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멀티홈드 노드의 MIPv4/MIPv6 이동성 시뮬레이션 모델

MIPv4/MIPv6 Mobility Simulation Model of the Multihomed Node

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요약 차세대 무선망에서는 이동 사용자들이 언제 어디서나 원하는 임의의 망을 통해 서비스를 제공받을 것을 기대하기 때문에 복수개의 망 인터페이스를 장착한 멀티홈드 호스트에 관한 연구가 최근 활발히 진행되고 있다. 본 논문에서는 802.16e WiMAX 망과 IEEE 802.11 WLAN 망에서 MIPv4 뿐만 아니라 MIPv6 기능도 지원하는 멀티홈드 노드의 이동성 지원 시뮬레이션 모델을 개발하였다. 개발된 모델은 Mobile IP 기능과 함께 핸드오버 발생시 망 선택 전략에 따라 디폴트 액세스 망을 선택할 수 있는 기능을 제공한다. 이러한 망 선택 기능은 노드의 이동시 수신되는 RA(Router Advertisement) 메시지와 이를 수신하는 인터페이스 정보를 인터페이스 종류에 따른 순서 리스트로 관리함으로써 이루어진다. 개발된 모델의 동작을 검증하기 위해 다양한 시뮬레이션 시나리오에 적용하였으며, 분석 결과를 제시하였다.

Abstract Nowadays, the multihomed host equipped with multiple network interfaces has been interested research in next generation wireless network, because the mobile users expect that they can be able to access services not only anywhere, at any time and from any network but also simultaneously. This paper addresses the mobility simulation model of the multihomed node for supporting MIPv4 and MIPv6 function in an interworking of Worldwide Interoperability for Microwave Access (WiMAX) and IEEE 802.11 WLAN. The multihomed node with two air interfaces has been developed based on WiMAX and WLAN workstation node model in simulation software. The main point of the developed model is to support both MIPv4 and MIPv6 function, and provide network selection policy for the multihomed node between WiMAX and WLAN network. Based on the received Router Advertisement along with the interface number, we can manage the access interfaces in ordered list to make handover decision while the multihomed node is moving. In the end of this paper, the simulation scenarios and results are shown for testing MIPv4 and MIPv6 function.

Key Words : MIP, multihomed host, WiMAX, WLAN

1. Introduction

As the exponential growth of wireless communications, it is well accepted that next generation wireless networks will be heterogeneous,

providing users of multi-interface devices the ability to roam between different access networks. To be worth mentioning, the increasing popularity of Wireless Local Area Network (WLAN) enabled devices that will integrate WLAN and cellular wide area data network

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technologies such as Worldwide Interoperability for Microwave Access (WiMAX) or Long Term Evolution (LTE) with support for vertical handoffs between the different access networks.^[1] By using the multihomed device, mobile users will be able to experience ubiquitous data services and very high data rates across heterogeneous networks by using WLANs as a complementary technology for next generation cellular data networks, while providing the end user with a seamless experience.^[2]

WiMAX Forum^[3] believes that Mobile WiMAX (IEEE 802.16e-2005) services will complement existing and future broadband technologies such as WiFi, because both of WLAN and WiMAX aim to providing ubiquitous low cost broadband wireless internet access. WLAN offers high data rates of 54 Mbps within a 100m range mostly used within buildings whereas WiMAX offers high bandwidth 70 Mbps wireless back haul in a 5 km range generally covering a large outdoor environment.

Even though the prospects of integrating WiMAX and WiFi look good in future, it should be noted that, at the time of this writing, the main problem for WiMAX and WiFi is IPv6 is available only on WiFi and virtual interfaces, but not on the cellular interface (e.g., WiMAX interface).^[4] Therefore, to provide MIPv6 mobility function in both WiMAX and WLAN becomes more and more significant in our further study.

Some case studies on multihomed mobile IPv6 have been done in some papers. In Karl Andersson et al.^[5], the authors provided network selection and handover timing with multihomed MIPv6 by using Round-Trip Times (RTT) and RTT jitter values. The simulation results showed the multihomed MIPv6 made good soft handover. Deguang Le et al.^[6] evaluated MIPv6 performance only in WLAN network with wlan_wkstn_adv and wlan_server_adv model. A proposal extending Mobile IPv6 with multihoming functionality is described in Ahlund, C. et al.^[7]. In this paper, the authors described Mobile IPv6 can be extended to handle port-based multihoming by

modifying the Binding Update header. The research work in S.D.Adeniji et al.^[8] described a basic concept of IPv6 multihoming models and policy based routing management. The paper also proposed one interface selection scheme in a multihoming environment according to the policy decision.

In contrast with our previous work^[9] that supports MIPv4 only, our main job in this paper creates a MIPv4/MIPv6 multihomed node model based on wimax_ss_wkstn_adv and wlan_wkstn_adv node model in OPNET^[10]. The OPNET original C code in our simulation has been modified to achieve two final goals, one is to support MIPv6 function, and the other is to provide the network interface managing algorithm for supporting the network selection policy in WiMAX and WLAN network. In our network interface managing algorithm, we bind the RA (Router Advertisement) message together with the received interface number into the ordered list in IP layer whenever the RA is received. By comparing the interface numbers, IP layer determines the default network interface. For our network selection policy, the multihomed node always prefers WLAN over WiMAX while in overlapping area between WiMAX and WLAN network.

The rest of the paper is organized as follows. In the following section, our proposed architecture technologies are briefly reviewed and studied. Section III describes the system model and network selection policy in OPNET. Then the simulated results are shown and analyzed in Section IV. Finally, conclusions and some recommendations for future work are given in Section V.

II. Overview of Network Technologies

1. IEEE 802.16e Mobile WiMAX

The IEEE 802.16e standard^[3] is a technology proposed to offer wireless access to network stations in a metropolitan area environment. These networks are designed to operate at high data rates and to deal with

several applications, resulting in different types of traffic profiles and demands. The motivation is to one day provide last mile broadband wireless access to the general population, it is seeking to implement a single standard for fixed broadband wireless access and mobility with high scalability and a low cost of deployment.

2. IEEE 802.11 Wireless LAN

IEEE 802.11 Wireless LAN^[11,12] is a flexible data communication system implemented as an extension to or as an alternative for a wired LAN within a building or campus using wireless radio technology. In WLAN it combines data connectivity with user mobility, through simplified configuration, and enable moveable LANs, which allows users to take advantage of the flexibility, convenience and portability that WLAN can provide.

3. Differences between MIPv4 and MIPv6

In order to better understand the simulation performance between MIPv4 and MIPv6 network, according to the IETF RFC 3344 and RFC 6275^[13,14] document, the main differences between MIPv4 and MIPv6 are summarized in Table 1.

표 1. MIPv4와 MIPv6 비교

Table 1. Comparison between MIPv4 and MIPv6.

Compared Items	Mobile IPv4	Mobile IPv6
Foreign Agent	YES	NO
Care-of address	FA CoA	Co-located CoA (no need for FA)
MN-CN communication	Triangular routing	Route optimization
Packet tunnel during route optimization	Require packet tunneling between MN and CN	Forward packets with no tunneling
HA involves route optimization	YES	NO

III. System Model and Network Selection Policy

1. System Model

The multihomed node model has been developed for MIPv4/MIPv6 mobility simulation in WiMAX and WLAN network. The developed node model has the structure shown in Figure 1, in which there are two WiMAX and WLAN interfaces. In Figure 1, in the protocol stack of the multihomed model, the network interface selection algorithm is implemented in IP layer to determine the one of interfaces through which higher layer transmits packets while the handover happens.

For testing MIPv4 and MIPv6 function, the multihomed node runs in the interworking of WiMAX and WLAN network, as shown in Figure 2.

