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Neighborhood-based interference minimization for stable position-based routing in mobile ad hoc networks

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HIGHLIGHTS

- First interference aware, stable position-based routing algorithms for MANETs.
- Next hop choice combines Conservative Neighborhood Range with interference awareness.
- Interference metrics of node are number of other paths part of, or neighbor count.
- Next hop node choice seeks shortest path while minimizing interference metric.

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ABSTRACT

For efficient communication in a mobile ad hoc network (MANET), dealing with interference while performing concurrent multi-hop routing is of great importance. By establishing an interference-aware route we can potentially reduce the interference effects in the overall wireless communication, resulting in improved network performance. Typically, mobile devices, represented by nodes in a MANET, broadcast in a limited shared media. Using both routing and scheduling mechanisms for wireless transmissions can reduce both redundancy and communication interference. We study communication interference problems in the context of maintaining stable connection routes between mobile devices in MANETs. This paper presents extensions of our previously studied position-based stable routing protocol Greedy-based Backup Routing Protocol with Conservative Neighborhood Range to maintain connection stability while minimizing the number of corrupted packets in the presence of more general communication interference. Simulation results demonstrate the effectiveness of the new protocols.

1. Introduction

Mobile ad hoc networks (MANETs) are a type of wireless network where mobile devices are themselves responsible for communication with each other without the presence of a centralized infrastructure. MANET networks are formed through interconnected devices communicating wirelessly within a relatively limited and shared area. Mobile devices in MANETs can typically move in any direction and therefore the shared media between the mobile devices may frequently change. To achieve high network efficiency in MANETs, nodes may transmit their packets (messages) concurrently on more than one link. Interference in MANETs is a result of such concurrent transmissions taking place in the neighborhood (asynchronous) and is also associated with collisions (which produce corrupted data) arising from nodes outside the range of each other transmitting to a common receiver at the same time (synchronous) [1,2].

In MANETs, interference can have an adverse influence on the performance of the networks [3]. This occurs due to the dynamic nature of the network structure as well as concurrent transmissions [4]. Therefore, interference modeling should be taken into account by routing and scheduling protocols. Thus, the effect of interference on the efficiency of our proposed routing protocols is a critical and challenging issue.

1.1. Definition of interference

Interference in MANETs is due to the possibility of a receiver node being positioned in the carrier sensing range for any other neighborhood node, other than the previous node in the path, in the same network. The carrier sensing range for any node is the range in which a node can receive signals but cannot appropriately decode them. Therefore, in MANETs, when interference is considered, an otherwise optimized route from a source to a destination,

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along a specific path [5], may not be the optimal choice, such as the shortest path.

1.2. Communication interference

In MANETs, during the route construction process, due to the communication being done wirelessly, the neighborhood nodes exchange messages in contention mode. This leads to heavy control message overhead and communication interference [6]. Indeed, interference affects the throughput of communication in MANETs by corrupting some of the packets that are exchanged among the mobile devices [3,7]. Therefore, it is important to study the interference-aware schemes that improve the throughput at the receivers in the MANET environment.

1.3. Proposed protocols

To develop interference-aware protocols for stable position-based routing in MANETs, we will develop extensions to our previous work based on the Greedy-based Backup Routing Protocol (GBR) [8].

In [9], we studied the idea of using a conservative neighborhood range (CNR) which eliminates the need to establish backup paths while maintaining stability. In Section 3.3, we introduce this routing protocol, called GBR-CNR, which is based on the original GBR [8]. Without the requirement of backup paths to maintain stability, we expect it can be modified to reduce the interference more effectively than the previously studied protocols where backup path mechanisms or multi-paths were used to maintain path stability. In order to establish the interference-aware stable paths, in this paper we introduce interference-aware versions of GBR-CNR, the first such interference-aware and stable position-based routing algorithms. The only other published interference-aware position-based routing algorithm we are aware of is by Khabbazian et al. [10] that assigns different transmission ranges to each node while minimizing the maximum interference and maintaining a connected communication graph. This latter algorithm is not a stable routing algorithm so will not be used for comparisons in this paper. In Section 3.4, for comparison purposes, we introduce the LEARN-based Backup Routing (LBR) [11] where the Greedy Routing protocol in GBR is replaced by an energy-efficient position-based routing protocol named LEARN introduced by Wang et al. [12].

