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Location aided probabilistic broadcast algorithm for mobile Ad-hoc network routing

Bai Yuan[1,2] (✉), An jie[1], Zhang Huibing[2]

1. School of Electrical and Electronic Engineering, Tianjin University of Technology, Tianjin 300384, China
2. Guangxi Key Laboratory of Trusted Software, Guilin University of Electronic Technology, Guilin 541004, China

Abstract

On-demand routing protocols are widely used in mobile Ad-hoc network (MANET). Flooding is an important dissemination scheme in routing discovering of on-demand routing protocol. However, in high-density MANET redundancy flooding packets lead to dramatic deterioration of the performance which calls broadcast storm problem (BSP). A location-aided probabilistic broadcast (LAPB) algorithm for routing in MANET is proposed to reduce the number of routing packets produced by flooding in this paper. In order to reduce the redundancy packets, only nodes in a specific area have the probability, computed by location information and neighbor knowledge, to propagate the routing packets. Simulation results demonstrate that the LAPB algorithm can reduce the packets and discovery delay (DD) in the routing discovery phase.

Keywords mobile Ad-hoc network, route protocol, broadcast storm problem, probabilistic broadcast

1 Introduction

In MANET, on-demand protocols and flooding are used to propagate the route packets. In low-density network flooding is the most efficient scheme which uses all neighbor nodes to discover route. However, the drawback of flooding is that overwhelming redundancy packets can cause the BSP due to collisions and contention as the number of nodes increases [1–2]. In order to alleviate the BSP probabilistic broadcast algorithms are proposed in the last decade [3–6]. In the probabilistic broadcast algorithms [7–9], a source node broadcasts the route request (RREQ) to its all neighbors. When first time receiving a RREQ, neighbor node with a probability P broadcasts RREQ to its neighbors and with an other probability to discard the RREQ.

Dynamic probabilistic broadcasting scheme (DPBSC) is proposed in Ref. [7], and it adopts the cross-layer design which lets routing layer share the received signal power information at medium access control (MAC) layer and adjusts the value of the rebroadcast probability dynamically according to its additional transmission range benefited from rebroadcast. After a node receives a broadcasting packet, DPBSC refers to its additional coverage of rebroadcast to determine the rebroadcast probability. However this algorithm based on the received signal power information will cause redundancy packets in high-density areas.

Probabilistic broadcast based on Jaccard distance is proposed in Ref. [8]. Instead of Euclidean distance the Jaccard distance is used to select dissimilar nodes during the discovery phase in order to reduce redundancy. The Jaccard distance is strongly dependent on the intersection area of two nodes' radio transmission ranges. But this algorithm cannot adjust the probability of broadcast when the density of network has changed.

Gossip is proposed in Ref. [9]. Gossip sets the optimum probability within the interval $[0.65, 0.75]$ in networks with fewer than 1 000 nodes. It also proposes $P = 0.5$ as an optimum value for network scenarios with certain node

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Corresponding author: Bai Yuan, E-mail: snowbaiyuan@163.com
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densities (150 nodes in a rectangular grid of $1\,650\ \text{m}\times 1\,200\ \text{m}$). Furthermore, when the node density becomes lower, the value of P should be set higher so that routing packets could be transmitted to the destination node.

In the probabilistic broadcast algorithms the key question is to find the optimum probability P. The optimum value for P should vary from scenario to scenario, which requires topologies and node mobile models being considered. The above algorithms cannot adjust the probability P as the changing of network environment. Furthermore, they may choose some farther nodes to transmit packets.

In this paper, LAPB algorithm is proposed. It uses an adaptive probability based on location information and neighbor knowledge to help routing. According to the location information, LAPB selects more effective nodes to broadcast RREQ packets in order to save overhead. By neighbor knowledge the changing of densities in local area can be recognized by forwarding nodes, and then the probability of broadcast is varied. Simulation results demonstrate that LAPB reduces the overhead and alleviates BSP in MANET.