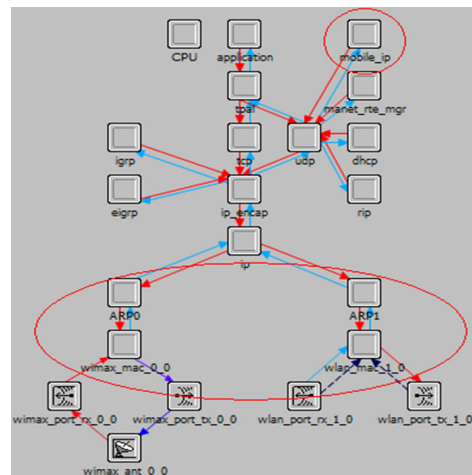


그림 1. 멀티홈드 노드 모델

Fig. 1. Multihomed node model

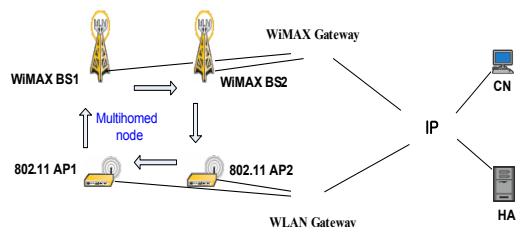


그림 2. 멀티홈드 노드 시험망 구조

Fig. 2. Multihomed node testing network Architecture

2. Network Selection Policy

In our multihomed node model, it has equipped two access interfaces. Whenever handover happens between WiMAX and WLAN, the IP layer should decide through which interface the higher data packet should be transmitted. In order to distinguish the multiple interfaces, we bind the received RA (Router Advertisement) message together with the received interface number into the ordered list. By comparing the interface number of the received RA, the network access interfaces can be efficiently managed in the ordered list, which is illustrated in Figure 3. Hereafter, the flow chart of the ordered list for WiMAX and WLAN is described.

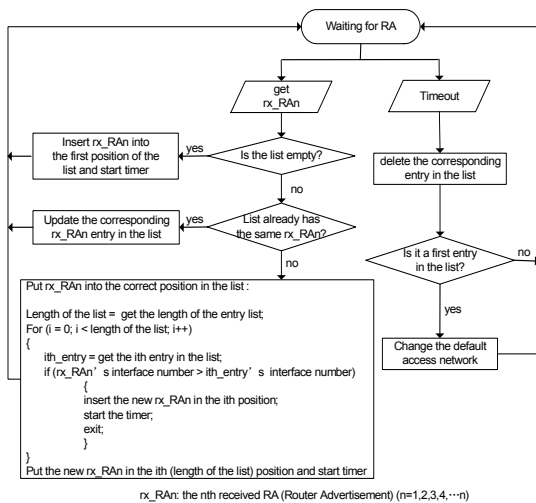


그림 3. 순서 리스트에서의 액세스 인터페이스 관리 흐름도
Fig. 3. Flow chart for managing access interfaces in the ordered list

In Figure 3, there are two cases for the multihomed node:

- Case 1: when the multihomed node receives rx_RA.
 - After receiving rx_RA, check whether the list is empty or not.
 - If it is empty, insert the rx_RA in the first position of the list, and then start timer.
 - Or else, check the list already has the same rx_RA or not. If yes, just restart the timer of the corresponding rx_RA entry in the list. If no, it is

the different rx_RA we got. By comparing the rx_interface number of the new rx_RA with the rx_interface number of each entry in the list, find out the correct position and put this new rx_RA into the correct position in the ordered list.

Case 2: when timeout is occurred.

- Deletes the corresponding entry in the ordered list
- If this entry is the first entry, it means the default access network should be changed.

It is worth highlighting that one of the conditions in Figure 3, whether the list already has the same rx_RA or not, can be decided in IP layer of the multihomed node. For instance, Mobile Node in MIPv6 network obtains its Care-of-Address by receiving Router Advertisement message. From the receipt of the Router Advertisement message, the mobile node determines that it has connected to a foreign link because the router advertisement contains a new network prefix. Hence, according to this receiving network prefix, IP layer will determine if this received RA is the same as previously received RA or not.

