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New efficient velocity-aware probabilistic route discovery schemes for high mobility Ad hoc networks

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ABSTRACT

Most existing route discovery schemes in MANETs are based on probabilistic models by which MANETs usually deploy broadcast mechanisms to discover routes between nodes. This is implemented by flooding the network with routing requests (RREQ) packets which usually result in the well-known broadcast storm problem. Due to the high mobility, frequent breakages are more likely to occur, leading to re-discovering the same routes frequently uncontrolled RREQ packets. Thus, the network may incur more channel contention and high packets collision rate. Existing solutions cannot accommodate the desired performance levels, especially in high mobility. Thus, this paper is the first that considers the velocity vector probabilistic route discovery in MANETs. Two new velocity-aware probabilistic route discovery models are presented to exclude unstable nodes while constructing routes between the source and its destination. The simulation experiments confirm the superiority of the proposed schemes in terms of RREQ packet overhead and link stability.

1. Introduction

Mobile Ad hoc Networks (MANETs) are cost-effective ubiquitous connectivity to offer a wide range of services in a given geographical area. This technology has been attracting tremendous research efforts and covers a wide range of real life applications in different fields. This networking technology can be used in a wide variety of operating environments such as transport, risk managements, smart cities and tactical operations as it is easy to deploy and can configure itself without depending on any pre-fixed infrastructure [1,2].

MANETs topology changes rapidly and frequently as nodes move freely with no restriction in terms of directions or mobility (i.e. speed and pause time). Data routing and packet dissemination is a challenging task typically for nodes that have high speed and different directions. Due to the high mobility and frequent topology changes, wireless links between such nodes might break or expire frequently. Hence, re-establishing wireless connection requires flooding the network with a large number of control packets such as Route Replay Packets (RREP) and Route Error Packets (RERR), in addition to the extra RREQ packets. For instance, in Ad hoc On Demand Distance Victor (AODV) protocol route discovery phase swaps the network with RREQ control packets to find an optimal route to the required destination [3]. In some cases, the established route could contain unstable nodes, where link breakage is frequent and can affect the overall network performance. Due to high node mobility frequent link breakages are one of the major problems that degrade network performance [4,5,25]. This

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occurs when a node that is a part of a route, loses connectivity to its neighbors and is no longer able to communicate with them. The disconnected node then announces itself to inform the source node that a new route discovery session is needed. This case imposes extra overhead on the network, increases the arrival times of the packets, and causes the *broadcast storm problem* [6,7,24].

Most recent proposed probabilistic routing schemes alleviate the broadcast storm problem in MANETs protocols by prohibiting nodes from participating in route discovery based on some predefined thresholds [8–10,26]. For instance, in [9] a node cancels its retransmission if it has a density degree above a predefined density threshold such as maximum network density. The rebroadcast probability is then calculated based on the distance between sender and receiver. The probability of the receiver to cancel its transmission is high if it is located close to the sender. Another example in [10], a node cancels its retransmission if it has a density level above a predefined density threshold. Although the current suggested probabilistic routing schemes succeed in reducing routing overhead, they fail to avoid frequent link breakages problem because the velocity of nodes is not included as a factor in routing decisions, and some unstable nodes form partly the routes.

In this paper, we utilize the probabilistic concept to develop new probabilistic routing schemes, namely *Simple Velocity Aware Probabilistic* (*SVAP*), and *Advanced Velocity Aware Probabilistic* (*AVAP*) route discovery schemes. Both the SVAP and AVAP are proposed to solve the frequent link breakages problem and guarantee that all constructed links are stable. The velocity of nodes is anticipated as a key parameter to control the routing function among the nodes. Nodes that move with the same velocity are called reliable nodes and should be assigned a high probabilistic routing decision, while nodes that move with different velocities are called unreliable nodes and should be assigned a low probabilistic routing decision. A cosine angle is calculated between a sender and a receiver, and is compared with a predefined cosine angle threshold, to identify whether the receiver is a reliable node or an unreliable one.

The rest of the paper is organized as follows. Section 2 introduces related work, problem statement and motivation. Section 3 presents a detailed description of the proposed schemes. Section 4 provides the performance evaluation of our schemes. Finally, Section 5 concludes this study and outlines our future work.

2. Preliminaries

In this section, related works under the umbrella of different categories on broadcast in MANETs are presented. Then, the problem statement, concepts and motivation are discussed.

2.1. Related work

A basic Fixed Counter (FC) broadcast scheme is a simple approach to suppressing unnecessary nodes' retransmission based on local network density (i.e. number of copy) within the transmission range [6,7]. This scheme works as follows: each node sets a random timer upon receiving RREQ packet. The node makes the rebroadcast decision blindly after timer expiration, and when the number of duplicated RREQ packet exceeds a predefined threshold. Otherwise, the packet is dropped. This scheme demonstrates the better performance in a dense network in terms of high reachability and saved rebroadcast, typically when it augmented with other broadcast schemes [11,12,24]. However, it fails to construct a reliable route between source(s)/destination(s) pairs, since velocity factor is neglected in this scheme.

A probabilistic scheme based on the network density information is suggested to mitigate the broadcast storm in AODV [13]. This scheme divides the nodes into four logical groups of density according to the maximum and minimum network density. The density information is collected by broadcasting HELLO packets every second to construct a 1-hop neighbor list at each node. The node then decides to which groups it currently belongs, by comparing its neighbor list with the maximum and minimum network density threshold $\mathrm{AVG}_{\mathrm{threshold}}$, which is computed as follow:

$$\mathrm{AVG}_{\mathrm{threshold}} = \sum_{i=1}^{n} \frac{N_i}{n} \tag{1}$$

where n is the number of nodes in the network and N_i is the number of neighbors for node X.

Another variation of the density probabilistic scheme is suggested in [14]. In this scheme, rebroadcast probability is set according to the number of duplicated RREQ packets instead of the number of neighbors. Each node counts the number of the same received packet (i.e. c) within a random timer. Upon the timer expiration, the node uses the ratio between the total numbers of received packets (i.e. c) within the timer and the predefined Counter threshold (i.e. C), to rebroadcast the packet with the following exponential probabilistic function:

$$F(c) = e^{-(\frac{c}{C})} \tag{2}$$

Two schemes based on the distance probabilistic and timer are suggested in [15] without neighbor knowledge information. The first scheme is called Weighted Probabilistic-Persistence Broadcasting (WP-PB) scheme. In this scheme, when a node j receives a packet from node i, node j waits for a period of time *WAIT-TIME* and checks the packet ID and rebroadcasts with probability P_{ij} if it receives the packet for the first time; otherwise, it discards the packet. The rebroadcast probability is adaptively calculated according to the distance from the sender. When the timer expired the node rebroadcasts the RREQ packet with the last smallest value of probability as in the following formula: