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SHORT COMMUNICATION

Ad hoc cooperative vertical handover for next-generation heterogeneous networks

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ABSTRACT

We propose a new vertical handover scheme that uses cooperative ad hoc nodes, instead of interworking via backhaul, for the fast handover of mobile nodes (MN) in next-generation heterogeneous network environments. An MN requiring a vertical handover requests an adjacent ad hoc node to undertake some of the handover procedures that require latency, such as authentication and registration procedures, and to process them in place of the requested MN before the handover completion. A vertical handover procedure that uses this takeover technique is described in detail and its performance is analyzed by investigating the success probability of takeover. The results confirm that the proposed vertical handover scheme using takeover reduces both connection disruption time and packet loss compared with conventional vertical handover schemes without takeover.

1. Introduction

Next-generation networks enable ubiquitous communications permitting a mobile node (MN) to communicate with various access technologies or other MNs anytime and anywhere. This pervasive environment characterizes heterogeneous and ad hoc networks. In heterogeneous networks, MNs undergo vertical handovers frequently as they move between different types of network. For this vertical handover, the MN must perform overall connection setup procedures such as layer 2 (L2) attachment, authentication, and L3 registration with a new access network (AN) [1]. This requirement induces extended handover latency and significant packet loss owing to connection disruptions during the vertical handover.

To resolve these vertical handover problems, previous studies have primarily considered interworking solutions between two different ANs [2–7]. Enhanced interworking architectures introducing a new network entity have been discussed [2,3]. Various mobility management solutions using pre-registration or post-registration technique have been proposed [4,5]. Recently, vertical handover decision algorithms that utilize the network intelligence based on self-organizing network (SON) and software-defined radio (SDR) technologies have been investigated [6,7]. Moreover, the interworking architecture and the vertical handover procedure for heterogeneous ANs have been standardized [8,9].

Unlike the previous interworking-based approaches, in this letter, we propose a new vertical handover scheme that uses cooperative ad hoc nodes instead of backhaul signaling between heterogeneous ANs. An MN requiring a vertical handover requests an ad hoc node to undertake some of the handover procedures that require large latency, such as authentication and registration procedures, and to process them in place of the requested MN before the handover completion. We call this concept *takeover*. Because an ad hoc node is used to assist the vertical handover, the proposed scheme has the advantage of not requiring an interworking architecture and signaling between the two ANs involved in the handover. In addition, because the takeover operation reduces the number of signaling procedures that the MN must perform during the vertical handover, the MN can connect with the new AN more quickly achieving a fast and seamless vertical handover. In this letter, details of a vertical handover procedure implementing the takeover concept are presented, and its performance is analyzed by considering MN mobility.

2. Proposed vertical handover scheme

Fig. 1 illustrates the basic operations of the proposed vertical handover scheme using takeover. We do not assume a specific AN to generalize the proposed concept. The old AN (oAN) and the new AN (nAN) can be one of several ANs such as IEEE 802.11 WLAN,

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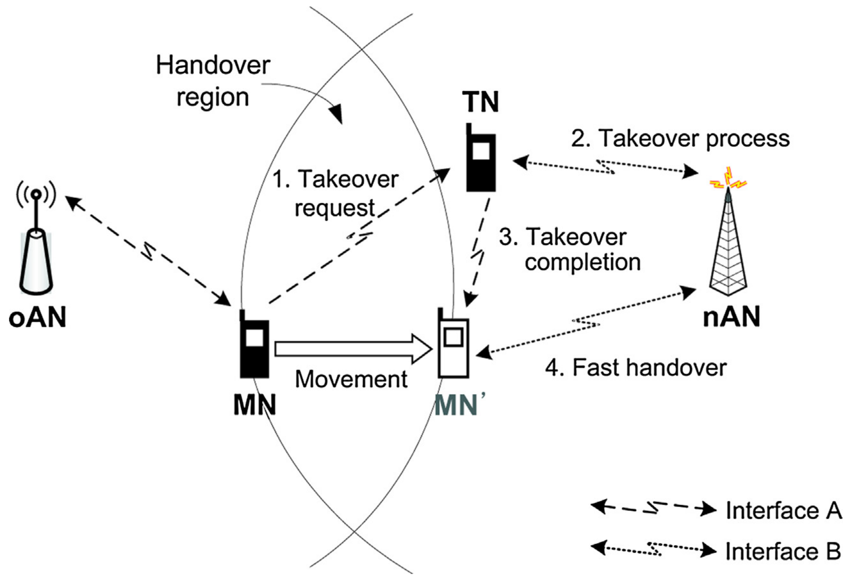

Fig. 1. Basic operations of the proposed vertical handover scheme.