The multihomed node can be attached to multiple networks simultaneously (WiMAX/WLAN) while staying in the overlapping area between WiMAX and WLAN network. In general network design, the multihomed node will, by default, choose any one from the list of available interfaces. However, in our designed network selection policy, it is worth highlighting that the first entry is always the default access network in the ordered list. Note that the default network connection policy will always prefer WLAN over WiMAX in our design, which can be seen in the following Figure 4.

In order to better understanding this network selection policy, an example of how to manage the access interface in ordered list is shown in Figure 4. Note that in Figure 4, we assume that the multihomed node (MN) is moving from point A to point B throughout the entire WiMAX and WLAN network. The right side of Figure 4 is the updated rx_RA list.

- Put the first BS1_RA in the ordered list.
- When getting the new RA from AP1, compare AP1_RA with BS1_RA, then put AP1_RA in the first position. Then change to WLAN network. Even though BS1_RA timeout has not occurred, we prefer the WLAN over WiMAX, so it should be changed.
- When MN moves out of WLAN, the AP1_entry would be deleted because of AP1_RA timeout and the default access network becomes WiMAX BS1 network again.
- When the MN gets into the overlapped area of BS1 and BS2, BS2_RA is attached after BS1_RA in the list.
- When the MN arrives at the overlapped region of AP2, BS1 and BS2, AP2_RA will be inserted as a first entry in the list because WLAN is preferred over WiMAX. The default access network becomes WLAN AP2.
- When the MN continues to move to point B, entry AP2 and BS1 will be deleted in order from the list.
- Finally, when the MN moves out of BS2, the rx_RA for BS2 would be deleted.

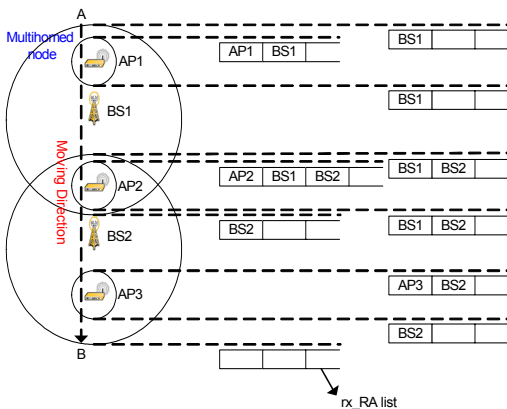


그림 4. 순서 리스트에서의 액세스 인터페이스 관리 예
Fig. 4. An example of managing access interfaces in the ordered list

The part of network selection policy code also has been shown in Figure 5. From Figure 5, it can be seen

that the user policy to choose the preferred interface is WLAN first, and then choose the WiMAX interface according to the interface index value. The code for obtaining the received interface index which was set in the ARP layer is shown in Figure 6. We modified the ARP layer code to add intf_recvd_index field information in ICI packet format. When IP layer gets the packet from ARP layer, it will parse this packet to get the intf_recvd_index value in this ICI field.

```

op_inet_obj_attr_get_str (pcmd_ptr->node_id, "name", 128, KJG_node_name_str);
if (strcmp(KJG_node_name_str, "multihomed", 10) == 0)
{
    // User Policy to choose the preferred interface : Prefer WLAN(WiFi) than WiMAX(WiFi).
    if (router_list_entry_ptr1->KJG_intf_recvd_index > router_list_entry_ptr2->KJG_intf_recvd_index)
    {
        // Entry1 has the larger KJG_intf_recvd_index value. Prefer it.
        FRET (1);
    }
    else if (router_list_entry_ptr1->KJG_intf_recvd_index < router_list_entry_ptr2->KJG_intf_recvd_index)
    {
        // Entry2 has the larger KJG_intf_recvd_index value. Prefer it.
        FRET (-1);
    }
    // Both entries have the same KJG_intf_recvd_index value.
    // The list will be ordered by OPNET original rules.
}
    
```

