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LLHS: Low Latency Handoff Scheme based on Buffering for Mobile Networks

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요 약 패킷 오버헤드 감소, 경로최적화, 핸드오프지연 그리고 핸드오프에 따른 신호량의 감소를 위해 이동망들에 대한 이동성 지원이 중요하다. MIPv6와 HMIPv6은 접근망에 관계없이 이동성을 제공하는 이동성관리프로토콜이다. 그러나 이들 기법은 핸드오프 발생으로 인하여 통신 품질이 크게 악화된다. MIPv6와 HMIPv6와 같은 기존의 이동성 관리프로토콜에서 발생하는 핸드오프 성능을 개선시키기 위한 방안으로서, 본 논문은 FMIPv6와 버퍼링 기능을 지닌 확장된 HMIPv6를 결합한 핸드오프지연감소기법 (LLHS)을 제시하였다. 여기서 MAP은 핸드오프 발생시 이동 망 내에 이동 라우터나 이동 노드로 향한 패킷들을 버퍼링한다. 모의실험을 통하여 제안 기법이 전송 지연과 패킷 손실을 감소시킨다는 것을 보였다.

Abstract Mobility support for mobile networks will be important to minimize the packet overhead, to optimize routing, to reduce handoff latency, and to reduce the volume of handoff signals. Mobile IPv6 (MIPv6) and Hierarchical MIPv6 (HMIPv6) are one of mobility management protocols (MMPs) that provides network layer mobility over all access technologies. However, the communication quality of these candidates is severely degraded during handoffs. As another way to improve the handoff performance of a mobile network by conventional MMPs such as MIPv6 and HMIPv6, we propose a Low Latency Handoff Scheme (LLHS) combining Fast MIPv6 (FMIPv6) with HMIPv6 extension with buffering function, in which Mobility Anchor Points (MAPs) buffer packets destined to the Mobile Routers (MRs) or MNs within a mobile network during handoffs. The simulation results show that the proposed scheme reduces transmission delay and packet loss in UDP communication.

Key Words : *handoff, latency, MIPv6, HMIPv6, MAP*

Ⅰ. INTRODUCTION

Mobile IPv6 (MIPv6) [1] is the current IETF proposal for a standard that enables a Mobile Node (MN) to maintain its IPv6 address and transport layer connections while its point of attachment to the network changes. One of the fundamental principles in MIPv6 design has always been, that mobility should never be visible to applications. MIPv6 cannot handle handoffs without a period of service disruption due to signaling latency between the MN and the Home Agent (HA). The problem arises when the HA or CN (Correspondent Node)is located geographically far away from the MN and when a MN moves in a small coverage area (micro-mobility) such that it will not be suitable for such scenario under that circumstance. The message exchange transmission time for MN to send a

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Binding Update (BU) message to HA/CN will become excessively high causing long delays or service disruptions in both macro and micro mobility. It generates significant signaling traffic load in the core network, even for local movement followed by long interruption during handoff

In order to reduce the handoff latency of a MN, Hierarchical Mobile IPv6 (HMIPv6) [2] has been proposed in IETF. The HMIPv6 concept is introduced in order to minimize signaling latency. HMIPv6 introduces a new mobility agent called Mobility Anchor Point (MAP) which acts as a HA in MIPv6. The MAP intercepts all packets on behalf of the MN it serves and tunnels them to the MN's On-link Care-of Address (LCoA). In HMIPv6 there are two types of handoffs. Local handoff occurs when the MN moves from one AR, but instead of sending a BU to the HA it is sent to the MAP. Global handoffs arise due to a change in MAP options advertised by the Router Advertisement (RA) message and so the MN binds to the new MAP and sends a BU to HA too. HMIPv6 reduces the signaling outside the MAP domain in case of handoffs within the same domain and may improve handoff performance reducing handoff latency and thus packet losses since intra-domain handoffs are performed locally. As conclusion, this mechanism can reduce BU signaling latency since it will take less time to update the MAP than it does the distant HA. However, this is not a perfect solution for packet loss.

MIPv6 and HMIPv6 were originally designed to use widely without possible applicability without any assumptions about the Layer 2 (L2) over which they would operate. The advantage of these approaches makes a clean separation between L2 and Layer 3 (L3), but these schemes also results in the following inherent source delays [3]: MN may only communicate with a current AR. This means that a MN may only begin the registration operation after an L2 handoff to new AR is completed. And, the registration operation takes some time to complete through the network between MN and MN's HA. The MN can not be received IP packets during this period.

