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Adjusted probabilistic route discovery in mobile ad hoc networks

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ABSTRACT

Conventional on-demand route discovery methods in mobile ad hoc networks (MANET) employ simple flooding method, where a mobile node blindly rebroadcasts received route request (RREQ) packets until a route to a particular destination is established. This can potentially lead to high channel contention, causing redundant retransmissions and thus excessive packet collisions in the network. This paper proposed two new probabilistic methods that can significantly reduce the number of RREQ packets transmitted during route discovery operation. Our simulation analysis reveals that equipping AODV with an appropriate probabilistic route discovery method can result in significant performance improvements in terms of routing overhead, MAC collisions and end-to-end delay while still achieving a good throughput when compared with the traditional AODV.
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1. Introduction

There has been a growing research activity on wireless mobile ad hoc networks (MANETs) over the past years due to their potential useful civilian and military applications. MANETs are formed dynamically by an autonomous system of mobile nodes (i.e. laptops, PDAs, etc.) that are connected via wireless links without using an existing fixed network infrastructure or centralized administration [1]. The nodes are free to move randomly and organise themselves arbitrarily. As a consequence, the network's wireless topology may change rapidly and unpredictably. Nodes in MANETs act as end points and sometimes as routers to forward packets in a wireless multi-hop environment.

One of the fundamental challenges in the design of MANETs in a multi-hop environment is the design of dynamic routing protocol that can establish routes to deliver data packets between mobile nodes with minimum communication overhead while ensuring high network throughput and low end-to-end delay. To this end, several routing protocols have been proposed [2–7]. In general, the routing protocols for MANETs fall into three categories based on the routing information update mechanism [8]: proactive, reactive (or on-demand) and hybrid. Proactive routing protocols, such as DSDV [2] and OLSR [3], attempt to maintain consistent and up-to-date routing information from each node to every other node in the network. In the on-demand routing protocols, such as AODV [4] and DSR [5] routes, are discovered only when they are needed. The hybrid routing protocols [6,7] combines the features of both proactive and on-demand protocols. In the case of hybrid routing protocols, each node maintains routing information about its zone using the proactive approach, but uses on-demand routing approach outside the zone.

The periodic routing information updates and updates due broken links that are inherent in proactive routing protocols can lead to a large routing control overhead when the network is scaled up and the mobility of nodes is high. As a

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consequence, these protocols are not suitable for use in ad hoc network scenarios where the network density can be large and the topology changes can be more frequent.

In traditional on-demand routing algorithms such as AODV [4] and DSR [5], a node that needs to discover a route to a particular destination, broadcasts a route request control packet (RREQ) to its immediate neighbours. Each neighbouring node blindly rebroadcast the received RREQ packet until a route is established. This method of route discovery is referred to as *simple flooding*. Since every mobile node rebroadcast the RREQ packet the first time it is received and assuming that the destination node is reached, the possible number of rebroadcasts is around $N-2$, where N is the total of number of network nodes. This method of broadcasting can potentially lead to excessive redundant retransmissions in congested networks and hence causing high channel contention and excessive packet collisions. Such a phenomenon induces what is known as broadcast storm problem, which has been shown to greatly increase network communication overhead in "pure" broadcast scenarios [9] where a broadcast packet require to reach all the nodes in the network. To reduce the deleterious impact of the simple flooding, a number of broadcasting techniques have been suggested in the literature [9–12].

Recently, probabilistic broadcast schemes for MANETs have been suggested [13–16] as one of the solutions to mitigate the broadcast storm problem associated with the simple flooding method. In conventional probabilistic broadcast methods, each mobile node rebroadcasts a received packet once based on a predetermined *fixed-value forwarding probability*. The probabilistic schemes do not require the global topological information of the network in order to make rebroadcast decisions. Therefore, these schemes are localized and can be used to significantly reduce the communication overhead associated with the dissemination of broadcast packets in a network. However, most of the proposed probabilistic broadcast methods have focused on pure broadcast scenarios [13,14] with relatively little investigations on the effects of such broadcast schemes on specific applications such as routing.

This paper proposes two new route discovery algorithms that utilises probabilistic broadcast methods to disseminate the RREQ packets. To evaluate the new route discovery methods we have considered using the AODV [4] routing algorithm. We have selected AODV in our present study as it is one of the early routing protocols proposed in the literature that has been widely investigated and analysed [4]. Our results reveal that equipping AODV [4] with the new probabilistic route discovery methods help to reduce the overall routing overhead while achieving good network throughput with improved end-to-end delay when compare against the traditional AODV [4].

The rest of the paper is organised as follows. Section 2 presents related work on some route discovery techniques. Section 3 provides a brief overview of on-demand route discovery process in AODV [4]. Section 4 presents the two new probabilistic route discovery methods. Section 5 conducts a performance evaluation of the proposed route discovery methods. Finally, Section 6 concludes this study and outlines some directions of future research work.

2. Related work

Recently there has been a lot of work devoted towards mitigating the communication overhead associated with the dissemination of RREQ packets for route discovery and maintenance processes in MANETs [4,17,18]. In [4], the traditional AODV protocol has been extended to incorporate *expanding ring search* which does consecutive flooding to search increasingly large regions around the source node. This is achieved by first setting the time to leave value, TTL = 1 for the first attempt, then to 2, and so on, until a destination reached. This incremental approach can increase the route discovery latency and the routing overhead if the destination is located far away from the source. To improve these performance metrics the authors have suggested a threshold of TTL = 3 for the expanding ring search.

A sophisticated technique called location-aided routing (LAR) [18] has been suggested as an optimization of on-demand routing protocol which relies on location-aided services such as global positioning system (GPS) [19] to localize the dissemination of the route request packets to a limited geographic area (*request zone*). The request zone defined based on the past location information of the destination node know to the sender. In this approach, each mobile node is assumed to be equipped with a GPS receiver for location information. However, in reality, position information provided by GPS includes some amount of error, which is the difference between GPS-calculated coordinates and the real coordinates. For example, NAVSTAR global positioning system has positional horizontal accuracy of about 100 m at 95% probability level [20] and differential GPS offers accuracies of a few meters [19]. Castañeda and Das [21] have proposed an optimization to on-demand routing algorithms that utilises prior route histories to limit the query flood to a region in the neighbourhood of the prior routes. The protocol maintains a set of nodes which include all the nodes on the last valid route between specific source–destination pairs. In subsequent route discoveries, only such nodes are privileged to propagate the query floods. The disadvantage of this method is that the route histories become staled quicker in a highly dynamic environment.

A zone routing protocol (ZRP) [17] has been proposed which exploits the concept of protocol hybridization to reduce the overhead associated with the dissemination of routing controls packets. ZRP attempts to balance the trade-off between proactive maintenance of routing tables and reactive route discovery floods. While proactive routing protocols can provide low delivery latency through frequent dissemination of routing information, they entail high routing overhead and scale poorly with increasing network density [22]. In contrast, reactive routing protocols can achieve low routing overhead, but may suffer increased delivery latency due to on-demand route discovery and route maintenance [22]. The ZRP defines a zone around each node consisting of its k-hop neighbourhood. Routing within a zone (i.e. intra-zone routing) is performed using a proactive routing protocol and routing between nodes in different zones (i.e. inter-zone routing) is performed by reactive rout-

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