Hierarchical Mobile IPv6 Based Fast Vertical Handover using IEEE 802.21 Media Independent Handover Function

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Abstract

In this paper, the new fast vertical handover scheme is proposed for the hierarchical Mobile IPv6 (HMIPv6) to optimize and enhance the existing fast vertical handover HMIPv6 (FVH-HMIPv6) in heterogeneous wireless access networks. The recently standardized IEEE 802.21 Media Independent Handover Function (MIHF) is adopted for the proposed FVH-HMIPv6. Firstly, the Media Independent Information Service (MIIS) is extended by including new L3 information to provide domain prefixes of heterogeneous neighbouring mobility anchor points (MAPs), which is critical to the handover performance of proposed FVH-FMIPv6 with MIHF. Secondly, the operation procedure for the proposed scheme is described in detail. Finally, the analysis for handover performance is performed for the proposed scheme and the existing scheme, which shows the proposed FVH-HMIPv6 with MIHF can optimize and enhance the handover performance of the existing scheme.

Keywords

Hierarchical MIPv6, Fast Handover MIPv6, IEEE 802.21, Media Independent Handover Function.

1. Introduction

As shown in [1]-[6], the integration of third-generation (3G) network, wireless local area network (WMAN), wireless metropolitan area network (WLAN) will be linked with many technical challenges including IP mobility, vertical handover, security, common authentication, unified accounting/billing, consistent QoS and service provisioning, etc. Among them, the IP mobility for vertical handover in heterogeneous wireless access networks is considered in this paper.

As the L3 handover solution for a vertical handover in heterogeneous access networks, the Mobile IPv6 (MIPv6) [7] can be considered. However, the MIPv6 has the inevitable L3 handover latency caused mainly by the movement detection latency, the care-of address (CoA) configuration latency and the authorizing binding latency. These combined latency could be appreciable for real-time applications and throughput sensitive applications [8]-[10]. Therefore, to resolve these problem of the MIPv6, the hierarchical MIPv6 (HMIPv6) [11] and the fast handover MIPv6 (FMIPv6) [12] have been standardized to support seamless mobility in IETF.

Recently, the fast vertical handover scheme was proposed for the HMIPv6 in heterogeneous wireless access networks [13]. In this existing work, the vertical handover HMIPv6 (VH-HMIPv6) was firstly proposed for IP mobility in heterogeneous wireless access networks. In addition, to reduce vertical handover latency, the fast vertical handover HMIPv6 (FVH-HMIPv6) was also proposed applying the fast handover strategy based on FMIPv6 [12] to the VH-HMIPv6 scheme. It was shown that the FVH-HMIPv6 could reduce remarkably the handover latency of the VH-MIPv6.

Meanwhile, to provide general solutions for the vertical handover in heterogeneous access networks, the IEEE 802.21 standards group has dealt with a new standardization issue called the media independent handover function (MIHF), which enables transparent service continuity while a mobile device switches between heterogeneous access network technologies [14][15]. The major purpose of MIHF is to provide abstracted services to upper layers by means of a unified interface and thus to enhance users' experience of mobile devices by supporting handover between heterogeneous access networks. So, it can be stated that the MIHF is very useful facilities for vertical handovers in heterogeneous wireless access networks.

In this paper, to optimize and enhance the existing one, the new FVH-HMIPv6 scheme is proposed by applying the IEEE 802.21 MIHF. Firstly, the Media Independent Information Service (MIIS) is extended by including new L3 information to provide domain prefixes of heterogeneous neighbouring mobility anchor point (MAPs), which is critical to the handover performance of proposed FVH-FMIPv6 with MIHF. Secondly, the operation procedure for the proposed scheme is described in detail. Finally, the analysis for handover performance is performed for the proposed scheme and the existing scheme, which shows the proposed FVH-HMIPv6 with MIHF can optimize and enhance the handover performance of existing schemes.

The paper is organized as follows. In Section 2, the existing FVH-HMIPv6 scheme is reviewed briefly in heterogeneous access networks. In addition, the IEEE 802.21 MIHF is overviewed briefly. In Section 3, the new FVH-HMIPv6 scheme is proposed. In Section 4, the analysis for handover performance is shown. Finally, concluding remarks are made in Section 5.

2. Technical Backgrounds

2.1 Review of Existing FVH-HMIPv6 Scheme

As shown in [13], the existing work proposed the vertical handover HMIPv6 (VH-HMIPv6) scheme for IP mobility in heterogeneous wireless access networks. For a corresponding access network, a new agent is defined to act as a mobility anchor point (MAP) which processes local mobility management within each access network. Therefore, in the proposed VH-HMIPv6, the global mobility management is performed for vertical handover between heterogeneous access networks and the local mobility management is performed for horizontal handover within each access network. Accordingly, the latency and signaling overhead problem in standard MIPv6 could be improved considerably while the MN is moving within the MAP domain. In addition, to reduce vertical handover latency, the fast vertical handover HMIPv6 (FVH-HMIPv6) was also proposed applying the fast handover strategy based on FMIPv6 [12] to the VH-HMIPv6 scheme. Through the analysis of the handover latency, it was shown that the FVH-HMIPv6 could reduce remarkably the handover latency of the VH-HMIPv6.