2 Proposed approach

In this paper, it is assumed that the mobile nodes are moving in a two-dimensional (2D) plane. Location information used in the LAPB algorithm may be provided by the global positioning system (GPS). With the availability of GPS, it is possible for a node to know its physical location. Each node gets its neighbor nodes' location information by periodic HELLO messages.

Assume that source node S knows the destination node D was at location L at time t_0, and the current time is t_1. Consider node S needs to find a route to node D. Node S defines (implicitly or explicitly) a forward zone for the RREQ. A node forwards a RREQ only if it belongs to the forward zone. If in high-density areas there are still too many neighbour nodes rebroadcasting RREQ in the forward zone which leads to a high overhead, see Fig. 1. LAPB uses location information to reduce the number of the nodes that will forward routing packets. The location information of neighbor node is shown in Fig. 2. In Fig. 2 $X_{I,J}$ represents the projection of neighbor node J, and it is on the line of current node I to the destination node D [10–11].

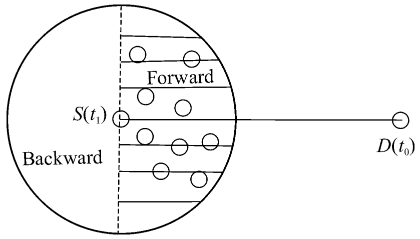

Fig. 1 Definitions of forward and backward zone

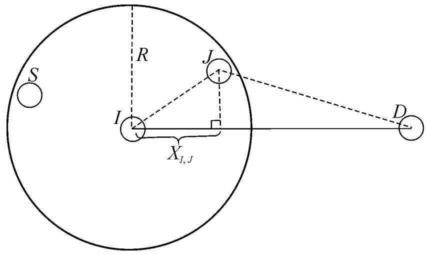

Fig. 2 Projection of neighbour node

$$X_{I,J} = d_{I,J}\frac{d_{I,J}^2 + d_{I,D}^2 - d_{J,D}^2}{2d_{I,J}d_{I,D}} = \frac{d_{I,J}^2 + d_{I,D}^2 - d_{J,D}^2}{2d_{I,D}} \tag{1}$$

where, $d_{I,J}$ is the Euclidean distance of node I, J. S and D represent source and destination node respectively.

I and J know the location information each other and the destination node's location information by RREQ, so that they can compute $X_{I,J}$ individually.

2.1 Algorithm of LAPB

In LAPB, the broadcast probability $P_{I,J}$ is determined by the projection of nodes J in forward zone of node I. At first, LAPB sets the probability function as

$$P_{I,J} = \left(\frac{X_{I,J}}{R}\right)^g;\quad 0 < X_{I,J} \leqslant R \tag{2}$$

where $P_{I,J}$ is in the interval $[0,1]$. R is the transmission range of the nodes. g is an adjust value. A big g is suitable for high-density networks. In case of low-density network, a small g is the best to ensure high reachability [2].

In large scale networks the densities in difference areas may be variable. LAPB wants to adjust the value of g through neighbour knowledge to reduce the overhead in some high-density areas of network.

LABP updates broadcast probability $P_{I,J}$ with following:

$$P_{I,J} = \begin{cases} \left(\dfrac{X_{I,J}}{R}\right)^{N_I}; & X_{I,J} > 0, N_I > k \\ 0; & X_{I,J} < 0 \end{cases} \tag{3}$$

where N_I is the quantity of neighbor nodes in the forward area belong to node I, k is an adjust value. Node I computes the projections of all its neighbor nodes. It also counts the nodes with the positive projections to get N_I.

Fig. 3 shows the half forward zone of node I. The half forward zone can be considered as rectangulars with the same width. A_1, A_2, …, A_n are area of the rectangulars.

$$0 \leqslant x_i = \frac{X_{I,J}}{R} \leqslant 1; \quad \Delta x = x_1 - x_0 = x_2 - x_1 = x_3 - x_2 = \ldots = x_n - x_{n-1},\ x_0 = 0,\ x_n = R \tag{4}$$