그림 5. 망 선택 정책 코드
Fig. 5. Network Selection Policy code

```

op_inet_obj_attr_get_str (pcmd_ptr->node_id, "name", 128, KJG_node_name_str);
if (strcmp(KJG_node_name_str, "multihomed", 10) == 0)
{
    // multihomed node must know the RA_received_interface when it changes the default router.
    // so, retrieve the received interface index of RA message and then save this information with
    // router_address in the router list.
    intf_ici_ptr = op_pk_ici_get (ip_pkptr);
    op_ici_attr_get (intf_ici_ptr, "ra_info_fields", &intf_ici_fdstruct_ptr);
    router_list_entry_ptr->KJG_intf_recvd_index = intf_ici_fdstruct_ptr->intf_recvd_index;
}
    
```

그림 6. RA를 수신한 인터페이스 번호 읽는 코드
Fig. 6. Code for obtaining the Rx Interface Index through which the RA was received

IV. Simulation Results

In order to verify that our developed multihomed node can support both MIPv4 and MIPv6 mobility functions, we create two BSs (Base Station) in WiMAX and two APs (Access Point) in WLAN as shown in Figure 2. The multihomed node starts moving from WiMAX network, and then goes through the WLAN network.

There are two scenarios included in our simulation, one is for MIPv4, and the other is for MIPv6. In both simulation scenarios, the UDP application traffic has been used for testing MIPv4 and MIPv6 functions.

In MIPv4 simulation results, Figure 7a shows that, the UDP traffic received performs similar with the UDP traffic sent, but still some packets losses are presented in Figure 7a when access interface is changed between WiMAX and WiMAX, WiMAX and WLAN, and WLAN and WLAN. In Figure 7b, when multihomed node changes network connection from WiMAX to WLAN, the data transmission also changes with the transition from WiMAX to WLAN. In Figure 7c, the WiMAX serving BS ID and WLAN AP connectively numbers identifies the current attachment to which the multihomed node is connected.

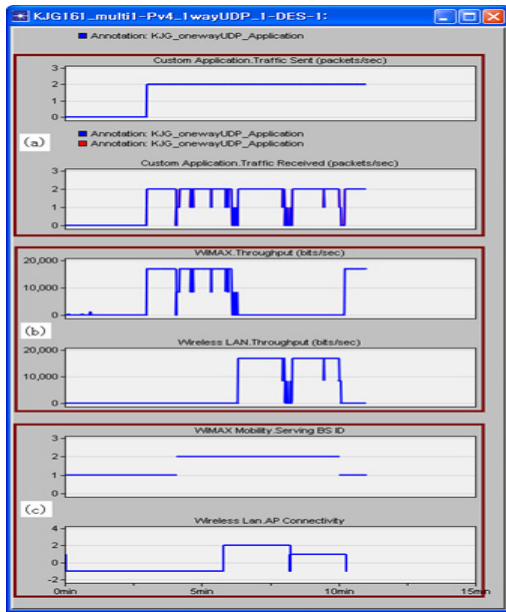


그림 7. MIPv4 망에서 WiMAX와 WLAN 핸드오버
Fig. 7. Handover in WiMAX and WLAN in MIPv4 network

In MIPv6 simulation results, Figure 8a depicts the UDP traffics are almost all received comparing with the MIPv4 case, but still experiences a few packet losses during handover period in WiMAX and WLAN network. In Figure 8b, the transmission of data packets through the WLAN interface starts after handover from WiMAX to WLAN has happened. Both WiMAX throughput and WLAN throughput in MIPv6 show better performance than the throughput in MIPv4

network. In Figure 8c, the numbers of BS ID and AP present the points of the attachment, which are changed as the BS1, BS2, AP2, and AP1.