2.2 Overview of IEEE 802.21 MIHF

To provide general solutions for the vertical handover in heterogeneous access networks, the IEEE 802.21 standards group is currently discussing the media independent handover function (MIHF)[14][15]. The major purpose of MIHF is to provide abstracted services to upper layers by means of a unified interface and thus to enhance users' experience of mobile devices by supporting handover between heterogeneous networks. These services provided by MIHF help the upper layers in maintaining service continuity, service adaptation to varying quality of service, battery life conservation, and network discovery and link selection. In a system containing heterogeneous network interfaces of 802 types and cellular 3GPP, 3GPP2 types, the MIHF can help the upper layers to implement effective procedures to couple services across heterogeneous network interfaces. Upper layers may utilize services provided by the MIHF across different entities to query and reserve resource required for a handover operation between heterogeneous access networks. Therefore, the MIHF can be very useful facilities for vertical handovers in heterogeneous wireless networks.

The MIHF defines three different services: Media Independent Event Service (MIES), Media Independent Command Service (MICS), Media Independent Information Service (MIIS). MIES can indicate changes in state and transmission behaviour of the physical, data link and logical link layers, or predict state changes of these layers. This service can also be used to indicate management actions or command status on part of network or some such management entity. Some of the common events defined include "MIH Link Up", "MIH Link Down", "MIH Link Going Down", etc. MICS enables upper layers to control the physical, data link and logical link layers (also known as "lower layers"). The upper layers may control the reconfiguration or selection of an appropriate link through a set of handover commands. Some examples of MICS commands are "MIH Poll", "MIH Scan", "MIH Configure", "MIH Switch", etc. MIIS provides a framework and corresponding schemes by which the MIHF entity can discover and obtain network information existing within a geographical area to facilitate the handovers. MIIS provides a framework and corresponding schemes by which the MIHF entity can discover and obtain network information within geographic area. MIIS primarily provides a set of information elements, the information structure and its representation and a query/reply type scheme. MIIS provides access to both static and dynamic information. Examples of dynamic information may include parameters such as channel information, MAC address and other information about higher layer services that will help make effective handover decisions. This information can be made available via both L2 and L3 layers.

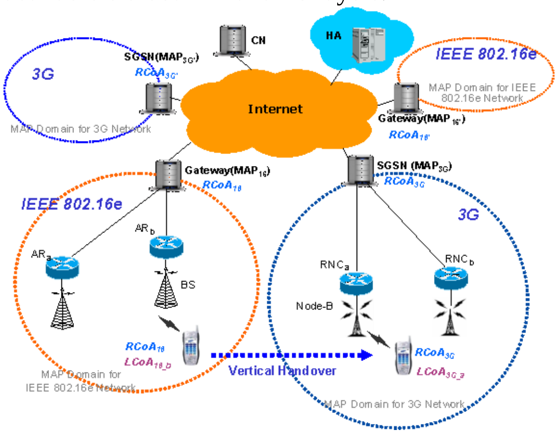

Figure 1. Vertical Handover HMIPv6 for 3G and IEEE802.16e Coexistence Networks

3. FVH-HMIPv6 with IEEE 802.21 MIHF

In this section, the new FVH-HMIPv6 scheme is proposed using IEEE 802.21 MIHF to optimize and enhance the handover performance of the existing scheme.

3.1 New Information Element for MIIS

In this paper, the provisioning of L3 information of heterogeneous neighbouring MAPs is included newly in the existing IEEE 802.21 MIIS service. In addition to existing Information Element (IE) with L2 information such as channel range, MAC address, data rates etc, a new IE with L3 information called the "Domain Prefix" is defined to provide domain prefixes of heterogeneous neighbouring MAPs. According to the MIIS specification, the MN can get this information including "Domain Prefix" by requesting the IE from the IS. It also allows the heterogeneous neighbouring MAP information to be delivered to the MN by using pre-defined vertical handover information (VHI). The VHI containing IEs with L2 information and L3 information is produced and stored in an IS.

With the L3 information of corresponding heterogeneous neighbouring MAPs, the MN knows domain prefixes of the new MAP (nMAP) and formulates a new on-link CoA (NLCoA) and a new regional CoA (NRCoA) prior to handover. This also reduces the router discovery time in the existing FVH-FMIPv6. Note that the VHI maintained by an IS will be similar to the mapping table maintained by the MAPs for resolving L2 identifiers of corresponding domain prefixes. This could eliminate the need for MAPs to exchange heterogeneous neighbouring MAP information mapping table and thereby tackling the candidate MAP discovery issue in FVH-HMIPv6.

