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A mobility aware protocol synthesis for efficient routing in ad hoc mobile networks ☆

Athanasios Bamis [a], Azzedine Boukerche [b], Ioannis Chatzigiannakis [c,d,*], Sotiris Nikoletseas [c,d]

[a] *ENALAB, Yale University, New Haven, CT 06520, United States*
[b] *SITE, University of Ottawa, Ontario, Canada K1N 6N5*
[c] *CEID, University of Patras, Rio 26500, Greece*
[d] *Research Academic Computer Technology Institute (RACTI), Research Unit 1, 61 Riga Ferraiou Strasse, Rio 26500, Greece*

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Abstract

In mobile ad hoc networks (MANETs), the mobility of the nodes is a complicating factor that significantly affects the effectiveness and performance of the routing protocols. Our work builds upon recent results on the effect of node mobility on the performance of available routing strategies (i.e., path-based, using support) and proposes a protocol framework that exploits the usually different mobility rates of the nodes by adapting the routing strategy during execution. We introduce a metric for the relative mobility of the nodes, according to which the nodes are classified into mobility classes. These mobility classes determine, for any pair of origin and destination, the routing technique that best corresponds to their mobility properties. Moreover, special care is taken for nodes remaining almost stationary or moving with high (relative) speeds. Our key design goal is to limit the necessary implementation changes required to incorporate existing routing protocols into our framework. We provide extensive evaluation of the proposed framework, using a well-known simulator (NS2). Our first findings demonstrate that the proposed framework improves, in certain cases, the performance of existing routing protocols.

Keywords: Wireless ad hoc; Mobile networks; Mobility classification; Routing; Algorithmic design; Simulation; Performance evaluation

1. Introduction

In mobile ad hoc networks, a (source) node that wants to communicate with another (destination) node might not be within communication range but could communicate if other hosts lying "in between" them are willing to forward packets for them. The simplest way to establish communication within such networks is to perform flooding. To avoid flooding, several protocols have been proposed. One approach

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* Corresponding author. Address: Research Academic Computer Technology Institute (RACTI), Research Unit 1, 1 N.Kazantzaki Str., University of Patras Campus, Rion 26500, Greece. Tel.: +30 2610 960333; fax: +30 2610 960490.
E-mail address: ichatz@cti.gr (I. Chatzigiannakis).

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tries to construct and dynamically update paths between the mobile hosts. Another approach, instead, avoids path creation and maintenance by taking advantage of the hosts' movements and accidental meetings in the network area.

The algorithms that follow *the path construction and maintenance approach* construct a connectivity related dynamic data structure (e.g., a dynamic graph) representing the topology of the network by a series of messages. Using such a data structure, messages can be transmitted over a limited number of intermediate hosts that interconnect the source with the destination, forming routing paths or *routes*. These routing protocols can be further classified into reactive (or on-demand protocols [2]) and proactive (or table-driven protocols [28]). Proactive protocols are those that always maintain a route to every possible destination, while reactive protocols are those that discover and maintain a route to a destination only when one is required.

The protocols that follow *the "Support" approach* are designed for the highly dynamic movement of mobile users by taking advantage of the mobile hosts' natural movement and exchanging information whenever mobile hosts meet incidentally [11]. This approach proposes the idea of forcing a small subset of the deployed hosts to move as per the needs of the protocol; this subset is called the "support" of the network. Assuming the availability of such hosts, the designer can use them suitably *by specifying their motion* during certain times as the algorithm dictates.

Recent studies [7] indicate that each class of protocol is best suited for certain network and user profiles. In particular, the protocols that follow the path construction approach behave well under low mobility rates, while their performance degrades in the case of highly mobile users. In the work of Busch et al. [4], it is shown that in the presence of user mobility, a path construction algorithm may require $\Omega(n^2)$ message exchanges to stabilize. Furthermore, the analysis provided in [17,23] indicates that in the path construction approach, capacity is also a limiting factor; throughput available to each node approaches zero as the number of nodes increases. On the other hand, the support approach always succeeds in delivering messages [11], and in fact benefits from high mobility rates [7]. However, the performance of the network is very low in terms of message delay, when compared to that achieved by path construction algorithms (for messages that are finally delivered) [9].

To improve the performance of path construction algorithms as the number of nodes and/or the network area increases, several cluster-based protocols have been proposed, some hierarchical [20] and some flat [12]. [27,18] attempt to combine proactive and reactive approaches in the zone routing protocol that limits the proactive procedure to the node's local neighborhood. Recently, Chatzigiannakis et al. [9] attempt to design new routing protocols that achieve good results in ad hoc networks consisting of hosts with mixed mobility rates. The basic idea is to synthesize the two different approaches in such a way that the new routing protocols will benefit from the very high delivery rates of the support approach, while delivering the messages with only short delays as done by the protocols following the path construction approach.

In this work, we continue this line of research by proposing a metric, named *stability*, which is used for characterizing the relative mobility of the nodes. The metric uses the notion of associativity [31], which is the time (in beacons) that nodes are associated (i.e., they retain a connection). According to its stability, every node is classified to a *mobility class*. Based on these mobility classes, we design a novel protocol framework that operates on top of the network layer and, for any pair of origin and destination nodes, determines the routing technique (among those available to the nodes) that best corresponds to their mobility properties.

In contrast to [9], we take special care to limit any changes made to the software agents that implement the routing protocols, avoiding re-designing and re-implementing the original protocol. This design decision allows us to integrate with relatively minimal effort the large variety of routing protocols available in literature about mobile ad hoc networks (e.g., we used the protocols available in *ns-2 without making any significant changes*). Our detailed performance evaluation (via software simulations) demonstrates the advantages of employing this mobility-sensitive approach.

2. Our model

A mobile ad hoc network consists of geographically dispersed mobile nodes that can exchange messages with other nodes that are within a given range (the transmission range). Two nodes that are within each other's transmission range are called *neighboring* nodes, and a *neighborhood* is any set of nodes