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ORIGINAL ARTICLE

A comprehensive approach to vertical handoff in heterogeneous wireless networks

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Abstract A multi-criteria vertical handoff system sensitive to various mobile-terminals' mobility parameters including distance and velocity in a heterogeneous wireless network is analytically formulated and validated via simulations. It is targeted to estimate the essential handoff parameters including outage probability, residual capacity, and signal to interference and noise threshold as well as network access cost. In order to avoid the ping–pong effect in handoff, a signal evolution prediction system is formulated and its performance is examined. Moreover, the handoff scheme is triggered using an on line handoff-initiation-time estimation scheme. When initiated, the handoff procedure begins with a network scoring system based on multi-attribute strategy which results in selection of potentially promising network parameters. Simulation results are shown to track well the analytical formulations.
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1. Introduction

For seamless wireless communications, integration of wireless local area network (WLAN) and third generation (3G) cellular networks (CN), should be developed, in order to achieve the targeted next generation wireless networks (NGWN). These wireless access networks (WANs) are combined to provide a ubiquitous environment of wireless access for terminals equipped with multiple network interfaces (see Fig. 1). When mobile terminals (MT) transfer from one network to another, the quality of service (QoS) offered by the network could decrease under certain predefined level. This transfer mechanism is known as vertical handoff (VHO). A great deal of, previous, studies on VHO are based on received signal strength (RSS), in which handoff decisions are made by comparing the received RSS with a preset threshold values (Benmimoune and Kadoch, 2010; Ahmavaara et al., 2006; Lott et al., 2006). Since RSS based VHO is not a QoS aware scheme, it cannot provide better QoS to user to support multimedia services (Han et al., 2009; Nasser et al., 2006; Rouil et al., 2010). However, as the achievable data rate of a MT is a function of received signal to interference and noise ratio (SINR). Therefore, a SINR based VHO is not expected to achieve maximum throughputs and minimum dropping probabilities only, but also, it is expected to provide a unified radio resource management for the heterogeneous wireless networks (Khadivi et al., 2006).

2. Literature survey

Vertical Handover (McNair and Zhu, 2004), is a mechanism in which user maintains connection when switched from one

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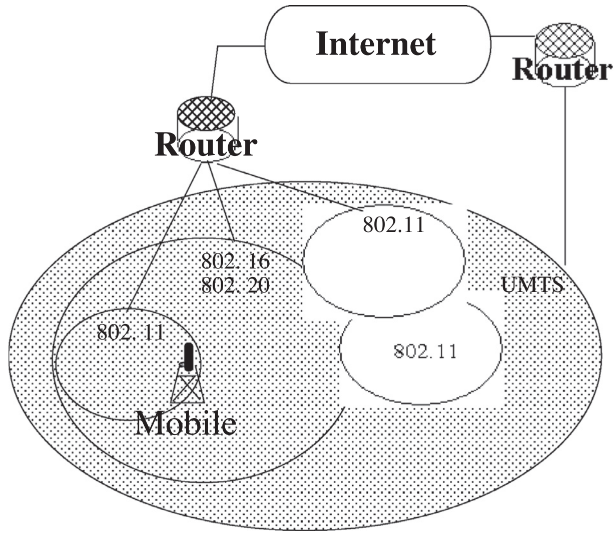

Figure 1 Heterogeneous network overlay.

WAN to another WAN technology (e.g., from WLAN to UMTS and vice versa (see Fig. 1). In IEEE, 2005; Lee et al., 2009, VHO is different from conventional horizontal handover where the MT moves from one base station to another within the same network. In VHO, a session is seamlessly handed over to a new WAN in an interoperable region based on a criterion which evaluates the signal quality. The handover management procedures remain a widely studied issue in the case of heterogeneous network environment. In (Patowary, 2010), MTs should be able to move among these heterogeneous networks in a seamless manner. Various activities of working groups are currently under way such as IEEE 802.21 (I. 802.21, 2006), IETF MIP (Perkins, 2002), or 3GPP standards (3GPP, 2007). IEEE 802.21 supports a mobile-controlled handover (MCHO) scheme and MIP as its mobility management protocol. The details of network selection entity and the specification of handover policies that control handovers are outside the scope of the 802.21.