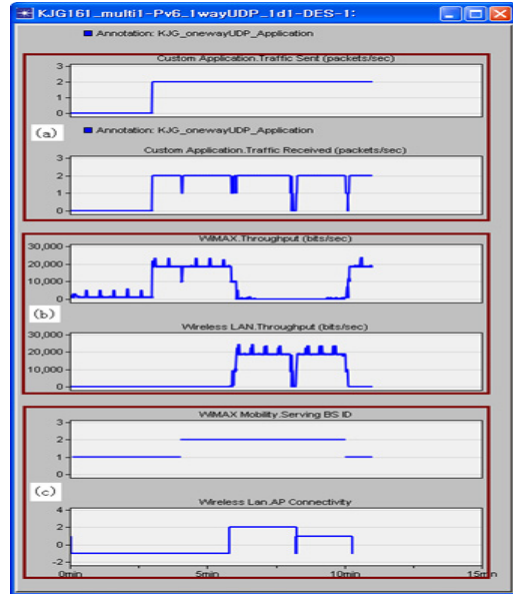


그림 8. MIPv6 망에서 WiMAX와 WLAN 핸드오버
Fig. 8. Handover in WiMAX and WLAN in MIPv6 network

Figure 9 shows the comparison of tunneled traffic sent/received in both MIPv4 and MIPv6. The Figure 9a shows the tunneled traffic has been sent and received without any loss in MIPv4 network. The detailed tunneled traffic sent/received in MIPv4 can be seen in Figure 10.

With the change of the attachment point, the Home Agent sends tunneled traffic to each BSs and FAs during the simulation time. In other words, while the multihomed node is moving from WiMAX to WLAN, MIP tunneled traffic is received continuously by BS1, BS2, FA2, and FA1 in consecutive order. However, in Figure 9b, because the MIPv6 route optimization is utilized, most of MIPv6 traffic is sent and received without tunneling.

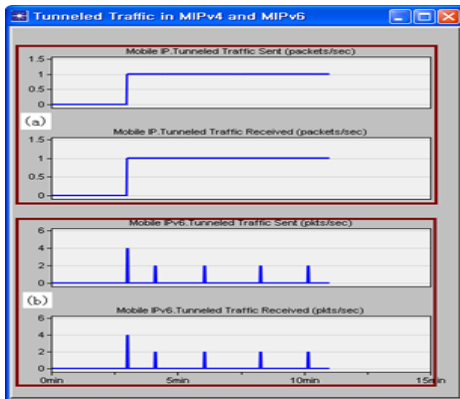


그림 9. MIPv4/MIPv6망의 송수신 터널통과 트래픽
Fig. 9. Tunneled Traffic sent/received in MIPv4/
MIPv6 network.

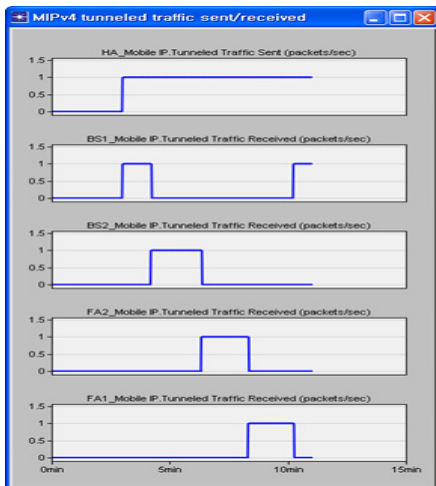


그림 10. MIPv4 터널통과 송수신 트래픽
Fig. 10. MIPv4 Tunneled Traffic sent/received.

V. Conclusion

In this paper, we tried to address the implementation of multihomed node simulation model in interworking of WiMAX and WLAN. By modifying the OPNET original code, the multihomed node can support MIPv6 as well as MIPv4 mobility function. It is worth noting that the network selection policy is performed well by comparing the interface type obtaining from the router advertisement. The developed multihomed node model maintains the ordered list of RA message and rx

interface pairs and decides which interface should be used as a default access network during handover period between WiMAX and WLAN network. Both of the simulation results of MIPv4 and MIPv6 show that the developed simulation model for the multihomed node works correctly while moving in WiMAX and WLAN networks.

In further research, the load sharing method between multi-interfaces will be considered to utilize both wireless networks.

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