Recognizing Handover Situation for Vertical Handovers using Mobile IPv6 Signaling

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Summary
In this paper, a new scheme is proposed to allow the correspondent node to recognize the handover situation of the mobile node for vertical handovers using Mobile IPv6 signaling. The proposed scheme might be helpful for quick adjusting real-time traffics between two nodes when a drastic change in a bandwidth occurs due to vertical handovers in heterogeneous access networks that have a quite different capacity and coverage. Firstly, this paper defines newly the care-of address configuration specified by the new link of the mobile node in Mobile IPv6. Secondly, this paper gives a new method for the correspondent node to recognize the handover situation of the mobile node using the return routability procedure with the link specified care-of address in the network layer. A guideline for the congestion control is provided for improving TCP performance during vertical handover. Finally, the analytical result shows the CN recognizes more quickly the MN's handover situation than the existing scheme.

Key words:
Mobile IPv6, Vertical Handover, Care-of Address, Handover Situation, Congestion Control.

1. Introduction

In recent, many works have been proposed to support seamless mobility for IPv6 based access networks. One of the challenges in keeping connection with the Internet, as a mobile node moves, is to communicate efficiently on the move and to minimize to packet loss caused by a vertical handover in heterogeneous access networks [1]-[6].

In the vertical handover in heterogeneous access networks, one of the issues is that throughput performance can be degraded significantly because the vertical handover causes drastic change in a bandwidth. Thus, it should be required to adjust real-time traffics in Mobile IPv6 based vertical handovers. This problem has been solved by some previous schemes that the TCP sender adjusts real-time traffics [4]-[6].

In this paper, the correspondent node (CN) in Mobile IPv6 [7] is assumed to be the TCP sender and the mobile node (MN) is assumed to be the TCP receiver that is going through the vertical handover in heterogeneous access networks. To adjust real-time traffics in Mobile IPv6 based vertical handovers, the CN have to get information on the handover situation of the MN. When applying the existing scheme [6], the CN can recognize the MN's handover situation using the handover option field in TCP header in the transport layer (L4). In addition, until the CN recognizes the MN's handover situation using the TCP packet, some basic operations for Mobile IPv6 registration between two nodes, such as the return routability procedure and the authorizing binding procedure, must be performed. However, these operations are somewhat time-consuming and computationally burdensome since cryptographic functions for authentication and encryption require considerable computation and CPU processing time, which might introduces the binding latency [8]. Especially, this might be serious when MN or CN is an embedded mobile platform whose processing capability, power and resource are limited. Thus, in the existing scheme, the CN can adjust real-time traffics after somewhat long time has passed from the MN's link layer (L2) handover.

In this paper, for Mobile IPv6 based vertical handovers, a new scheme is proposed to allow the CN to recognize the handover situation of the MN using Mobile IPv6 signaling in order to adjust quickly real-time traffics between two nodes. Note that this paper will focus on only how can the CN recognize quickly the MN's handover situation. So, the specific method for adjusting real-time traffics is out of the scope of this paper and thus one of existing TCP control methods in [1]-[6] can be adopted. The MN's handover will be defined by three situations; a horizontal handover, an upward vertical handover, a downward vertical handover.

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0                                64                             127
| Subnet prefix for foreign link | Interface ID (EUI-64 identifier) |
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Fig. 1. Format of Care-of Address

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0                 16                 32                 47
| cccccc0gcccccccc | ccccccccmmmmmmmm | mmmmmmmmmmmmmmmm |
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Fig. 2. 48bit MAC Address

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0                  16                 32                 48                 63
| cccccc0gcccccccc | cccccccc11111111 | 11110000mmmmmmmm | mmmmmmmmmmmmmmmm |
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Fig. 3. EUI-64 identifier of IEEE 802.11b for link specified CoA

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0                  16                 32                 48                 63
| cccccc0gcccccccc | cccccccc11111111 | 11010000mmmmmmmm | mmmmmmmmmmmmmmmm |
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Fig. 4. EUI-64 identifier of IEEE 802.16e for link specified CoA

