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MSAR: A metric self-adaptive routing model for Mobile Ad Hoc Networks

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ABSTRACT

This paper proposes a metric self-adaptive routing scheme for Mobile Ad Hoc Networks (MANET). By applying the proposed model, each node is able to detect whether the mobility states of the network is relatively static or mobile without the support of the Global Positioning System (GPS). The mobility state detection model is designed based on an indicator named MSI (for proactive routing) or GMSI (for reactive routing) computed at each node. Based on MSI/GMSI, an adaptive algorithm is then designed to employ the appropriate routing metric, i.e., either Expected Transmission Count (ETX) or Path encounter Rate (PER), for each detected state in order to achieve the optimum routing performance for different network conditions (i.e., static or mobile).

1. Introduction

Though MANET has been developed for the past decade, routing in MANET is still facing to many challenges caused by the random movements of nodes and limited transmission capacity of mobile devices. The network topology might change as time and space evolve and the established route for sending data could be broken when the intermediate node(s) move out of the communication range of the others (Boukerche et al., 2011). Routing performance will become very poor if the mobility of nodes is high. To achieve a high routing efficiency, routing protocols therefore should be adaptive to the changes of MANET.

In real a scenario, nodes in a MANET might not move all the time. It could be absolutely stationary (e.g., people are sitting in a meeting/theatre); or relatively stationary (e.g., people are sitting on a coach/train). That introduces a complex mobility pattern of MANET including absolutely/relatively stationary or mobile.

Unfortunately, current routing metrics proposed for MANET produce an optimal routing performance for a specific condition, either static or mobile, not for all network mobility conditions. For example, Expected Transmission Count (ETX) (De Couto et al., 2003) or Expected Transmission Time (ETT) metric (Draves et al., 2004a) helps nodes find the highest throughput path for routing in static condition (all nodes are stationary). If the network is mobile, nodes have insufficient time to calculate ETX or ETT (De Couto et al., 2003; Draves et al., 2004a), thus inducing an inaccurate routing decision. Such a routing decision causes a degradation of routing performance of MANET. Meanwhile, mobility metrics such as link expiration time metric (Su et al., 2001), link duration metric (Boleng et al., 2002), contact-based mobility metrics (Khelil et al., 2005), mobility factor (Wu et al., 2009), and path encounter rate (Son et al., 2014) produce a best routing performance for mobile condition (nodes arbitrarily move in network area). If the network becomes static for some reason, those proposed mobility metrics do not have any advantages. Even they take a higher complexity than simple hop-count metric and others.

It is generally acknowledged that designing an *one-size-fit-all* metric for MANET routing is likely to be impossible (Zhang and Matolak, 2012) because of the unpredictable change of MANET topology. However, that can be achieved by adaptively applying a proper metric for each network state (i.e., absolutely static, relatively static or mobile). This inspires the adaptive routing model proposed in this paper. The key contributions of this paper are as follows:

- Proposing a model which allows each node to detect whether the mobility states of the network is static (including absolutely and relatively static) or mobile. The detection model is based on Mobility State Indicator (MSI) designed for proactive routing or Global MSI (GMSI) designed for reactive routing. MSI/GMSI is calculated at each node without the support of the GPS.

- Proposing metric self-adaptive routing (MSAR) model which enables nodes to adapt routing metrics (i.e., ETX, PER), to the network mobility states (i.e., static, mobile respectively) based on the detection above.

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Related work

Many adaptive unicast routing have been proposed in the literature to enable nodes to adapt to the unpredictable changes of MANET topology.

Cong Liu et al. (Liu and Wu, 2008) introduced a routing protocol named Adaptive Routing in Dynamic Ad Hoc Networks (AROD), which is seamless integration of existing routing models to adapt to node density and mobility pattern. Routing performance is presented as highly scalable and adaptable to different network scenarios.

To avoid packet loss due to link breakages, Lin et al. (Lin and Ke, 2009) presented an adaptive routing protocol named Adaptive Route Selection (ARSMA) under which a source node discovers multiple routes to the destination, one for primary, and the others for backup. When the primary route is broken, the source node tries to switch data from the primary route to one of the backup routes. As a result, the ARSMA enhances packet delivery ratio and reduces end-to-end delay of the network. However, the information of backup routes stored in the routing table could become stale due to the movement of nodes, which results in inaccurate routing decisions.