Furthermore, in order to reduce the adverse impacts of the long anticipation time in the existing FVH-HMIPv6, it is assumed that VHI is stored and maintained in the MN, which would help to reduce several signalling messages during the anticipation phase and thereby reducing the overall anticipation latency. The VHI will be delivered to the MN through "MIH Get Info" request and reply primitives. Thus, the configuration procedure time for NLCoA and NRCoA can be decreased

In addition, the proposed FVH-HMIPv6 can use the IEEE 802.21 MIES to get the L2 trigger, and therefore quickly detect any L3 movement and perform handover initiation for NLCoA and NRCoA configuration before a L2 handover.

3.2 Operation Procedures of Proposed Scheme

This paper assumes the vertical handover from IEEE 802.16e network to 3G network occurs as shown in Fig. 1. The MN with MIHF sends a "MIH Information" request message to its old MAP (oMAP) in IEEE 802.16e network via its current access router, AR_b, to get the VHI on new MAP (nMAP) in 3G network. Note that oMAP and nMAP can be MAP_{3G} and MAP_{16}, respectively, as shown in Fig. 1. In response, the oMAP with MIHF in IEEE 802.16e network sends a "MIH Information" reply message containing the VHI on the nMAP of 3G network to the MN via RNC_a. Note that the "MIH Information" request and reply messages are done much before the L2 trigger (i.e. "MIH Link Going Down"), unlike the existing FVH-HMIPv6 in which RtSolPr and PrRtAdv messages only occur after L2 triggers (when the MN senses the signal strength of the link in existing access network is becoming too weak). Later, when the signal strength of the BS of IEEE 802.16e network that the MN is connected with becomes weak, the MIHF MIES will be informed by the MAC layer of the MN. The MIES will scope and filter this link layer information against the rules set by the FVH-HMIPv6 with MIHF, and then produce a "MIH Link Going Down" event indication message, and sends it to L3 layer where the proposed FVH-FMIPv6 protocol is working. Upon receiving this notification, the MN selects the 3G network to handover to. Since the MN knows the radio link information such as MAC address and channel range of Node-B in the nMAP (i.e. 3G network), the time to discover them is eliminated.

After selecting the 3G network, the MN can utilize MIHF MICS, and generate a link switch command using "MIH Link Switch" request primitive.

Then the MN uses "Domain Prefix" in the VHI to formulate the NLCoA and the NRCoA. Note that NRCoA and NLCoA can be $RCoA_{3G}$ and $LCoA_{3G\_a}$, respectively, as shown in Fig. 1. Then, the MN sends a Fast Binding Update (FBU) message to the oMAP via its current access router, AR_b. Therefore, the MN needs not exchange RtSolPr and PrRtAdv messages for router discovery since heterogeneous neighbouring MAPs information, "Domain Prefix" in IE, is stored and maintained already in the MN. After receiving FBU, the oMAP in IEEE 802.16e network sends a Handover Initiation (HI) message to the nMAP to establish tunnel between two heterogeneous access networks and determine whether NRCoA and NLCoA are acceptable to the nMAP in 3G network. In response to the HI message, the nMAP determines whether NRCoA and NLCoA supplied in the HI message are valid for use. After the nMAP considers NRCoA and NLCoA acceptable for use, it sends a Handover Acknowledgement (Hack) message to the oMAP. Then, the oMAP sends a Fast Binding Acknowledgement (FBack) to the MN. After the receiving the FBack message on the oMAP's domain and necessary L2 authentication and association procedure, a "MIH Link Up" primitive notification will be sent to inform the FVH-HMIP6 that the L2 connection in nMAP is established. The result of the FBU and FBack processing is that the oMAP in IEEE 802.16e network begins tunneling the MN's packets for previous RCoA (PRCoA) and previous LCoA (PLCoA) to NRCoA and NLCoA, the nMAP in 3G network begins buffering copies of incoming packets from the oMAP. Such a tunnel remains active until the MN completes the binding update with its HA and correspondents.

After a "MIH Link Up" primitive notification is obtained in the nMAP on IEEE 802.16e network, the Fast Neighbor Advertisement (FNA) message is immediate sent. Then the nMAP forwards arriving and buffered packets to the MN right away. Once the traffic starts to flow from the nMAP, the MIHF in the MN sends a "MIH Link Switch" reply primitive.

After the fast vertical handover procedure is completed, the MN sends an LBU to the nMAP in 3G network in order to establish a binding between the NRCoA and NLCoA. After registering with the nMAP for NRCoA and NLCoA, the MN register its NRCoA with its HA by sending a BU that specifies the binding (NRCoA, Home Address) as in standard MIPv6.

