Computer Communications 35 (2012) 2055–2068

Contents lists available at SciVerse ScienceDirect

Computer Communications

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

Review

A review on mobility management and vertical handover solutions over heterogeneous wireless networks

Mariem Zekri [a,*], Badii Jouaber [a,b], Djamal Zeghlache [a,b]

[a] INSTITUT Mines-Telecom – Telecom SudParis, Evry, France
[b] CNRS, UMR SAMOVAR, France

ARTICLE INFO

Article history:
Received 17 September 2011
Received in revised form 30 May 2012
Accepted 20 July 2012
Available online 4 August 2012

Keywords:
Heterogeneous wireless networks
Vertical handover
Multihoming
Vertical handover decision algorithm
Mobility management protocols

ABSTRACT

In the nowadays heterogeneous wireless environment, a plethora of access networks have to be interconnected in an optimal manner to meet the *always best connected* paradigm. This paper highlights some of the main technical challenges in heterogeneous wireless networks underlying seamless vertical handover making as a fundamental feature to all future networking endeavors. It provides a survey on the vertical mobility management process and mainly focuses on decision making mechanisms. After presenting the related standards, the main vertical handover approaches in the literature are analyzed and compared. The paper also points out the importance of multihoming in a such heterogeneous environment and provides an overview of the most known supporting mobility protocols. Finally, the main research trends and challenges are discussed.

1. Introduction

Wireless networks, applications and devices have been undergoing a breathtaking evolution over the last decade. Because of the complexity of the wireless environment, no single technology can be efficient to provide mobile users with high data rate and good Quality of Service (QoS) over all situations. Indeed, to meet the increasing demand of mobile users, next generation wireless systems are relaying on cooperative heterogeneous wireless technologies allowing the users to be connected at any time and anywhere.

Heterogeneous wireless networks may incorporate different radio access technologies including GSM, GPRS, HSPA, UMTS, WiFi, WiMax and even LTE which is becoming the new 4G standard for wireless communication. The main promise of the interworking of these heterogeneous networks is to provide high performances by achieving high data rate and supporting video telephony, streaming and multicasting with high QoS levels.

Several issues related to the heterogeneity of a such wireless environment should be addressed, namely, mobility and multihoming management, resource allocation, security, high QoS support and seamless handover.

Handover is the action of moving a Mobile Terminal (MT) from one wireless cell/technology to another. Traditionally, the handover process has been studied between access points (AP) or networks using the same radio technology. This process, denoted by the Horizontal Handover (HHO), is mainly based on the received signal strength (RSS) levels. With the emergence of a multitude of overlapping wireless networks, MTs have to switch their connections between different access technologies with different capabilities and characteristics. In this case, the handover process is more complex and is denoted by Vertical Handover (VHO). Fig. 1 illustrates both horizontal and vertical handovers.

In this paper, we mainly focus on the vertical handover management. It is a central issue as it is intended to ensure seamless roaming of users from one wireless access technology to another. It requires mobility decision mechanisms and mobility protocols.

Mobility decisions are based on vertical handover decision criteria and algorithms aiming to ensure automated, quick and right decisions for network selection.

Mobility protocols tackle addressing and routing procedures including the support of multihoming allowing users to be simultaneously connected to multiple wireless networks.

Mobility decisions and protocols are included in the VHO management process that consists in three steps, namely, system discovery, handover decision, and handover execution. During the system discovery phase, the information required to identify the need for vertical handover is collected. Both Mobile Terminals (MT) and networks participate to gather these data. This information is then used during the handover decision phase to evaluate the available networks and determine the most suitable one for each ongoing application. Finally, during the handover execution

* Corresponding author. Tel.: +33 628615551.
E-mail addresses: mariem.zekri@it-sudparis.eu (M. Zekri), badii.jouaber@it-sudparis.eu (B. Jouaber), djamal.zeghlache@it-sudparis.eu (D. Zeghlache).

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http://dx.doi.org/10.1016/j.comcom.2012.07.011

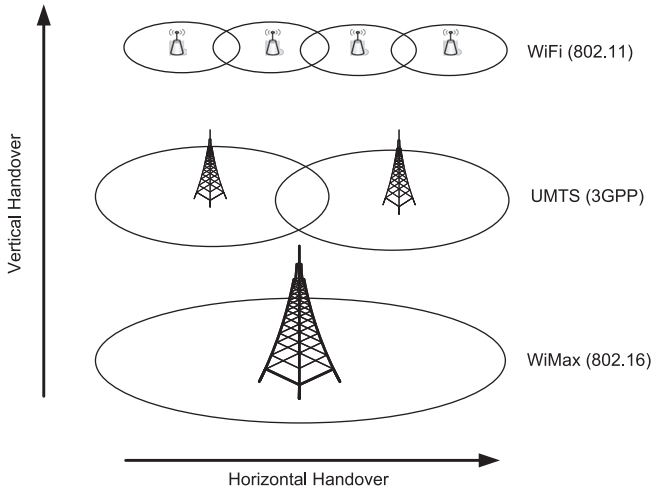

Fig. 1. Illustration of horizontal and vertical handover.

step, a new connection is established and old resources are released. Once the new access network is selected, the communication sessions have to be transferred from the old radio interface to the new one. A new routing path is then established.