The objective of a VHO strategy is to guarantee QoS for a variety of applications. In general, the strategy can perform a complex decision criterion that combines large number of (QoS) metrics. The first VHO decision scheme, that considered multiple criteria policies, was proposed by Wang et al. (1999). It introduced a cost function to select the best available WAN based on three policy parameters (bandwidth, power consumption, and cost). Reference (Zhu and McNair, 2006) proposed also a multiservice VHO decision algorithm based on cost function. However, for more efficiency and taking into account more criteria, context-aware decision solution has inspired the authors in Ahmed et al. (2006), Hasswa et al. (2006), Balasubramaniam and Indulska (2004). In Hasswa et al. (2006), Saaty (1990), the authors designed a cross-layer architecture providing context-awareness, smart handover, and mobility control in a W-WAN to WLAN environment. They proposed a VHO decision, with a cost function-based solution, taking into account network characteristics and higher level parameters from transport and application layers. References (Ahmed et al., 2006; Balasubramaniam and Indulska, 2004; Xu et al., 2010) are based on a multiple criteria decision-making algorithm, analytic hierarchy process (AHP). A more advanced multiple criteria decision algorithms are presented in Chan et al. (2001, 2002), wherein the authors applied the concept of fuzzy logic (FL). They employ decision criteria such as user preferences, link quality, cost, or QoS. Upon literature review, mobility prediction schemes in handoff procedure were found to be very critical in the handoff performance. The handoff procedure is typically based on the received RSS from the base station. There exist several models, schemes and algorithms for handoff procedure which is based on the RSS values as proposed in Chiu and Bassiouni (2000), Pollini (1996), Liu et al. (2008), Taniuchi et al. (2009). These published methods are regularly based on hysteresis and threshold methods.

In this paper, we propose a comprehensive methodology for mobility-prediction based VHO scheme. In this respect, the proposed VHO algorithm considers the received SINR as its handoff criterion. Moreover, the handover process is split into number of phases: handover initiation decision which involves the decision to which point of attachment to execute the handover and its timing. Next is the radio link transfer, which is the task of establishing links to the new point of attachment. This phase is based on the estimates of a number of significant QoS metrics that are seen to satisfy the basic requirements of a variety of applications. This paper is organized as follows; Section 3 outlines the SINR based VHO strategy. Section 4, presents a signal prediction model to predict future SINR evolution and enhances the handoff process. In Section 5, a set of QoS parameters necessary for handover is analytically formulated. Section 6, presents a network selection scheme with examples to validate its performance in Wi Fi, Wi MAX and UMTS networks. The research work carried out in this paper is concluded in Section 7.

3. SINR-based vertical handoff strategy

In order to provide guaranteed QoS, the VHO algorithm must be QoS aware. Traditional received signal strength (RSS) based vertical handoff algorithm cannot achieve this (Yang et al., 2007; Xiaohuan et al., 2010). Therefore, we have considered the SINR as handoff criteria similar to that proposed in Xu et al. (2010). A SINR based vertical handoff technique, according to Shannon's capacity formula, states that, the maximum achievable data rate R_{AP} from WLAN (Access point, AP) and, R_{BS} from WCDMA (Base station, BS) can be represented by the receiving SINR: γ_{AP} and $\gamma_{\mathrm{BS},}$.

$$R_{\mathrm{AP}} = W_{\mathrm{AP}} \log_2\left(1 + \frac{\gamma_{AP}}{\Gamma_{\mathrm{AP}}}\right) \tag{1}$$

$$R_{\mathrm{BS}} = W_{\mathrm{BS}} \log_2\left(1 + \frac{\gamma_{\mathrm{BS}}}{\Gamma_{\mathrm{BS}}}\right) \tag{2}$$

where $W_{\mathrm{AP}} = 22\,\mathrm{MHz}$ Krishnamurthy et al. (2006), and $W_{BS} = 5\,\mathrm{MHz}$ Zahran and Liang (2005) are carrier bandwidths of WLAN and WCDMA, $\Gamma_{AP} = 3\,\mathrm{dB}$ (Kim et al., 2010) and $\Gamma_{BS} = 12\,\mathrm{dB}$ (Krishnamurthy et al., 2006) are channel coding loss factors. Since, the data rates of both the networks are different, therefore to compare the SINR of the two networks, the SINR from the source network must be converted into the SINR of the destination. Thus, assuming that the data rates R_{AP}, *and* R_{BS} are equal, the relationship between the SINR of WCDMA and Wi-Fi can be obtained as given below:

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