Note that the proposed FVH-HMIPv6 with MIHF has two scenarios as shown in [12]. The one is that the MN sends an FBU and receives an FBack on the oMAP domain, which is called the "predictive" mode of operation. The other is that the MN sends an FBU from the nMAP domain, which is called the "reactive" mode of operation. Fig. 2 shows the "predictive" mode for the proposed FVH-HMIPv6.

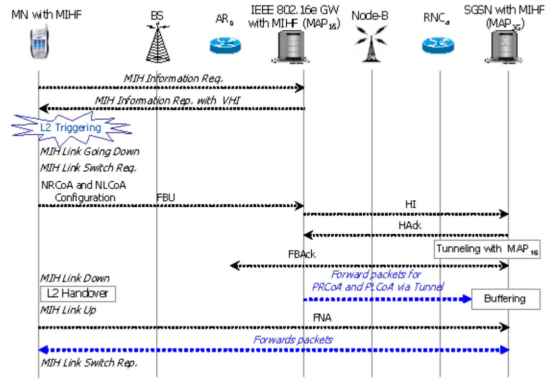

Figure. 2. Proposed FVHO-HMIPv6 Scheme using IEEE 802.21 MIHF for 3G and IEEE802.16e Coexistence Network

4. Analysis for Handover Performance

In this section, the handover performance is analyzed for the proposed FVH-HMIPv6 with MIHF and the existing scheme in heterogeneous access networks. To present the analytical result, the following parameters are considered for estimating the handover latency and the handover initiation time.

- T_{L2HO}: Time required for L2 handover.
- T_{BU} : Time required for BU operation between MN and HA via nMAP.
- T_{FNA} : Time required for FNA to reach nMAP.
- $T_{\text{RtSolPr–PrRtAdv}}$: Time required for exchange of RtSolPr and PrRtAdv messages.
- $T_{\text{FBU-FBack}}$: Time required for exchange of FBU and FBack messages.
- $T_{\text{HI-HAck}}$: Time required for exchange of HI and HAck messages.

For both schemes, analytical results of the handover latency and the handover initiation time are as follows:

- *Handover Latency of existing FVH-HMIPv6 :*

$$T_{\text{HO–Existing}} = T_{\text{L2HO}} + T_{\text{FNA}} + T_{\text{BU}}$$

- *Handover Latency of proposed FVH-HMIPv6 with MIHF :*

$$T_{\text{HO–Proposed}} = T_{\text{L2HO}} + T_{\text{FNA}} + T_{\text{BU}}$$

- *Handover Initiation Time of existing FVH-HMIPv6 :*

$$T_{\text{HI–Existing}} = T_{\text{RtSolPr–PrRtAdv}} + T_{\text{FBU–FAck}} + T_{\text{HI-HAck}}$$

- *Handover Initiation Time of proposed FVH-HMIPv6 with MIHF :*

$$T_{\text{HI–Proposed}} = T_{\text{FBU–FAck}} + T_{\text{HI-HAck}}$$

Above analytical results show that the proposed FVH-HMIPv6 with MIHF cannot reduce the handover latency as compared with the existing FVH-HMIPv6. However, the handover initiation time is reduced in the proposed FVH-HMIPv6 with MIHF. During the handover initiation in the FVH-HMIPv6, the MN could lose its connectivity to the oMAP due to a sudden degradation of the link quality. In this case, the FVH-HMIPv6 performs in the reactive mode or in the normal VH-HMIPv6 and thus the handover latency can be increased. Therefore, the proposed FVH-HMIPv6 with MIHF can reduce the expected handover latency. In addition, since the long anticipation time can be reduced by eliminating the exchange of RtSolPr and PrRtAdv messages, the proposed scheme can increase the probability predictive mode of operation.

5. Conclusion

This paper has proposed the new fast vertical handover scheme for the hierarchical Mobile IPv6, called the FVH-HMIPv6, to optimize and enhance the existing scheme in heterogeneous wireless access networks. The recently standardized IEEE 802.21 MIHF has been adopted for the proposed FVH-HMIPv6. Firstly, the MIIS has been extended by including new L3 information to provide domain prefixes of heterogeneous neighbouring MAPs, which is critical to the handover performance of proposed FVH-FMIPv6 with MIHF. Secondly, the operation procedure for the proposed scheme has been described in detail. Finally, the analysis for handover performance has been performed for the proposed scheme and the existing scheme, which shows the proposed FVH-HMIPv6 with MIHF can optimize and enhance the handover performance of the existing scheme.

As a future work, to verify the proposed scheme in various actual situations, extensive simulations and experiments will be performed.

6. Acknowledgement

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7. References

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