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A hybrid (N/M)CHO soft/hard vertical handover technique for heterogeneous wireless networks

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ABSTRACT

In this paper we investigate the potentiality and the benefits of a soft Vertical Handover (VHO) mechanism, compared with the traditional hard approach. More specifically, we present an analytical scheme for seamless service continuity in a heterogeneous network environment, modeled by means of a multi-dimension Markov chain. The call blocking probabilities, as well as the soft and hard vertical handover probabilities, are computed for specific networks (*i.e.*, UMTS and WLAN).

We propose a soft/hard VHO technique working either as (i) a Mobile Controlled Handover, on the basis of a reward and cost model, which consider the data rate and the bandwidth allocation, or (ii) as a simple Network Controlled Handover scheme, by assuming a probabilistic approach as the handover decision metric. Simulation results validate the benefits of the proposed handover algorithm when operating in soft mode, which outperforms the traditional hard approach in terms of network performance and limitation of unwanted and unnecessary handovers. Finally, the effectiveness of the proposed approach is proven with respect to other single and multi-parameter VHO techniques, by extensive simulations.

1. Introduction

Heterogeneous Wireless Networks (HWNs) represent the new scenario of Next Generation Network (NGN) architecture, where different technologies, such as GSM (Global System for Mobile Communications), GPRS (General Packet Radio Service), UMTS (Universal Mobile Telecommunications System), WLAN (Wireless Local Area Network), WiMAX (Worldwide Interoperability for Microwave Access), and LTE (Long Term Evolution), co-exist and offer an overlapped wireless coverage [1].

Currently, wireless mobile networks and devices are becoming increasingly popular to provide user seamless Internet access, anytime and anywhere. This has led to the concept of *nomadic computing*, which involves portable devices (such as smartphones, laptop and handheld computers) providing Internet access to users connecting from their home or office networks. Furthermore, multimedia services requirements encompass not only large bandwidth communications, but also *on-the-move* facilities. NGN communication systems aim at providing seamless mobility support to access heterogeneous wired and wireless networks [2,3].

NGNs are based on the cellular approach where the area is covered by cells that overlap each other. User services available in such scenario are several, such as entertainment, video on demands, and also emergency and safety assistance. In all these cases, connection quality provision between Mobile Terminals (MTs) is the main factor of network performance and represents a challenging issue [4]. In NGN scenarios, high-quality services can be guaranteed through the interoperability and interworking with NGN-compliant networks, by (i) managing heterogeneous

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wireless networks to service continuity support, and (ii) preserving the connectivity to mobile users moving across different radio access technologies with no noticeable performance degradation [4].

The use of reconfigurable devices, equipped with several network interfaces, is an open issue that has the objective of facilitating coordination among major co-existing mobile and wireless access systems. Currently, as no single wireless communication technology can provide a high performance to mobile users, networking in NGNs gives a solution to this limitation.

Seamless service continuity can be guaranteed by the *handover* process, which represents the switching of the connection from a Serving Network (SN) to a Candidate Network (CN), needed when a user moves [1,5]. In NGNs, both intra and inter-technology handovers take place [4]. The first one reflects the traditional *Horizontal Handover* (HHO) process, in which the MT hands-over between two neighboring cells of the same access technology [6]. On the other hand, inter-technology handover, referred as *Vertical Handover* (VHO), occurs when the MT moves between different access technologies, *e.g.* from WLAN to UMTS, and vice versa [7]. Hence, the HHO is a symmetric process because the MT switches from a cell to another one of the same access technology [6], while VHO is asymmetric as the MT moves between different networks.

The benefits of vertical handover mechanisms are well-known in literature, and several surveys have investigated them [5,8–10]: user connectivity is preserved by switching technology, and service quality is improved due to a reduced number of disconnections. However, vertical handovers are typically performed through *hard* mechanisms, where the connectivity between mobile users and the serving network is broken before the connection with a new network is established (namely, "*break-before-make*"). In this vision, the *soft* vertical handover mechanism (namely, "*make-before-break*") represents a viable solution to improve seamless connectivity [5,8,9].

Typically handover procedures fall into two main categories, (i) the Network Controlled Handover (NCHO) and (ii) the Mobile Controlled Handover (MCHO), depending on whether a handover is initiated and controlled by the network or by the MT, respectively [8,11]. In horizontal handover management, MCHO is the most common case, especially for WLAN environments, while NCHO is generally the preferred choice for cellular networks where resource optimization and load management are centralized. To the best of our knowledge no scheme currently exists that is able to use both approaches.

In this paper, we propose a novel VHO algorithm, relaying on both MCHO and NCHO mode and making hard/soft vertical handover decisions. Our approach has been tested in WLAN and UMTS heterogeneous networks, in order to prove the benefits of Soft Vertical Handover (SVHO) as opposed to Hard Vertical Handover (HVHO). In this way, service continuity in NGNs can be assured by a soft network switching, while assuring high network performance as well as low handover occurrences.

The contribution of this paper can be summarized as follows:

1. We propose a mathematical analysis of both hard and soft vertical handover schemes based on a six-dimension (6-D) Markov chain model.
2. We define a *reward* and *cost* model based on the data rate and the bandwidth allocated to the incoming calls. The model can be used by mobile users working in MCHO mode to decide whether perform a hard/soft handover or not.
3. We define a *soft/hard handover decision technique*, which can work by using either the NCHO or the MCHO approach, depending on the decision metric used. Handover decisions made on the basis of hard/soft vertical handover probability are well suitable for NCHO, while a handover decision based on the *gain function* is a viable solution for MCHO.

We first compare network performance by evaluating (i) the handover gain, expressed in terms of user bandwidth, as well as (ii) the handover frequency, in two cases, such as with and without the possibility for the MT to perform a SVHO. Then, we simulate the performance results of the proposed handover scheme, which aims at maximizing the network performance (*i.e.*, throughput and cumulative received bits), and limiting the unnecessary and unwanted vertical handovers. Finally, a comparison to other techniques (*i.e.*, single and multi-parameter based vertical handover algorithms) is carried out, in order to highlight the benefits of our approach. The Markov chain model is exploited in our technique by using both the HVHO/SVHO occurrence probabilities, as well as the gains associated to the execution of a HVHO/SVHO. Acting in both NCHO and MCHO modes, as well as in hard and soft approach, the proposed handover model results as a more efficient technique, with respect to traditional approaches, which perform only hard or soft handover.

The paper is organized as follows. In Section 2 we investigate related works on vertical handover schemes, specifically those techniques exploiting Markov chains. Section 3 describes the system model for an overlay network architecture. The proposed 6-D Markov chain is illustrated in Section 4; both hard and soft vertical handover cases are analyzed by a probabilistic approach and an analytical model. We also describe how a soft and hard vertical handover decision problem can be modeled as a Markov decision process. In Section 5 the benefit and penalty functions are defined, in order to compare hard and soft VHO cases in terms of *bandwidth gain*. The proposed hard/soft vertical handover algorithm is described in Section 6, while in Section 7 we define our simulation overlay heterogeneous network environment, and present the obtained results. As expected, from the comparison between hard and soft mode, we show that system that use soft handover perform better than systems using the hard approach. Finally, conclusions are drawn in Section 8.

2. Related work

In this section we first recall the handover concept and different types of handover decisions. Then, we classify