Computer Networks 54 (2010) 558–572

Contents lists available at ScienceDirect

Computer Networks

journal homepage: www.elsevier.com/locate/comnet

A mobility management scheme for wireless mesh networks based on a hybrid routing protocol ☆

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ARTICLE INFO

Article history:
Available online 10 September 2009

Keywords:
Mobility management
Wireless mesh networks
Handoff
Seamless roaming
Real-time application

ABSTRACT

Recent advances in wireless mesh networks (WMNs) have overcome the drawbacks of traditional wired networks and wireless ad hoc networks. WMNs will play a leading role in the next generation of networks, and the question of how to provide seamless mobility management for WMNs is the driving force behind the research. The inherent characteristics of WMNs, such as relatively static backbones and highly mobile clients, require new mobility management solutions to be designed and implemented.

In this paper, a hybrid routing protocol for forwarding packets is proposed: this involves both link layer routing and network layer routing. Based on the hybrid routing protocol, a mobility management scheme for WMNs is presented. Both intra-domain and inter-domain mobility management have been designed to support seamless roaming in WiFi-based WMNs. During intra-domain handoff, gratuitous ARP messages are used to provide new routing information, thus avoiding re-routing and location update. For inter-domain handoff, redundant tunnels are removed in order to minimize forwarding latency. Comprehensive simulation results illustrate that our scheme has low packet latency, low packet loss ratio and short handoff latency. As a result, real-time applications over 802.11 WMNs such as VoIP can be supported.

1. Introduction

Wireless mesh networks (WMNs) are an innovative network technology that has emerged in recent years. Compared to original wireless networks, WMNs have many advantages: dynamic self-organization, self-configuration, high scalability, low cost, and easy maintenance. These characteristics allow WMNs to play an important role in the next generation of wireless networks.

A comprehensive survey of WMNs is given in [2]. In summary, two types of nodes are involved in a WMN: mesh routers and mesh clients. Mesh routers are responsible for routing and maintaining the network topology. Mesh routers, also called access routers (ARs), provide a connection to the network for mesh clients. Certain special mesh routers also perform gateway functions. Mesh clients include mobile devices, such as laptops, PDAs and sensors. An example of a wireless mesh network is shown in Fig. 1.

Generally, there are three types of WMN architecture: infrastructure/backbone WMNs, client WMNs, and hybrid WMNs [2]. In infrastructure/backbone WMNs, mesh routers construct a backbone, and mesh clients can connect to each other by communicating with the mesh routers. Some mesh routers work as gateways that provide a connection to the Internet. The mobility of mesh clients is much greater than that of mesh routers; thus, a backbone composed of mesh routers is almost static. In client WMNs, there are no mesh routers in the network, and mesh clients provide routing, bridging and gateway functions by themselves. This architecture is similar to that of a conventional wireless ad hoc network. In hybrid WMNs, mesh clients

☆ This work is partially supported by NSERC, Canada Research Chairs Program, The Ontario Research Fund (ORF), ORNEC, The Early Ontario Researcher Award, The Ontario Centres of Excellence (OCE), and MRI Ontario Funds.

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doi:10.1016/j.comnet.2009.08.020

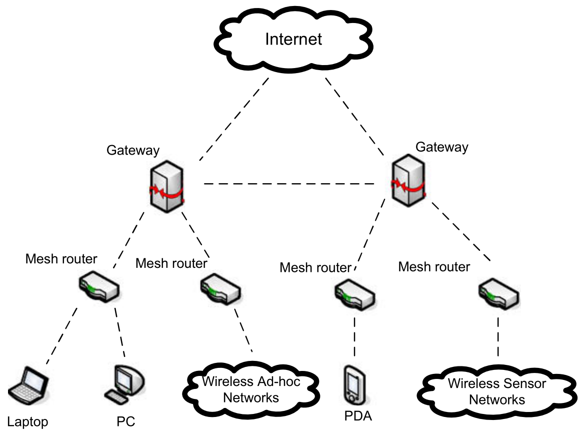

Fig. 1. An example of a wireless mesh network.

can communicate through both mesh routers and mesh clients. Infrastructure/backbone WMNs are the most popular type of architecture, and all of the WMNs discussed in this paper will be of this type.