IEEE 802.16e mobile WiMAX, 3GPP UMTS or 4G LTE, subject to that they are different types of AN each other. Thus, vertical handover is required for the MN to move from the oAN to the nAN. As an example scenario, we can consider a WLAN-UMTS interworking. In this case, the oAN and the nAN become 802.11 WLAN and the UMTS, respectively, or vice versa.

Fig. 2 illustrates the detailed signaling procedures of the proposed vertical handover. The overall handover procedures consist of four phases: takeover request, takeover process, takeover completion, and fast handover.

2.1. Takeover request phase

When an MN that moves from an oAN to a nAN enters the handover region,[1] it begins to search for an ad hoc node, called the *takeover node* (TN), that is suitable for the takeover process. This search is initiated by broadcasting a *Ready-to-Takeover* message, which contains the MN's address and the nAN's identity, to find the TN.

To qualify as a TN, an ad hoc node must conform to the following conditions: (1) The ad hoc node must be capable of performing not only ad hoc mode operations with the MN via radio interface A but also infrastructure mode operation with the nAN via radio interface B. For example, if the oAN is the 802.11 WLAN and the nAN is the UMTS network, the TN must be able to communicate with the MN via the 802.11 ad-hoc mode and also with the nAN via the UMTS radio interface. (2) The ad hoc node must simultaneously have acceptable communication quality with both the MN and nAN. Thus, a TN is selected from nodes located in the joint coverage of the MN and nAN, excluding the handover region. We call this area the *takeover region*. (3) The ad hoc node must not be communicating with others; that is, it must be ready to take the MN's request. (4) The ad hoc node must be a secure node to protect the privacy of the MN.[2]

If an ad hoc node qualifies as a TN, it replies with a *Clear-to-Takeover* message that includes its address. When the MN selects a TN from those nodes that replied based on channel quality with the MN itself, it sends a *Takeover Request* message to the TN. This message carries an instruction to perform pre-authentication and pre-registration with the nAN by delivering the identity number and IP address of the MN and information and security key related to the authentication. If the TN receives the *Takeover Request* message, it transmits a *Takeover Reply* message.

2.2. Takeover process phase

If the MN receives the *Takeover Reply* message, it initiates a timer T_w, which is the time that the MN must wait until the takeover process has been completed. Therefore, it is set to a greater value than the time required for takeover processing (T_p). Simultaneously, the TN executes the pre-authentication and pre-registration procedures with the nAN using an acceptable communication link. The pre-authentication follows the authentication method specified in the nAN and the pre-registration follows mobile IP registration procedures [2].

2.3. Takeover completion phase

If the TN accomplishes the takeover process, it sends the MN a *Takeover Completion* message that reports the takeover result and contains related information, such as the MN's new IP address and authentication key, which will be used after the MN attaches to the nAN. Thereafter, the MN replies to the TN with a *Takeover Thank* message. If the timer T_w has expired before the takeover process is completed, the MN interrupts the current takeover process by sending a *Takeover Stop* message to the TN and performs the vertical handover procedures directly with the nAN by itself.

2.4. Fast handover phase

If the takeover procedures are completed successfully, the MN executes the L2 detachment procedures with the oAN and L2 attachment procedures with the nAN. Consequently, the MN can connect with the nAN using only L2 attachment procedures, without new authentication and registration procedures, achieving a fast handover.

[1] The handover region is determined from the comparison of signal strength levels received from two ANs. The handover is triggered based on the received signal strength.

[2] The security issue is excluded from the focus of this study assuming that the TN is selected from secure nodes.