The handoff performance of MIPv6 and HMIPv6 was degraded due to the inherent delay. However, the inherent source delay can be reduced using the information called L2 trigger [3] which is sent from L2 to L3 in order to inform L3 of the occurrence of events involved in L2 handoff sequencing.

As a solution that achieves better handoff performance, the Fast Handoff in Mobile IPv6 (FMIPv6) [4] was presented to address the problems that MIPv6 could not start before L2 handoff is completed and it may induce unacceptable latency for real-time services. FMIPv6 reduces handoff latency as minimizing the movement detection delay during a handoff process by using L2 trigger and prevents packet lossesby creating a bi-directional tunnel between a MN's previous subnet's AR (PAR) and next subnet's AR (NAR). This allows a MN to send packets before it finishes theMobile IP registration process. However, although this scheme significantly reduces the handoff latency, some extensions are necessary unless the networks are overlapped enough to perform Fast Handoff protocol.

As a solution to reduce L2 disconnection period, a HMIPv6 extension (HMIP-B) [5] was proposed that employs a buffering function at the MAP, which is aimed to prevent packet loss completely. In HMIP-B protocol, 1-bits field (buffering flag) is added to the BU for a buffering request. The MAP buffers packets destined to the MN during its handoff. The MN sends a BU to MAP with a buffering flag set. Then, MAP returns a Binding Acknowledgement (BA) message to the MN. On receiving the BU with the buffering flag set, MAP starts buffering packets for the MN. On receiving the BA, the MN performs an L2 handoff from PAR to NAR. Then, the MN sends a Router Solicitation (RS) message and receives a RA from this NAR and configures the NCoA. After the MN sends a BU containing the NCoA to MAP, in which the buffering flag is not set, the MAP returns a BA. On receiving the BU, MAP quits buffering and sends to the MN all the buffered packets for the MN with the NCoA.

In this paper, we propose a new fast handoff scheme, Low Latency Handoff Scheme (LLHS), combining FMIPv6 and HMIPv6 extension with buffering functionfor preventing packet loss completely during handoff to support the mobility of a mobile network.

The remainder of this paper is organized as follows: Section 2 describes our proposed architecture and provides the detailed handoff procedures. A performance evaluation of the proposed scheme is described in Section 3. Finally, in Section 4, we present some concluding remarks.

2. PROPOSED HANDOFF SCHEME

Fig.1 shows the network architecture for our proposed handoff scheme to meet the requirements for mobile network mobility management. It consists of an IP network with MAPs in addition to Mobile IP components, namely MR, MN, HAs, CN, and AR. In this scheme, MAP keeps the binding cache for all active MRs/MNs in its domain. The MAP's binding cache is composed of home address (HoA), LCoA, network prefix (MNP), and upper router (UR) fields to enable data packets to be tunneled to them. Each MR also keeps the binding information for MNs connected to it in its cache which includes the LCoA of MNs (MN-LCoA) and their HoA (MN-HoA). MR also stores the addresses of CNs which have ongoing session with MNs to perform a BU with CNs on behalf of active MNs when the network moves into other MAP domain.

2.1 Intra-MAP Domain Handoff

Our proposed handoff scheme (LLHS) supports efficiently fast handoff and prevents packet loss completely, where it is a hybrid protocol integrating FMIPv6 and HMIP-B.

In LLHS, 1-bit field (buffering flag) for a buffering request and 1-bit field (inter-handoff flag) for representing whether or not inter-domain handoff is added to the BU. We assume that The ARs and MAPs know their respective neighboring AR's address information using the neighbor discovery scheme.

Fig. 2 shows the handoff of a mobile network within a MAP domain where MR1's mobile network moves from AR1 to AR2 within MAP1 domain when referring to Fig. 1. MAP1 periodically sends its address to AR1 and AR2, which are connected as subordinates of MAP1. When MR1 knows its movement into NAR (AR2) by L2 trigger that includes link layer address of NAR, MR1 decides to initiate L2 handoff and sends a Router Solicitation for Proxy (RtSolPr) message to request the information of NAR to MAP1. RtSolPr includes the link-layer identifier of NAR to request the NAR's information (i.e., the networkprefix and global address of the NAR). In response to RtSolPr message, the AR1 sends a Proxy Router Advertisement (PrRtAdv) message, which provides the network prefix and global address of the NAR (AR2), plus MAP (MAP1) address attached newly in our scheme.