The performance of WMNs is affected significantly by how the network manages the movements of mesh clients. Therefore, mobility management is one of the most important problems of WMNs. Although many existing mobility management solutions for conventional wireless networks can be applied to mesh networks, new mobility management solutions should be designed and implemented specifically for WMNs, considering their differences.

There are two kinds of roaming: *inter-domain roaming*, which refers to movement across different domains, and *intra-domain roaming*, which means movement among different access routers in the same domain. Accordingly, mobility management requires both inter-domain and intra-domain mobility management. This paper proposes an innovative scheme to provide both intra-domain and inter-domain mobility management within WMNs. The proposed solution uses a hybrid routing protocol, which integrates the network layer routing and link layer routing to forward packets and achieves easier handoff. For intra-domain handoff, our scheme avoids location update in the centralized location server, while also decreasing the time for re-routing after the handoff. In addition, our scheme can provide inter-domain handoff with low overhead by minimizing redundant tunnels. It provides seamless handoff with high scalability for real-time applications such as VoIP.

The remainder of this paper is organized as follows. Section 2 presents typical mobility management solutions for WMNs. The hybrid routing protocol is presented in Section 3, and our mobility management scheme is proposed in Section 4. Section 5 describes the simulation set-up and discusses the performance results. Finally, Section 6 summarizes our work and concludes this paper.

2. Related work

An extensive survey of mobility management in wireless networks is given in [1,3]. Mobility management includes location management and handoff management. With regard to location management, a mobile node updates its location information in a location database, and the system uses this location information to determine the mobile node's current position. Handoff management is responsible for establishing a new link when a mobile node changes its access router. Handoff is also referred to as handover. The access routers involved in the handoff may belong to the same domain (intra-domain handoff) or to two different domains (inter-domain handoff). Although many mobility management solutions over conventional wireless networks could be migrated to mesh networks, new mobility management solutions should be designed and implemented specifically for WMNs. In this section, some mobility management schemes that can be adopted in WMNs are reviewed.

2.1. Intra-domain mobility management

For conventional wireless networks, a variety of intra-domain solutions to reduce handoff latency have been proposed, such as HMIP [26], IDMP [19], MIP-RR [12], HAWAII [24], Cellular IP [8], and more [7]. However, these solutions are not suitable for WMNs. In this subsection, some intra-domain mobility management schemes that support seamless real-time applications for WMNs are reviewed. They can be classified within three groups: tunnel-based, routing-based, and multicast-based. Tunnel-based solutions always adopt a hierarchical architecture. The high-level agent encapsulates the low-level agent's address in an extra IP header, and forwards packets to the client's low-level agent first. The low-level agent, in turn, decapsulates the packets and sends them to the client. Routing-based solutions update routing tables in order to re-establish the connection after the handoff. The new multicast-based solution assigns the ARs of the same mesh client to two multicast groups; the multicast is then applied to support seamless mobility management.

2.1.1. Tunnel-based solutions

In [30], Wang et al. introduce Ant, a network-based intra-domain fast handoff scheme. When a mesh client begins handoff, the new access router sends a location update message to the location server. The former AR sets up a temporary tunnel with the new AR, and forwards the buffered packets. This former AR then informs the correspondent node's AR to set up a data path with the new AR for the mesh client. To decrease the delay that comes with establishing a temporary tunnel, all tunnels between the neighboring ARs are set up in advance. Updating the location information immediately in the handoff process is the main cost, while pre-establishing all bi-directional tunnels introduces other costs.

Huang et al. propose the hierarchically structured Mesh Mobility Management (M^3) in [13]. Three types of mesh routers are employed: gateways, superior routers, and access routers. When a handoff is activated, the prior AR adds a temporary routing entry to forward the packets to the new AR; then, the location information of the mesh client is updated at the superior router. The location information of the mesh client at the gateway is updated after a certain