Computer Networks 60 (2014) 46–59

Contents lists available at ScienceDirect

Computer Networks

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

Studying the integration of distributed and dynamic schemes in the mobility management

Tiago Condeixa *, Susana Sargento

Instituto de Telecomunicações, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal

ARTICLE INFO

Article history:
Received 17 April 2013
Received in revised form 17 October 2013
Accepted 16 December 2013
Available online 23 December 2013

Keywords:
Distributed mobility management
Decoupling of mobility functionalities
Handover management
Data management

ABSTRACT

The raise of demanding multimedia content and the increasing number of mobile devices originated a rapid growth of mobile Internet traffic, which is expected to continue increasing with an exponential behavior in the next years. In order to cope with this rapid increase, service providers are already developing new strategies, such as the selective traffic offloading through the wireless local area networks. Moreover, a new trend is to flatten the network architectures for mobile Internet, and hence, IP mobility management protocols need to be adapted for such evolution. However, current mobility management models rely on a centralized entity, called mobility anchor, which routes the whole data traffic and manages all bindings of its users. With the increase of the mobile Internet traffic and the number of users' devices, such centralized models encounter several barriers for scalability, security and performance, such as a single point of failure, longer traffic delays and higher signaling loads. Hence, we study the distribution of mobility management based on the decoupling of functionalities into: handover management, location management and data management. We evaluate distinct approaches to distribute the mobility functionalities closer to the end-user. We demonstrate, through analytical and simulation results, that distributed mobility management approaches improve the data delivery when compared with current centralized models.

1. Introduction

With the evolution of the society towards a mobile environment, the importance of the mobility management in the network has been increased. Mobility management is responsible to maintain the ongoing communications while the user roams among distinct networks, and to provide reachability of the mobile device in new communications. While moving and attaching to heterogeneous networks, the user desires to maintain the quality of the required services. Users are requiring more demanding mobile multimedia services everywhere and anytime, which consume a great part of available network resources and poses an extra stress in the mobility management. Operators statistics show that the usage of mobile data traffic has doubled during the last year, and this is expected to continue in this decade [1,2], resulting in an explosion in mobile Internet traffic. Thus, service providers are already developing new strategies, such as selective traffic offloading through wireless local area networks, in order to deal with traffic that exceeds the available capacity. However, the mobility support needs also to be guaranteed to the mobile device when the user communicates through different wireless local area networks.

Moreover, users have been playing a more active role in communications, controlling connectivity and content in cooperative environments. They develop spontaneous wireless networks, simply based on cooperation and access sharing on particular communities. Such user-centric environments raise new challenges to the traditional and tightly controlled mobility management schemes. Moreover, a more flattened network architecture for mobile

* Corresponding author. Tel.: +351 234377900.
E-mail addresses: tscondeixa@ua.pt (T. Condeixa), susana@ua.pt (S. Sargento).

1389-1286/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.bjp.2013.12.013

Internet is anticipated to meet the needs of increasing traffic from the mobile users and to reduce costs in the core network. To accomplish these trends, there has been a paradigm shift in users traffic behavior with the increase of communication between devices in the same geographical area due to the migration of content servers closer to the end-user, such as Content Delivery Networks. However, current mobility management models have been developed for centralized networks, such as Mobile IPv6 (MIPv6) [3] and Proxy MIPv6 (PMIPv6) [4], which brings several limitations when applied to recent trends [5,6]. In current centralized models there is a central and static entity, called Mobility Anchor (MA), which is in charge of the mobility management functionalities of a large number of Mobile Nodes (MNs), regarding data, context information and signaling. All data traffic traverses the centralized MA, such as the Home Agent (HA) in MIPv6 and the Local Mobility Anchor (LMA) in PMIPv6, and all bindings are managed at this MA as well. As the number of MNs increases and the mobile data traffic explodes, such centralized architectures may encounter several problems. First, the routing is performed via the centralized mobility anchor, which is often longer. This increases the operational cost of the network, the consumption of core network resources, and the end-to-end delay of applications. Moreover, the centralized mobility anchor manages the mobility context and mobility routes of all MNs, which may increase the mobility signaling and handover latency. The adoption of current centralized models forces a static mobility support, independently of the mobility requirement in the MN. Current mobility models always provide mobility support to MNs' sessions while the MN is connected to the network, even for a session initiated and terminated in the same network. Furthermore, a centralized point is commonly more vulnerable to failure or attack.