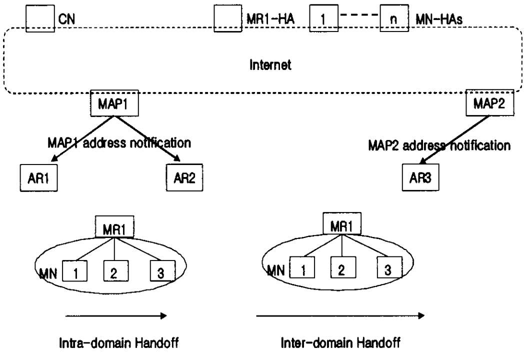

Fig. 1 Network architecture for proposed handoff scheme

MR1 knows that its movement to AR2 will be within MAP domain due to the same MAP address in PrRtAdv message. MR1 sends a BU message to MAP1 via AR1 with a buffering flag set and an inter-handoff flag unset. On receiving the FBU, MAP1 also starts buffering packets for the MR1 and MNs behind MR1 and returns a BA to MR1.

After receiving the BA, the MR1 performs a L2 handoff from AR1 to AR2. When MR1 gets the connection to NAR (AR2), MR1 sends a RS to NAR to request the network prefix of NAR and MAP option including MAP1 address. Then, MR1 creates its new LCoA (NLCoA), and sets its Regional CoA (RCoA) from a RA received from AR2, containing the network prefixof AR2 and MAP1 address. MR1 then sends a BU to MAP1, containing itsNLCoA with the buffering flag not set. MAP1 returns a BA. After receiving the BU, MAP1 quits buffering packets for MR1 and MNs behind MR1 and sends to them all the buffered packets destined for them.

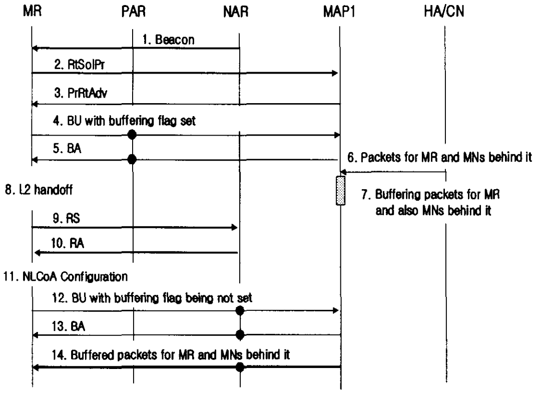

Fig.2 Signal flows of Intra-MAP domain Handoff

2.2 Inter-MAP Domain Handoff

Fig. 3 shows the signaling flows of the proposed inter-MAP domain handoff, showing the case MR1's mobile network moves from AR2 in the MAP1 domain to AR3 in the MAP2 domain in Fig. 1.MAP2 periodically sends its address to AR3, which are connected as subordinates of MAP2. When MR1 receives a beacon message from NAR (AR3), MR1 decides to initiate L2 handoff and sends a RtSolPr message requesting the information of NAR (AR3) to MAP1. In response to RtSolPr message, the MAP1sends a PrRtAdv message, which provides the link-layer address and network prefix information about the NAR (AR3), and MAP (MAP2) address.

MR1 knows that it is to move to other MAP domain due to the different MAP address in PrRtAdv message. Then, MR1 sends a BU message to MAP1, containing MR1-HoA, MR1-NLCoA and MR1-prefix with a buffering flag set and an inter-handoff flag set. On receiving the BU, MAP1 starts buffering packets destined for MR1 and MNs behind MR1where MNs could be found as the children of MR1 using the upper router field in its binding cache. MAP1 returns a BACK to MR1. Next, on receiving the BACK, MR1 performs an L2 handoff form AR2 to AR3. When MR1 connects to AR3, MR1 sends a RS containing a request for NAR's network prefix. Next, AR3 sends a RA to MR1, containing AR3-prefix and MAP2 address. Then, MR1 creates its NLCoA and its RCoA. MR1 then sends a FBU containing its NLCoA and IP address of NAR (AR3) to MAP1 in which the buffering flag is not set and the inter-handoff flag is set. Then, a bi-directional tunnel between MAP1 and AR3 is created and packets destined to MR1 and MNs behind MR1, and packets destined to them are forwarded via the tunnel temporarily until MR1 performs its handoff at its new MAP domain (MAP2).

