The simulation area was set to 900 m × 900 m. IEEE 802.11a was used for the wireless medium, and the data rate was set to 6 Mbps. All the nodes send data, which consists of one thousand 1 Kbyte packets, to a random destination via the user datagram protocol. Here, each destination was different from each other. The evaluation items were the packet arrival rate and the number of control messages.

A. Simulation 1

This simulation evaluated the impact of the flooding area restriction under the grid topology and random topology. Note that, for the grid topology, we adopted plane grid and the distance between adjacent grid points was set to 100 m.

Figures 3–4 show that the number of control messages and packet arrival rate under the grid and random topologies.

In the grid topology, the proposed method achieves both the smaller number of control messages and higher packet arrival rate compared to AODV since the proposed method can reduce the network resource consumptions to suppress to

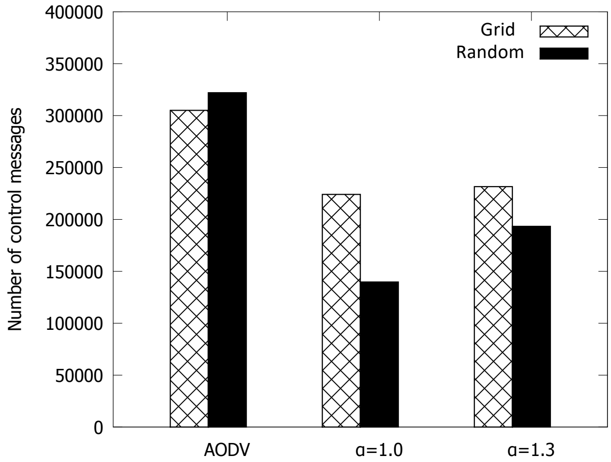

Fig. 3. Simulation 1: number of control messages.

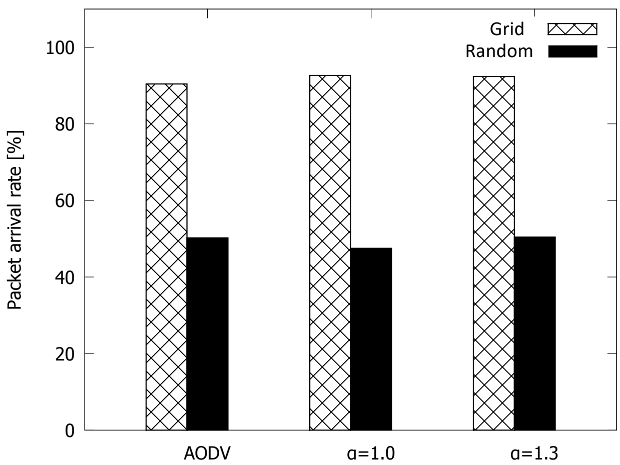

Fig. 4. simuation1: packet arrival rate.

send the unnecessary control messages based on the restricted flooding area.

In the random topology, AODV increases the number of control messages compared to that of grid topology. This is because that nodes need to discover various paths in the random topology since AODV indiscriminately sends a control message to discover the destination. On the other hand, the proposed method ($\alpha = 1.0$) in the random topology significantly reduce the number of control messages compared to that of the grid topology. This is because that the proposed method can narrow the flooding area based on the locations of the source and destination, and therefore it reduces the paths for discovering the destination, especially in the random topology.

However, the proposed method ($\alpha = 1.0$) decreases packet arrival rate, although it can reduce the number of control messages compared to that of AODV. Due to the flooding area restriction, the proposed method restricts the nodes for the route construction in the elliptical area. As a result, the proposed method may fail to establish the route due to few or

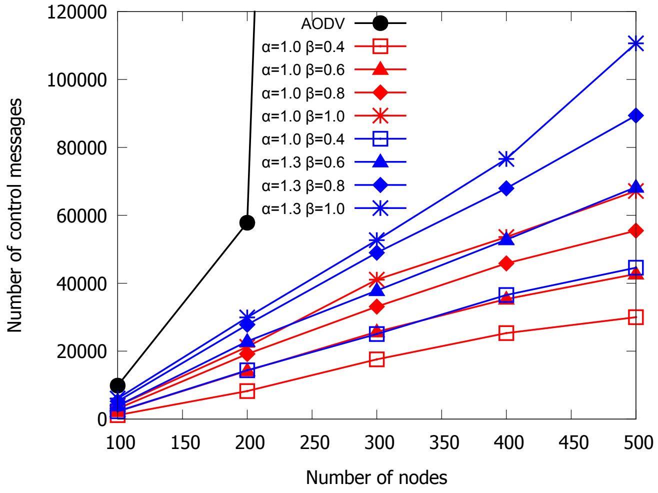

Fig. 5. Simulation 2: number of control message.

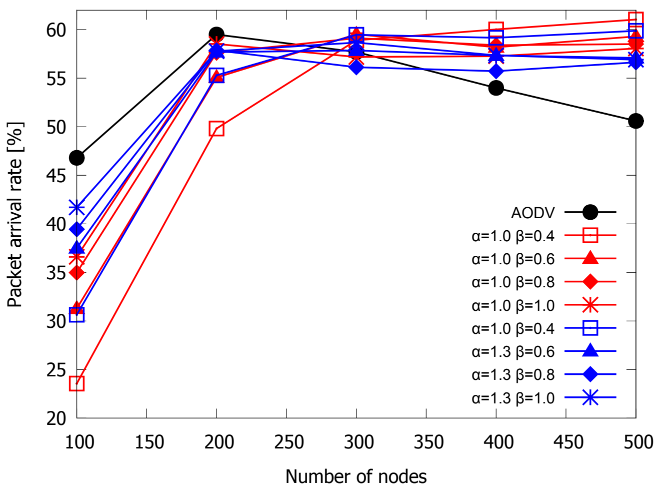

Fig. 6. Simulation 2: packet arrival rate.

no relay nodes. In addition, the proposed method ($\alpha = 1.3$) achieves higher packet arrival rate compared to the proposed method ($\alpha = 1.0$) since proposed method ($\alpha = 1.3$) can secure the sufficient number of relay nodes due to the large flooding area.

B. Simulation 2

This simulation evaluated the impact of node density changes. This simulation varies the number of nodes from 100 to 500 in steps of 100, and the number of sources was set to 20.

Figures 5–6 show that the number of control messages and packet arrival rate.

In the proposed method, under the sparse environments, the packet arrival rate becomes higher as expanding the flooding area. Especially, AODV has the highest packet arrival rate in the sparse environments since it performs the route request flooding without the area restriction. This is because that AODV and the proposed method with the large flooding area can select a route from various paths when expanding the flooding area.

On the other hand, under the dense environments, the packet arrival rate becomes smaller as expanding the flooding area. Especially, AODV has the lowest packet arrival rate in the sparse environments in contrast to the sparse environments. In the dense environments, if the flooding area is large or without any restrictions, many nodes participate the route discovery process. As a result, they send enormous control messages, and hence the fact degrades the packet arrival rate since the excessive network resource consumptions and packet collisions may occur.

V. Conclusion

This paper proposed a mobile-assisted ad hoc routing to reduce control messages to narrow the flooding area based on location information. We also conducted the simulation, and the results show that the proposed method achieved both improvement of the packet arrival rate and the reduction of control messages in comparison with a traditional reactive routing protocol.

For further study, we should discuss the appropriate values of scaling factors α and β. In addition, we plan to consider an adaptive algorithm to change the flooding area dynamically.

Acknowledgement

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