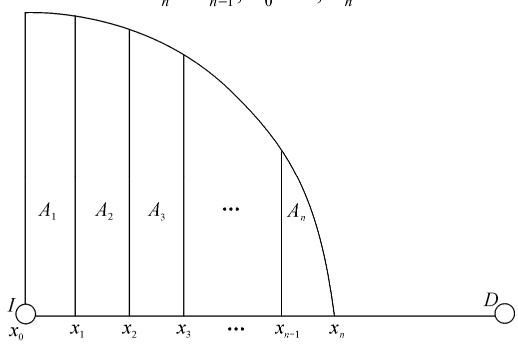

Fig. 3 Half forward zone

$$\left.\begin{aligned} A_1 &= \int_0^{x_1} \sqrt{1-x^2}\,\mathrm{d}x \\ A_2 &= \int_{x_1}^{x_2} \sqrt{1-x^2}\,\mathrm{d}x \\ &\vdots \\ \sum_{i=1}^{n} A_i &= A = \frac{\pi}{4} \end{aligned}\right\} \tag{5}$$

$$P_i = P_{I,J} = x_i^{N_I} \tag{6}$$

$$E_I = 2\sum_{i=1}^{n} \frac{A_i}{A} N_I P_i = \frac{8}{\pi} N_I \sum_{i=1}^{n} \left(x_i^{N_I} \arcsin\frac{x}{2} + \frac{\sqrt{x(1-x^2)}}{2} \right); \quad x_0 = 0 \tag{7}$$

where E_I is the expected number of neighbour nodes which will rebroadcast RREQ packets in forward zone of I.

Fig. 4 depicts the relationship of E_I and N_I which decided by density of network.

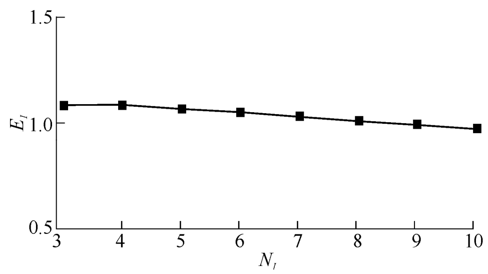

Fig. 4 E_I vs. N_I

When the number of neighbor nodes increases, E_I decreases slowly and LAPB chooses at least one neighbor node to rebroadcast RREQ packets.

In order to augment E_I and get the better reachability, LAPB updates Eq. (3) with Eq. (8). Where k is an adjust value to change E_I, it also can be adjusted according to the situation. Fig. 5 depicts the new relationship of E_I and N_I. k is suggested to set 1.5 in this paper.

$$P_{I,J} = \begin{cases} 1; & X_{I,J} > 0, N_I \leqslant 2k \\ \left(\dfrac{X_{I,J}}{R}\right)^{\frac{N_I}{k}-1}; & X_{I,J} > 0, N_I > 2k \\ 0; & X_{I,J} < 0 \end{cases} \tag{8}$$

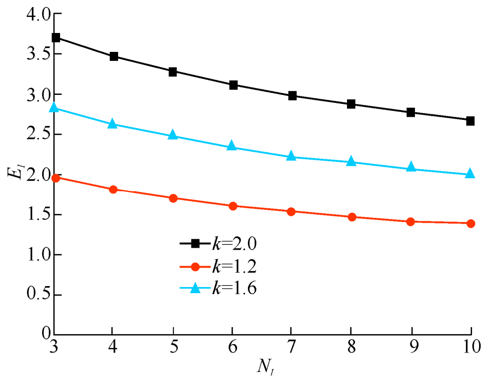

Fig. 5 E_I vs. N_I

2.2 RREQ format of LAPB:

The RREQ format is shown as Fig. 6:

Type	J	R	G	D	U	PB	Nb	Reserved	Hop count
RREQ ID									
Destination IP address									
Destination sequence number									
Originator IP address									
Originator sequence address									
Destination location									

