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A novel encounter-based metric for mobile ad-hoc networks routing

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ABSTRACT

So far the hop-count has been considered as a good metric for routing in wired and wireless networks thanks to its simplicity and effectiveness. In spite of that, the hop-count still manifests itself to be low adaptable to the environment in which nodes may be densely distributed and move at high speeds as in mobile ad-hoc networks (MANETs). Several metrics have been proposed as the replacements for the hop-count in routing of MANET such as the Expected Transmission Count (ETX) and the Expected Transmission Time (ETT). However, they only showed their outperformance in static scenarios. To deal with the mobility, some routing models employed a metric named Mobility Factor (MF) based on detecting the change of neighbour sets in a period of HELLO messages to examine the link stability before sending a packet. Nonetheless, to calculate MF values, each node needs to keep historical information of its neighbours which causes more resource usage and more computational complexity when MANETs scale up. In an attempt to find a suitable and effective metric for MANET's routing, this paper introduces the Path Encounter Rate (PER) metric based on the concept of "encounter". The proposed metric reflects the environment's changes and therefore boosting the performance of routing protocols in MANETs. The throughput achieved by using the proposed metric is 30% higher than those obtained by the hop-count metric when 100 nodes move at a maximum speed of 20 m/s in the area of 300×1500 m^2. This is a remarkable improvement compared to other metrics in mobility scenarios. Additionally, the proposed metric is much simple and has less computation compared to MF metric in terms of implementation. Though, the proposed metric and routing model in this paper is demonstrated on the Ad-hoc On-demand Distance Vector (AODV) protocol, it is generic and can be applied for various kinds of routing protocols in MANETs.

1. Introduction

1.1. Introduction

The mobile ad hoc network (MANET) [1,2] is a form of wireless networks in which mobile nodes move autonomously and communicate to others directly or indirectly without pre-existing communications infrastructure. Data packets can be relayed at intermediate nodes before reaching the destination which explains why MANETs are also known as the mobile multi-hop networks. Thanks to those characteristics, MANETs have gained great attraction in recent years and been applied in various fields such as military communications, disaster management, and emergency services where the telecommunication infrastructures have been damaged or not available.

One of the main challenges in MANETs is how to route data packets across the network while its topology is changing unpredictably due to the movements of mobile

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nodes [3,4]. Study results in [3] showed that the higher mobility the mobile nodes are, the lower throughput the network reaches. Another factor that also exerts a great impact on the performance of routing is the network density [4]. The higher the network density is, the lower throughput the network achieves.

Routing in MANETs is typically classified into two main strategies: proactive routing and reactive routing [2,5]. In proactive routing, each mobile node maintains a routing table to record available routes leading to all nodes in the network. This routing type is also recognized as table-driven routing. Whenever a node needs a route to a specific destination, it will just simply look up the routing table and determine a proper route to forward the data packets. This kind of routing requires mobile nodes to send broadcast packets periodically to all nodes in the network for the purpose of updating their routing tables. However, this routing strategy is likely to impose MANETs on a big problem called "broadcast storm" [6] under which MANETs are flooded by itself broadcast messages, resulting in a degradation of the network throughput. In contrast, reactive routing protocols do not actually need a routing table. Instead, it starts to discover a route by broadcasting the probe packets "on-demand"; the first replying route will be chosen for routing. This strategy eliminates disseminating probe packets periodically, and hence reduces the broadcast storm problem.

Routing protocols in MANET, therefore, consist of proactive routing protocols and reactive routing protocols according to two routing strategies mentioned above. Moreover, they can be categorized into several more types such as hybrid, location-aware, power-aware, multi-path routing protocols, and so on based on their underlying architectural framework [7].

It is generally acknowledged that the most common metric used for routing in MANETs is "hop-count" [7–10] (HOP metric). This metric reflects the length of the end-to-end path in hop. So far, it has been assessed as a good indicator for routing performance in wired and wireless networks [5,11]. However, the network's mobility and density are not concerned in this metric; therefore the selected route might not be the best quality one for sending data. In other words, the HOP metric is not an optimal solution for routing in mobile ad hoc networks.

1.2. Related works

Recently many studies have tried to introduce alternative metrics which have the ability to adapt to the mobility and/or the density changes of MANETs. Adya et al. [12] proposed a new metric relied on per-hop round trip time (RTT) concerning the duration of sending and receiving a probe packet from a sender to 1-hop neighbours. The sender then updates the estimated weighted average RTTs which are recorded the routing table to its neighbours. The target of the routing machine is to look up a minimum RTT path. However, the periodic dissemination of probe packets and probe acknowledgement packets for getting the RTT value may consume more bandwidth and cause more network contention, and therefore employing this metric is not effective in dynamic and dense networks [11].

In another approach, Khelil et al. [13] exhibited several metrics called contact-based mobility metrics relied on the concept of "encounter". Two nodes encounter to each other when the distance between them becomes smaller than the communication range R. The encounter e_{nm} between node n and node m is defined as:

$$E_{nm} = \{n, m, t, \Delta t\}, \tag{1}$$

where t is the incident time of the encounter and Δt is the lifetime of the encounter. The simulation results and analysis in [13] signify that the number of new encounters in a given duration is linearly proportional to the mobility and the density of the network. In other words, in a given node density, by observing new encounters in certain duration, a node can basically predict its relative velocity [14] to other nodes around.

From the same perspective, Boleng et al. [15] introduced a mobility metric named "link duration" defined as the time that two nodes are within the transmission range of one another.

Both contact-based and link duration metrics have been evaluated by those authors as good metrics to indicate the mobility and density changes [15,16] in MANETs. However, the effectiveness of them on routing performance has not been expressed explicitly in mobility scenarios [11,16].

De Couto et al. in [17] introduced a well-known metric, the ETX, which helps a routing protocol in MANETs find the highest throughput path to forward packets. The ETX of a link is the expected number of data transmissions required to send a packet over that link, including retransmissions in MAC layer. Mathematically, ETX of a link can be calculated by:

$$ETX = \frac{1}{d_f \times d_r}, \tag{2}$$

where d_f is the forward delivery ratio which represents the probability of successful packets arrived at receiver; d_r is the reverse delivery ratio which represents the probability of successful ACK packets received. Since the ETX is based on link delivery ratios, it directly reflects the throughput of communication links. The protocol aims to choose the highest throughput link with minimum ETX to forward data packets. The experimental results showed the improvement of the throughput up to 40% compared to HOP metric achieved as nodes were stationary.

To calculate the d_f and d_r in Eq. (2), a routing protocol needs to collaborate with the link layer to periodically broadcast the fixed size messages to its 1-hop neighbours. The broadcast rate is basically equal to the data rate at physical layer. This process may occupy the additional bandwidth and cause more network contention.

Based on the ETX metric, Draves et al. [18] introduced the ETT metric to overcome the ETX shortcomings by adjusting the broadcast process in different rates and packet sizes rather than remaining in basic rate and fixed packet size as ETX did. The authors showed that the throughput under ETT metric could be enhanced by 16% compared to the ETX.

In an attempt to mitigate the effects of noise and router congestion, the authors in [19] exhibited a new time-based