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Scalable and efficient dual-region based mobility management for ad hoc networks

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ABSTRACT

In this paper, we propose and analyze the design notion of dual-region mobility management (DrMoM) for achieving scalable, efficient location management of mobile nodes in ad hoc networks. The basic idea is to employ local regions to complement existing home region based location service schemes that assign a home region through hashing to a mobile node and have mobile nodes in both the home and local regions serve as location servers for that node. The most salient feature of DrMoM is that the optimal home region size and local region size can be dynamically determined *per mobile user* based on mobility and service characteristics of individual mobile nodes to minimize the overall network cost incurred by location management and data packet delivery. Moreover, DrMoM is completely distributed. Each node determines its optimal home region size and local region size autonomously. A performance analysis is performed to demonstrate the benefit of DrMoM over existing region-based location management schemes.

1. Introduction

A mobile ad hoc network (MANET) is a self-configuring network, in which mobile nodes form and maintain a dynamic network topology without a fixed infrastructure. In this paper, we will use the terms location management and mobility management interchangeably as there is no fixed infrastructure in MANETs for handoff management and the central issue for mobility management is location management. While location management research is well developed for wireless mesh networks [1], cellular networks [2–5], and mobile IP networks [6], scalable location management for MANETs is an open issue [7].

In this paper, we propose and analyze a scalable, efficient mobility management scheme for MANETs called **D**ual-**r**egion **M**obility **M**anagement (DrMoM) based on the idea of employing local regions to complement existing home region based location service schemes in MANETs that assign home regions to mobile nodes and have mobile nodes in both the home and local regions of a mobile node serve as location servers for that node. Relative to existing work utilizing home region based location service [8–12] and local region based location service [7,13–18], our contribution is to dynamically determine the optimal home region size and local region size for *each* mobile node based on the mobile node's runtime mobility and service characteristics to minimize network cost.

DrMoM is based on the design notion of integrated mobility and service management for network cost minimization [19]. Specifically, unlike existing location services that define the home region size statically at design time, DrMoM dynamically determines the optimal home region size and local region size (defined by their respective radii denoted by R_h and R_l), which together minimize the overall network cost incurred by location management and data packet delivery. Moreover, DrMoM is completely

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distributed. Each node determines its optimal home region size R_h and local region size R_l autonomously. We develop a performance model for deriving the optimal values of the two key design parameters R_h and R_l and for calculating the overall network cost incurred by DrMoM, given system parameters characterizing the mobility and service characteristics of mobile nodes. To demonstrate the benefit of our dual-region location management scheme, we compare location-based routing based on DrMoM against a well-known scheme called SLURP [9] based on static home regions as well as a region-based location management scheme called RUDLS [16] which claims to outperform contemporary region-based location management schemes. We show that DrMoM outperforms both SLURP and RUDLS in terms of the overall network cost incurred.

The paper is organized as follows. Section 2 surveys related works and contrasts DrMoM with existing approaches for mobility management in MANETs. Section 3 describes our scalable design for DrMoM. Section 4 presents a performance model for analytically evaluating the performance of DrMoM. Section 5 performs a comprehensive performance evaluation, focusing on the effect of various parameters on the performance of DrMoM, as well as a comparative performance analysis of DrMoM against SLURP and RUDLS. Section 6 performs simulation validation of the analytical results and tests the sensitivity of the results with respect to node distribution and node mobility patterns. Section 7 discusses the applicability. Finally Section 8 summarizes the paper and outlines future research areas.

2. Related work

In contrast to other types of wireless networks such as cellular networks, IP networks, and wireless mesh networks, a MANET lacks pre-existing network infrastructures. Therefore, mobility management schemes proposed for other types of networks are generally not appropriate for MANETs.

A recent study [20] reveals that hierarchical region-based location management [7,13–16] is the most promising location management scheme for achieving scalability and efficiency.

A prevalent region-based location service in MANETs is *hashing-based* with which each mobile node is assigned a *home region* through hashing [8–12]. The nodes in the home region serve as *location servers* for that mobile node. A mobile node sends location updates to its location servers when it moves. To locate a destination node, a source node sends a location query to the destination node's home region location servers. Although a hashing-based location service is highly scalable, it has a major drawback: a source node has to contact the location servers of the destination node regardless of how close it is away from the destination node. If the two nodes are close to each other, contacting the location servers which may be far away geographically incurs unnecessary overhead. One way to solve this problem is to have a mobile node periodically exchange up-to-date location information with neighboring nodes in a *local region* [17,18]. If some node in the local region of the source node knows the location of the destination node, the source node can locate the destination node utilizing only local location information from the neighboring nodes, without having to query the destination node's home region. It is also possible that the source node is within the local region of the destination node and therefore knows where the destination node is located using only local location information it keeps.

Among the above protocols cited, SLURP [9] and RUDLS [16] are introduced in more detail below as they are selected as baseline schemes against which DrMoM is compared in this paper. The reason we select these two schemes is that SLURP represents the most original work in region-based location management and RUDLS is a very recent location management protocol proposed which claims to outperform existing region-based location management protocols.

SLURP [9] handles location management using a scalable location service based on statically partitioned and assigned home regions. When a mobile node moves, it updates its location with the location servers in its home region by sending location update messages. To locate a destination mobile node D, the node's home region is queried to locate the current region in which D resides. Geographical routing is used to forward a data packet sent to D towards the center of the current region of D. When the data packet arrives at the first node within the current region, Dynamic Source Routing (DSR) is employed to deliver the data packet to D within the region. SLURP defines the region size statically when the coverage area of a MANET is partitioned into grids, each of which corresponds to a region. There are two major differences between DrMoM and SLURP:

- Although both DrMoM and SLURP assign each mobile node to a static home region center through hashing, the home region size in SLURP is fixed while the home region size in DrMoM varies dynamically in order to minimize the location query and update cost.
- SLURP does not use local regions for location query. As a result, SLURP incurs a high query cost because it always queries home region location servers for the location of the mobile user. DrMoM uses local regions for location query to save location query location overhead because it will query local region location servers first before querying the home region location servers for the location of the mobile node. Moreover, DrMoM assigns each mobile node to a local region which can change in size and location, depending on the mobility and service characteristics of the mobile node in order to minimize the location query cost.

RUDLS [16] on the other hand is a region-based hierarchical location management scheme consisting of level 1 and level 2 location servers. Each level 1 location server keeps track of the locations of mobile users in its region each covering 9 grids. When a mobile user moves from one grid to another grid within the same region, only the location database of the level 1 location server is updated. On the other hand, each level 2 location server covers a number of level 1 location servers (e.g., 9×9 grids). When a mobile user moves from one level 1 region to another