Fathy et al. (2012) proposed an Adaptive Cross Layer Protocol (ACRP) using Fuzzy Inference System to adapt to the mobility and application types. The model has the ability to switch between routing modes, i.e., proactive and reactive, based on network mobility and traffic types. The achieved routing performance is shown as very stable and much enhanced compared to the routing performance of the Ad Hoc On-demand Distance Vector (AODV) (Perkins et al., 2003) protocol and the Destination-Sequenced Distance Vector (DSDV) protocol (Perkins and Bhagwat, 1994) in different speeds and traffic loads. However, the ACRP faces a challenge related to synchronisation among nodes while switching between routing protocols and updating routing information for different types of routing.

From the same perspective, the authors in Kum et al. (2012) proposed a Mobility Adaptive Hybrid Routing (MAHR) scheme to adapt to the mobility of the network. To detect the network mobility, every node uses Mobility Ratio (MR) metric which is calculated based on the duration of connected links to neighbours. When the MR value exceeds a given threshold, a node changes its operation mode to be proactive. This model has been implemented on AODV and achieved a better performance than the original AODV and Optimized Link State Routing (OLSR) protocol (Clausen and Jacquet, 2003). This approach also faces the same challenge as that of Fathy's model.

To take advantages of proactive and reactive without switching between two routing types, authors in Jiaqi et al. (2014) are based on Zone Routing Protocol (ZRP) (Haas, 1997) to develop a centralized adaptive hybrid routing (CAHR) mechanism for MANETs. Their model adapt to the frequent changes of zones' topology by periodically electing the key nodes. This helps to reduce the number of forwarding control messages and routing overhead over the network.

Another interesting approach for adapting to the mobility of the network which is proposed in Ingelrest et al. (2007) is to adjust the HELLO frequency based on the appearance rate of new neighbours in the neighbourhood table. This model named Turnover based Adaptive HELLO Protocol (TAP) relies on the fact that the more mobile a node is, the more frequently new neighbours appear. The HELLO frequency is adjusted to be higher if the number of new neighbours is high and vice versa. This solution helps nodes reduce the number of redundant HELLO messages while still ensuring a quick check neighbours' appearance and link availability.

To save the energy consumption at each node, the authors in Han and Lee (2013) proposed a Hello Messaging Scheme named Adaptive Hello (AH) to adapt the HELLO frequency to the traffic demand. If a node has no packets to forward, it reduces the frequency of sending HELLO messages to neighbours for checking link availability. This model helps MANETs diminish the number of HELLO messages while still checking properly link availability to save energy consumption.

In MANET, congestion is one of the main causes for a poor routing performance (Tran and Raghavendra, 2006), hence, awareness of and adapting to network congestion will allow nodes to improve routing performance. By monitoring the number of packets stored in the buffer, the Congestion Adaptive Routing Protocol (CRP) can detect and classify congestion status whether it is free or likely to be congested or already congested. If the congestion is more likely to be occurred, nodes split their traffic over a "bypass" routes to diminish the congestion beforehand and balance the traffic load all over the network.

Another approach to improve routing performance is to determine the route request (RREQ) forwarding probability of a node based on its residual energy and energy drain rate proposed by authors in Chettibi and Chikhi (2016). This model applies adaptive fuzzy logic system for energy-aware RREQ probability forwarding tuning, therefore their proposed model can maximise the network lifetime. However, applying an adaptive fuzzy logic system with reinforcement learning mechanism might increase the complexity at the network layer of a node.

It can be seen that none of above-mentioned protocols has concerned about the adaptation of routing metrics to the mobility states of the network as introduced in this paper.

The rest of this paper is structured as follows. Section 2 introduces MSI/GMSI used for detecting mobility state of the network. Section 3 proposed MSAR model to adapt routing metric to network mobility state for both proactive and reactive routing. Section 4 follows up by a comprehensive performance evaluation in different mobility models. Finally, Section 5 concludes the paper.

2. MSI indicator and analysis

A MANET is represented by graph G (V, L), where V is a set of nodes, L is a set of links between pairs of nodes in the graph. A link $\{a, b\}$ from nodes a to node b appears when node b comes into the communication range of node a. Each node is equipped with a single radio with a fixed transmission range R.

2.1. Definitions

Definitionn 1. (Encounter)—Two nodes encounter each other when the distance between them becomes smaller than the communication range R (Khelil et al., 2005). The encounter e_{ab} between node a and node b is defined as

$$e_{ab} = \{a, b, t, \Delta t\} \tag{1}$$

where t is the incident time of the encounter and Δt is the duration or lifetime of the encounter.

Definition 2. (Average encounter rate)—The Average Encounter Rate (AER) is the average number of *new* encounters experienced by each node in a duration T. Let N_E (A) be the set of *new* encounters observed by node A within duration T, the AER of node A can be calculated as follow (Khelil et al., 2005):

$$AER_A = \frac{|N_E(A)|}{T} \tag{2}$$