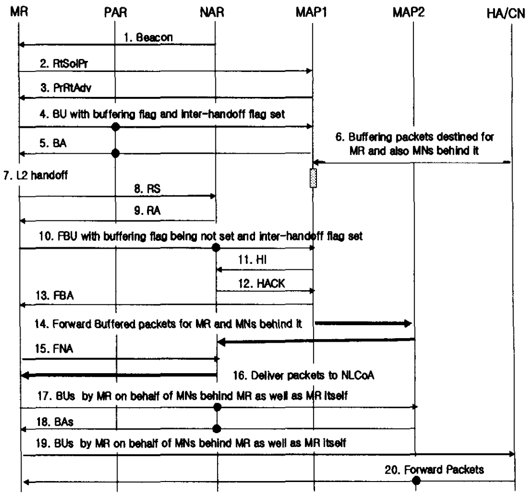

Fig. 3. Signal flows of Inter-MAP domain Handoff

3. PERFORMANCE ANALYSIS

We have evaluated LLHS and NEMO Basic Support Protocol (hereafter referred to as NEMO Basic) [6], using the Network Simulator (NS-2) in a mobile network environment. This simulation assumedthat the MAP was placed optimally, as shown in Fig.4. The simulation time was 10 seconds, and the date in the first 2 seconds was discarded because the network initializing procedure was executed during that time. Here, 10 seconds was enough to evaluate each method after several iterations. In order to simulate real traffic, we set up the CN as a traffic source at a Constant Bit Rate (CBR) over a User Datagram Protocol (UDP), producing fixed length packets of 1500 bytes every 10 ms. Then the MN acts as a sink node receiving packets from CN. The setup link topology consists of wired link and wireless link. The wired link is fixed and used at the connection of CN to MAP, CN to HA, HA to MAP, MAP and MAP, and MAP to the AR. The wired link bandwidth is set to 100 Mbps. The wireless link bandwidth is set to 11 Mbps with the wireless link latency set to 2 ms. The packet service rate (λ_P) was 100 packets/second corresponding to data rates of 1.2 Mbps. The handoff interval was set to 2 seconds. We evaluated each scheme assuming 10, 50, 100 MNs in the mobile network.

The simulation assumes that delay between HA and HA is 100 ms, delays between CN and HA, CN and MAP and HA and MAP are the same, 50ms, delay between MAP and MAP is 10 ms and delay between MAP and AR is 5ms. Furthermore, packet header size, BU size and BACK size are also predefined: 40 bytes, 112 bytes and 96 bytes respectively.

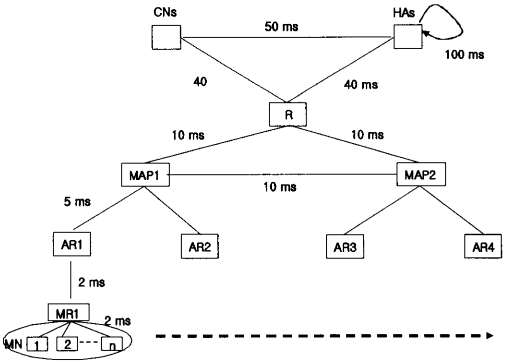

Fig. 4. Network Topology for Simulation

3.1 End-to-End Packet Delay

End-to-end delay is the mean in packet transmission from a CN to a MN in the mobile network, and indicates the degree of route optimization. In this analysis, T_P(i, j) represents total session delivery time between i and j. nMN represents the number of MN in a mobile network. The end-to-enddelay time of the LLHS is given by Eq. (1).

$$T_p^{LLHS} = (T_p(CN,MAP) + T_p(MAP,MR) + (T_p(MR,MN)) \cdot nMN \qquad (1)$$

In the case of NEMO Basic, the propagation delay between MNs attached to the low level mobile network and a CN is given by Eq. (2)

$$T_P^{NEMO} = (T_p(CN,HA) + \sum_{i=1}^{NL} T_p((HA,HA) + T_P(MR,MR)) + T_P(HA,TLMR)) \bullet nMN \qquad (2)$$

Fig. 5 shows that LLHS is superior to NEMO Basic regardless of the number of MNs. The degree of superiority increases further if the distance between MR-HA and MN-HA and the distance between MR and MR-HA is father from what we consider in this environment, because in NEMO Basic the packets must pass through the bidirectional tunnels from the MR to MR-HA and the MN and MN-HA. However, in LLHS, the packets are transmitted optimally from a CN to a

MN in the mobile network via MAP.