The rest of this paper is organized as follows. In Section 2, we review specifically related work including giving a brief description of different approaches to studying the interference in MANETs. We provide details of related stable routing protocols in Section 3. In Section 4, we will give brief study of quality of service and minimizing interference. In Section 5, we propose our developments to improve a network throughput introducing stable routing protocols that minimize communication interference in MANETs. Experimental results are given in Section 6. Finally, concluding remarks are made in Section 7.

2. Related works on interference minimization in MANETs

Many routing protocols have been proposed to improve the routing efficiency in MANETs, and the process of selecting the path on which network traffic is sent. We consider these routing protocols as being broadly categorized into two approaches, topology-based routing and position-based routing [13].

2.1. Interference-aware topology-based routing

Topology-based routing protocols use link information available from the network to determine a route between the nodes [14]. The most recent work on stability-oriented routing has been for topology-based routing [15–26]. Agarwal et al. [20] and Wenqing [21] proposed path stability routing protocols which were modifications of DSR. Sun et al. [22] presented a link stability based routing protocol based on AODV. Hu et al. [23] presented a stability-enhanced routing protocol based on AODV which determines an alternate stable path when dictated by asynchronously updated link lifetimes. Hamad et al. [24] presented a routing protocol called Line Stability and Energy Aware (LSEA) which was a modified version of AODV. For protocols based on multicasting, Zhang et al. [25] use multicast trees and a stability evaluation metric to propose a stability-based multicast routing protocol, while Mohamamdzadeh et al. [26] used multicast trees to create an energy-aware, stable routing protocol.

Similarly, most research on interference-aware routing in MANETs is based on topological routing. Interference limits the throughput of communication in MANETs by corrupting some of the packets that are exchanged among the mobile devices. Therefore, it is of critical importance to study the interference that affects the receivers in the MANETs environment. Pyun et al. [27] proposed a distributed topology control scheme in MANETs where the transmission power of each node was adaptively adjusted based on both the number of its neighbor nodes and the amount of interference that the node generated for its neighbors. To maintain the number of targeted neighbors, a mobile node may change (increase or decrease) its transmit power accordingly to its number of neighbors.

De Rango et al. [28] considered a protocol that introduced the concept of interference in the choice of optimum routes in order to improve wireless system performance. Two distinct metrics were proposed: the first one was based on global interference perceived by nodes involved in the communication. The second one was based on the interference perceived only on the links belonging to the route from the source to the destination. The novelty of the proposal was to adopt these two metrics for the procedure to select the optimal route from the source to the destination and for the route maintenance procedure. The proposed metrics were not based on the minimum hop number, such as with the AODV protocol, but on the global interference perceived by nodes (the first metric), and on the interference affecting the link involved in the transmission (the second metric).

In 2013, Gu and Zhu [29] presented the Interference Aware Cross Layer Routing protocol (IA-CLR). This is an interference aware routing protocol based on a node's sending and receiving capacities. IA-CLR builds the routes with the minimum bottleneck link interference by using the new routing metric that can comprehensively reflect the real network condition. In IA-CLR, when a node seeks to transmit a packet, it will continue sending the Request-To-Send (RTS) control packets. It does so until it successfully occupies the channel after receiving the Clear-To-Send (CTS) control packets from the next hop or the number of retransmissions exceeds the threshold of six, as described in their work. Similar to channel reservation, the node will continue sending the packets until it successfully delivers the packet to the next hop or the number of retransmissions exceeds the threshold (three times).

2.2. Position-based routing for MANETs

In position-based routing, each network node is informed about itself, its neighbors' positions, the source of a message, and the position of its destination [13,30]. Position-based routing algorithms forward packets in the direction of the destination using this positional information. Each node in a mobile ad hoc network must periodically exchange information with its neighbors to update its