In the literature, many vertical handover decision mechanisms and mobility management protocols supporting multihoming have been proposed.

In this paper, we provide a complete overview of the most interesting and recent VHO decision making mechanism and mobility management protocols supporting multihoming. These solutions are then analyzed and discussed.

The remainder of this work is organized as follows. Section 2 presents Standards and Working Groups and their main proposals for vertical mobility support. Section 3 provides an overview on heterogeneous wireless networks interworking including Mobile communication (GSM), Universal Mobile Telecommunication System (UMTS), High Speed Packet Access (HSPA), Wireless Interoperability for Microwave Access (WiMAX), Wireless Fidelity (WiFi), Long Term Evolution (LTE) and Femtocell. Section 4 details the parameters collected during the vertical handover information gathering phase. Section 5 analyzes the different existing strategies and provides a comparative study of these algorithms. Section 6 describes the VHO execution strategies and protocols. Section 7 introduces multihoming and describes some related mobility management protocols. Section 8 provides a subset of heterogeneous wireless networks' applications and trends. Finally, Section 9 concludes the paper.

2. Vertical handover and standardization (3GPP, IEEE, IETF)

To construct efficient vertical mobility solutions, many aspects have been considered within standardization bodies, including convergence, cooperation, interoperability, integration and interworking. Several approaches have been proposed at different layers of the ISO/OSI reference model.

2.1. 3GPP related activities

Regarding heterogeneity, the 3GPP is mainly focusing on the interworking between 3GPP and non 3GPPP networks at different levels. In [1], six different scenarios of 3GPP-WLAN interworking, are given.

- *Scenario 1*: Common billing and customer care.
- *Scenario 2*: 3GPP system-based access control and charging.
- *Scenario 3*: Access to 3GPP system packet-switched services.
- *Scenario 4*: Service continuity.
- *Scenario 5*: Seamless services.
- *Scenario 6*: Access to 3GPP circuit-switched services.

These scenarios deal with systematic increase of network integration, starting from simple 3G/WLAN interworking with common billing and customer care (loose coupling) to letting access to 3GPP system packet-switched services over WLAN (very tight coupling). Fig. 2 summarizes the main characteristics of each scenario. The 3GPP/WLAN system integration framework also deals with other important features such as interworking security aspects and charging management.

2.2. IEEE related activities

Within the IEEE, two working groups are dealing with vertical handover and heterogeneous network cooperation.

2.2.1. IEEE 802.21

The main proposal of this working group [3] is the Media Independent Handover (MIH) standard to support seamless mobility. The group proposes a new MIH Function (MIHF) to be integrated as a new logical entity between layer 2 and upper layers in the protocol stack. The main task of this MIHF is to assist the vertical handover decision making by providing the required information to the mobility management entities. It provides three main services: Media Independent Event Service (MIES), Media Independent Command Service (MICS) and Media Independent Information Service (MIIS). These services are, respectively, responsible of (a) reporting dynamic changes in link conditions and quality, (b) enabling MIH Users to manage and control parameters related to link operation and (c) gathering static information about the characteristics of the current network and other available networks. Fig. 3 illustrates the IEEE 802.21 general reference model.

2.2.2. IEEE P1900

This standard describes architectural building blocks including network and device resource managers and exchanged information between these building blocks. It enables network-device distributed decision making for optimized radio resource management in heterogeneous wireless access networks. Initially, the standard was limited to the architectural and functional definitions [4]. Then it tackled policies [5] and protocols definition associated with interoperability and information exchange over heterogeneous wireless network [6]. The purpose of this standard is to improve the overall capacity and quality of wireless services based on information exchange between networks and Mobile Terminals under the simultaneous coverage of multiple radio access technologies.

2.3. IETF related activities

The main focus of IETF in the context of heterogeneous integration is on the Network Layer (L3) and above. The IETF Working Group "Mobility for IPv4" dealt with system integration in the sense of macro mobility support [7] and mobility for IPv6 [8]. Mobile IP, allows a node to keep using its permanent home address as it moves. It supports transparency above the IP layer, including active TCP connections' preservation and UDP port bindings. The Mobile IP procedure is also referred to as L3 handover. In addition to the basic Mobile IP protocols, the IETF is working on several other drafts dealing with optimization, security, extensions, Authentication, Authorization, Accounting (AAA) support and deployment issues.