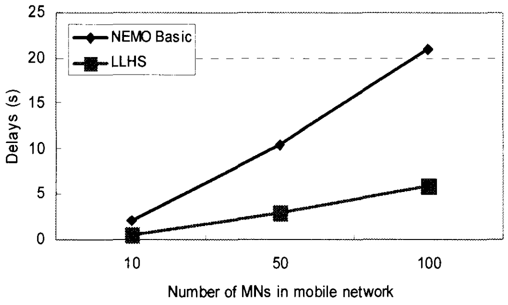

Fig. 5. End-to-End Packet Delay

3.2 Packet Loss

An analytical model for evaluating the possible number of packet losses during handoff is discussed in this subsection. First of all, the Handoff latency (T_h) of mobile router MR1 is equal to layer 2 handoff time (T_{L2}) plus the sum of times to carry out the following functions: a movement detection and link switching (T_{md}), CoA configuration (T_{coa}), and registration delay to HA (T_{ha_bu}). With the NEMO based approach, the handoff latency can be represented as:

$$T_h^{NEMO} = T_{L2} + T_{md} + T_{coa} + T_{ha\_bu} \tag{3}$$

The number of packet losses in the case of NEMO Basic is thus

$$L_h^{NEMO} = N1\lambda_P T_h^{NEMO} \tag{4}$$

Where $N1$ is the number of MNs having active communication session through MR1 and λ_P is the mean packet arrival rate of an MN. On the other hand, our proposed scheme LLHS has no packet losses because MAP buffers packets destined to the MNs during handoff.

Fig. 6 shows thepossible numbers of packets destined for MNs via MR1 but lost during handoff process, compared to NEMO Basic and LLHA. This figure shows that the packet losses in LLHS is not occurred, because of using buffering function in MAP before handoff and tunneling the buffered packets to MNs via MR1 after handoff. In contrast, the NEMO Basic has to perform home agent binding update, which requires time proportional to the packet delivery latency between MR and its HA. Until receiving the BU, HA keeps forwarding the packets to PAR, where packets to MR's mobile network get dropped.

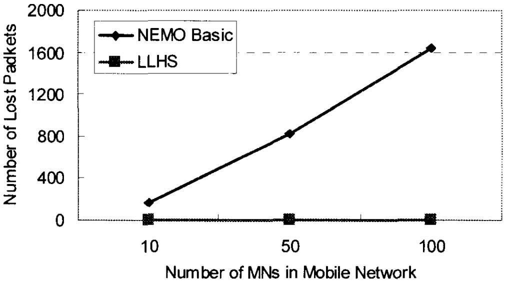

Fig. 6. Number of average packet losses with different scheme versus number of MNs (N1 = 10, 50, 100 nodes, λ_P=100 pkt/s, T_{L2} = 50 ms).

4. CONCLUSIONS

This paper has proposed new handoff scheme (LLHS)combining FMIPv6 with HMIPv6 extension with buffering function. The proposed handoff schemeallows each AR and MAP to know its neighboring ARs and MAPs, which makes it possible for a MR to sends a BU to MAP with a buffering flag set immediately before L2 handoff. During handoff, MAP receiving packets from CNs buffers those packets until it receives a BU from MR with buffering flag not set.

We verified the effectiveness of LLHS compared to NEMO Basic, using NS2. The end-to-end delay from CNs to MNs in a mobile network obtained using LLHS was reduced compared to NEMO Basic, because LLHS provides an optimized routing path. LLHS does not occur the loss of UDP packets regardless of the number of MNs during intra-domain or inter-domain handoff. The discarded packets in NEMO Basic depend on the number of MNs, e.g. 815 with 50 MNs, 1640 with 100 MNs.

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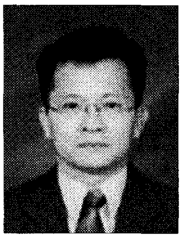

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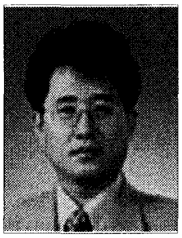

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