Fig. 6 The RREQ format

In Fig. 6, type (8 bit) is 1 which represents RREQ. J (1 bit) is join flag which reserved for multicast. R (1 bit) is repair flag which reserved for multicast. G (1 bit) is gratuitous RREP flag which indicates whether a gratuitous RREP should be unicast to the node specified in the destination Internet protocol (IP) address field. D (1 bit) is destination only flag which indicates only the destination may respond to this RREQ. U (1 bit) is unknown sequence number which indicates the destination sequence number is unknown. PB (1 bit) is probability broadcast flag which decides whether a received node probability broadcast or not. Nb (8 bit) is equal to N_I. Reserved (2 bit) is sent as 0 and ignored on reception. Hop count (8 bit) is the number of hops from the originator IP address to the node handling the request. RREQ ID (32 bit) is a sequence number uniquely identifying the particular RREQ when taken in conjunction with the originating node's IP address. Destination IP address (32 bit) is the IP address of the destination for which a route is desired. Destination sequence number (32 bit) is the latest sequence number received in the past by the originator for any route towards the destination. Originator IP address (32 bit) is the IP address of the node which originated the route request. Originator sequence number (32 bit) is the current sequence number to be used in the route entry pointing towards the originator of the route request. Destination location (32 bit) is the 2D coordinates of the destination node *D*.

2.3 Process of LAPB

This part presents the LAPB algorithm which entails three phases: generating and forwarding RREQ, route selection, generating and forwarding RREP. The details are described below.

The source node would initiate generating and forwarding RREQ phase when it has no route to destination node *D*.

Step 1 The current node *I* (the first current node is the source node) generates the RREQ in which Nb and PB should be updated. N_I (Nb) can be got by node *I*. If N_I is larger than 2*k*, PB is set to 1, otherwise PB is set to 0 in RREQ. Current node *I* broadcasts RREQ to its neighbors.

Step 2 When a node *J* receives a RREQ, it judges whether it is the destination node *D*. If it is, turn to route selection phase, otherwise go to Step 3.

Step 3 Node *J* judges whether the RREQ has been received, if not go to Step 4, otherwise discard it.

Step 4 Node *J* judges whether the PB in received RREQ is 1. If not, node *J* becomes the current node and go to Step 1, otherwise node *J* evaluates $P_{I,J}$ using Eq. (8) and compares $P_{I,J}$ with a random number which helps to realize the probabilistic broadcast. If $P_{I,J}$ is larger than random number node *J* becomes the current node and goes to step 1, otherwise node *J* discards RREQ.

When destination node receives a RREQ, it waits for a time to select a less hop route. A route has the minimum hop and the least delay will be prior selected.

After the destination node selects the best route, it generates and sends a RREP to the source node along the reverse path by the RREQ. If the source node receives a RREP within a time data packets are transmitted in the route. Otherwise the source node sends a new RREQ.

3 Performance analysis

The Matlab and network simulator 2 (NS-2.34) have been used to simulate the proposed approaches. The approaches use the random waypoint mobility model in this simulation [12], where a node moves from its current position to a new position by selecting a random direction and a random speed in the range 1 m/s~10 m/s. The pause time is 0, which means the node is always moving. In this paper networks scenarios are $1\ 620\ \text{m} \times 1\ 620\ \text{m}$. These scenarios evaluate the four proposed algorithms for increasing node density. The simulation time for both scenarios is 100 s. The used traffic is constant bit rate with a packet size of 512 B, and a packet rate of 4 packet/s. The number of nodes in the network varies from 70 to 120 nodes, and the nodes' initial positions are distributed even.

The performance of LAPB is compared with the DPBSC [7], Gossip [9], location-aicled routing (LAR) [13]. The performance metrics used for the comparison are:

1) Saved rebroadcast (SRB) [8]. Let *w* be the number of nodes that received the broadcast packet and let *y* be the number of nodes that actually transmitted the packet. The SRB is then defined by $(w-y)/w$. It represents the effectiveness of network.

2) DD [8]. It is the time elapsed since the source node sends the request packet until it reaches the destination node.

3) Discovered route (DR) rate. It is the probability of destination node receives the request packet.

SRB, DD and DR rate are the most used metrics for evaluating broadcasting schemes.

Fig. 7 depicts the results of the SRB vs. the network node density for all four algorithms.