It is therefore of major importance to re-think mobility management from an out-of-the-box perspective, and in particular, to consider the distribution of mobility management and how it can assist the individual user and the provider in terms of mobility coupled to the day-to-day living of Internet users. Accordingly, the IETF charted recently the Distributed Mobility Management (DMM) working group [7], where various efforts from both industry and academia are being performed on specifying DMM schemes.

In this article we start by studying the impact of distributing the mobility management functionalities. Our aim is to assess the main guidelines for a distributed mobility management architecture. Our first approach, presented in [8], compares different distributed mobility management schemes based on the decoupling of the mobility functionalities into data management, handover management and location management. We extend the presented study on improving the description of the evaluated approaches with examples, and on proposing an analytical model to improve the evaluation of the approaches with data and signaling costs. Moreover, we perform a more exhaustive evaluation through simulations with different scenarios, comparing both analytical and simulation results.

The article is organized as follows. The related work is briefly presented in Section 2. Section 3 explains the decoupling of mobility management functionalities, while Section 4 describes the distributed mobility management approaches. Section 5 describes analytical models to evaluate the distributed approaches and the centralized one. Section 6 evaluates them through the analytical models and simulation. Finally, Section 7 concludes the paper and introduces the future work.

2. Related work

The currently adopted IPv6 host-based mobility protocol, called MIPv6 [3], was envisioned to provide global IPv6 mobility to the user's device without any support from the network infrastructure. In MIPv6, the data packets are always routed via the HA, which encapsulates them to the current IPv6 address of the MN, in its current location. The HA maintains a binding between the well-known IP address of the MN and the IP address obtained from the current IP network.

The currently adopted IPv6 network-based mobility protocol, called PMIPv6 [4], was developed with a different idea than MIPv6: the network is responsible to provide IP mobility support transparent to the user. The user's mobile device does not require any mobility support, since the Mobile Access Gateway (MAG) implements the same functionalities as the MN in MIPv6. The mobility functionalities are moved from the MN to MAG, which are usually implemented in the Access Routers (ARs). The MAG is responsible to detect the MN handover and signal the centralized mobility management entity, called LMA, with the new network of the MN. The tunnels are established between the LMA and MAGs, being the MN agnostic to the movement.

Hierarchical Mobile IPv6 (HMIPv6) [9] is an attempt to optimize the micro-mobility of MIPv6 through the introduction of a hierarchical level for the management of the bindings and traffic forwarding. It introduces a new entity placed closer to the user's mobile device, called Mobility Anchor Point (MAP), that creates an IP abstraction level in its coverage domain with two IPv6 addresses. The MAP maintains the updated binding of the MN, forwarding data packets to MN while it remains in its coverage domain, reducing signaling cost and handover latency for micro-mobility. The HA and MN remains with the same mobility management functionalities.

There is an increasing interest in the topic of distributed and dynamic mobility management, specially in the problem statement and definition of guidelines for a base distributed mobility management. This increasing research on the distribution of mobility management led to the creation of the IETF Distributed Mobility Management (DMM) working group [7], where several authors are contributing to provide novel work on the topic. Following the idea of splitting the mobility management, the authors in [10,5,6] analyze the issues of the centralized approaches when integrated in flatten network architectures. They highlight the main problems of current mobility management approaches, and propose the initial requirements for a distributed and dynamic mobility management.