Chapter 1

Inter-Domain Routing in Mobile Ad Hoc Networks: Challenges and New Directions

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ABSTRACT

Because of the increasing number of diverse routing protocols proposed to deal with the network dynamics in mobile ad hoc networks (MANETs), the heterogeneity of MANETs has increased dramatically. While many of these extant proposals only concern enhancing routing in a single domain, little attention has been given to the interoperations among heterogeneous MANETs. Moreover, the existing inter-domain routing protocols (i.e., BGP) that have been designed for the Internet cannot cope with the new challenges derived from the MANETs, such as (1) the rapid dynamic changes of network topology due to mobility, and (2) the larger diversity in intra-domain ad hoc routing protocols. In this chapter, the authors address some of the major challenges and identify new directions to the development of seamless inter-domain routing for enabling end-to-end communications over heterogeneous MANET domains.

INTRODUCTION

The value of a network lies in the ability of interconnecting its systems. Often a network is used to interconnect multiple heterogeneous sub-networks, which may be controlled by different administrative domains, adapted to different missions, or optimized for different environments. The internetwork consisting of heterogeneous sub-networks of different administrative domains is fundamentally different from the interconnection in a homogeneous network, where the later is usually controlled to optimize a

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certain global objective, while the former does not always optimize any global objective. In the Internet, the Border Gateway Protocol (BGP) (Rekhter & T. Li, 1995) provides a mechanism for interconnecting heterogeneous administrative domains of different intra-domain routing protocols, mechanisms, and policies. The mechanism to interconnect heterogeneous administrative domains is known as *inter-domain routing*, and the domains are called autonomous systems (AS) in the Internet.

*Mobile ad hoc networks* (MANETs) also require effective interconnections of multiple domains in dynamic uncertain environments, such as coalition military operations, emergency operations for disaster recovery, and communication in vehicular ad hoc networks (VANETs). In these situations, multiple organizations in different administrative domains often need to communicate and cooperate with each other. For example, in a disaster recovery scenario, the local police force may need to coordinate with fire fighters, military forces, and medical crews by sharing information and communicating with each other regardless of particular networking technologies that are used by different groups. In another example, a group of cars on the road may instantly form a communication network for sharing traffic information, preventing accidents, and sharing data. In practice, it is unlikely that these different MANETs support the same network technologies, routing protocols and routing policies. These applications call for the development of inter-domain routing over heterogeneous MANET domains.

Although inter-domain routing is a well-developed technology in the Internet, the inter-domain routing problem in MANETs is fundamentally different from that of the Internet. In MANETs, the network connectivity changes dynamically due to user mobility, and these changes can happen in the order of minutes or even seconds. On the other hand, in BGP, these network dynamics usually happen in the order of days (Oliveira & Zhang & Zhang, 2007), and the static gateway assignment in BGP cannot adapt to the frequent connectivity changes in the MANET environments. In addition, there are no clear boundaries among network domains, and multiple domains can overlap in the same geographic region. Moreover, different routing protocols for MANETs, such as reactive routing protocols (Perkins & Royer & Das, 2003; Johnson & Hu & Maltz, 2007), proactive routing protocols (Clausen & Jacquet, 2003; Perkins & Bhagwat, 1994), geo-routing protocols (Basagni & Chlamtac & Syrotiuk & Woodward, 1998; Karp & Kung, 2000), etc., may be employed by different domains. A well-designed inter-domain routing framework should be able to handle the interaction among different intra-domain MANET routing protocols.

In this chapter, we study some of the major research challenges of providing inter-domain routing over MANETs, and identify new directions and ideas for a solution. In particular, we discuss the related issues of inter-domain routing over MANETs as follows:

i) *Function of BGP*: We clarify the function of BGP as an interoperation mechanism, rather than a unified routing protocol over heterogeneous routing protocols. This motivates our design of an inter-domain routing mechanism over MANETs.

ii) *Issues of BGP over MANETs*: We discuss some of issues when we directly apply BGP on MANETs, and the source of the problems.

iii) *Issues of Existing Ad hoc Routing Mechanisms*: There are a number of ad hoc routing mechanisms akin to integrating heterogeneous routing protocols. We compare these with the problem of inter-domain routing, and identify the differences.

iv) *Issues of Mobile Ad hoc Inter-domain Routing Protocols*: We present some general challenging issues in various aspects of protocol design and related implementations.