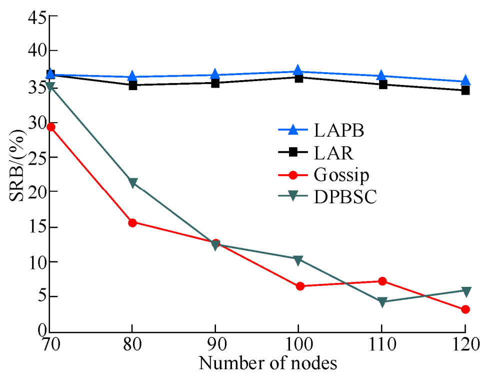

Fig. 7 The SRB of four algorithms

When the number of nodes increases which means that the density becomes higher LAPB can reduce more redundancy packets than LAR, DPBSC and Gossip. With the number of nodes increasing, an optimal route could be finally found even if the condition of selecting intermediate node becomes more strictly. LAPB can save about 3% SRB than LAR.

Fig. 8 depicts the results of DD for LAR, Gossip, LAPB and DPBSC. When the number of nodes increases, all the four algorithms will discover routes at a higher delay, LAPB discovers route faster than LAR, Gossip and DPBSC do. As shown in Fig. 7, LAPB reduces the most redundancy packets which means that LAPB has lower probability of collisions and contention.

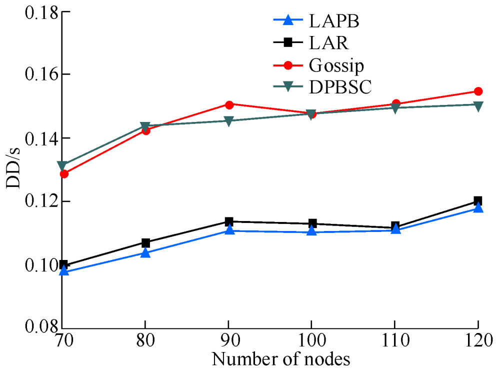

Fig. 8 The DD of four algorithms

Fig. 9 depicts the results of DR for LAR, Gossip, LAPB and DPBSC. When the number of nodes increases the route is more successfully built. The route is easier to be discovered by LAPB than LAR, but more difficult than Gossip and DPBSC. The probability of discovering route of LAPB is catching up with Gossip and DPBSC in high-density areas.

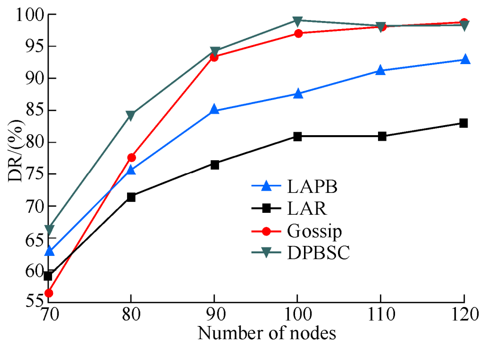

Fig. 9 The DR of four algorithms

Fig. 10 depicts the results of SRB for LAR, Gossip, LAPB and DPBSC. When the speed of nodes increases, there is little impact of SRB. Because speed changes the times of route broke and location error, they do little effect to save rebroadcast.

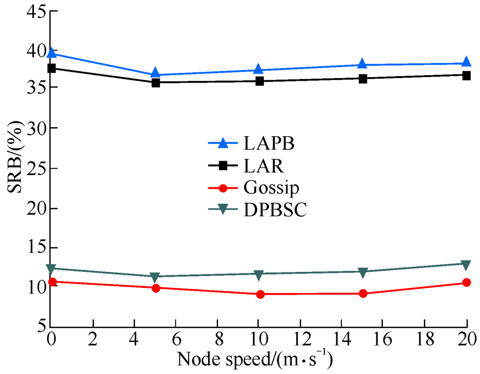

Fig. 10 The SRB of four algorithms

4 Conclusions

This paper proposes a LAPB algorithm which takes advantage of adjusting the probability of node according to the density, and chooses some efficient intermediate nodes to discover route. LAPB improves the performance whether nodes in high-density or low-density areas. Simulation results demonstrate that LAPB outperforms routing methods in terms of SRB and DD in the process of routing. The future work will consider speed information of node and different node mobility models.

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