Firstly, this paper gives a new method for the MN to create a care-of address (CoA) which is specified by the new link. In this method, a EUI-64 identifier for the CoA configuration is made from an IEEE 48bit MAC identifier using the link type value. Secondly, this paper gives a new method for the CN to recognize the MN's handover situation using the care-of test init (CoTI) message of RR procedure with the link specified CoA in the network layer. Using these two methods, the CN recognizes more quickly the MN's handover situation than the existing scheme in [6], since the RR procedure in the network layer (L3) precedes TCP packet resolution in the transport layer (L4). Therefore, the proposed scheme can adjust more quickly real-time traffics according to the new link's available bandwidth of the MN than the existing scheme. Although, the specific method for adjusting real-time traffics is out of the scope of this paper, a guideline for the congestion control is provided for improving TCP performance during vertical handover.

Finally, to present the analytical result, several parameters are considered for estimating the delay time to recognizing handover situation from L2 handover. The analytical result shows the CN can recognize more quickly the MN's handover situation than the existing scheme in [6]. Therefore, it can be expected the proposed scheme can adjust quickly real-time traffics than the existing one.

The paper is organized as follows. In Section 2, a new method is given for the MN to create a link specified CoA. In Section 3, a new method is given for the CN to recognize the handover situation of the MN in the network layer. In Section 4, a guideline for the congestion control is provided for improving TCP performance. In Section 5, the analytical result is shown. Finally, concluding remarks are made in Section 6.

2. Configuration of Link Specified Care-of Address

According to the Mobile IPv6 specification, the MN should generate a new primary care-of address (CoA) using normal IPv6 schemes, after detecting that it has moved to a foreign link. In order to form a new CoA, the MN may use either stateless [9] or stateful (e.g., DHCPv6 [10]) address autoconfiguration. In case of the stateless address autoconfiguration, a mobile node can generate its CoAs using a combination of locally available information and information advertised by routers in foreign links. Routers advertise prefixes that identify the subnet(s) associated with a foreign link, while mobile nodes generate an "interface identifier" that uniquely identifies an interface on a subnet. An address is formed by combining the two. Generally, the CoA using stateless autoconfiguration has the form of Fig. 1.

To indicate the currently active link of the MN for vertical handovers in heterogeneous access networks environment, this paper gives a new method to create a CoA which is specified by the new link. This CoA will be called the *link spcified CoA*. In this method, a EUI-64 identifier is made from an IEEE 48bit MAC identifier using the link type value as shown in Table 1. As shown in [9], in order to make 64 bits EUI-64 from 48 bits MAC, two hexadecimal values of "0xFF" and "0xFE" is added in the middle of the 48 bit MAC (between the company ID and vendor supplied ID).

Table 1. Link Type Values

Link type value	IEEE link type
0xF0	802.11b (WLAN)
0xF1~FD	IEEE 802.11 Family Networks
0xD0	802.16e (WiMAX or WiBro)
0xD1~DF	IEEE 802.16 Family Networks
0xC0~CF	IEEE 802.15 Family Networks
0xA0~BF	Reserved for other networks

To create link specified CoA, the second hexadecimal value “0xFE” will be replaced by the link type value defined as Table 1. Note that the second hexadecimal value can be “0xFE” as the original one, which means the MN doesn't support the creation of the link specified CoA.

For example, an IEEE interface has the 48 bit MAC as shown in Fig. 2 where ‘c’ are the bits of the assigned company ID, ‘0’ is the value of the universal/local bit to indicate global scope, ‘g’ is individual/group bit, and ‘m’ are the bits of the manufacturer-selected extension identifier.

The link type value of IEEE 802.11b (WLAN) is “0xF0”, then the interface identifier with 64 bits EUI-64 for the link specified CoA has the form of Fig. 3. As another example, the link type value of IEEE 802.16e (WiMAX or WiBro) is assumed to be “0xD0”, then the interface identifier with 64 bits EUI-64 for the link specified CoA has the form of Fig. 4.

3. Recognizing Handover Situation

In the vertical handover in heterogeneous access networks, one of the issues is to adjust the CN’s real-time traffics after the MN moves into a new network environment. Each access network within heterogeneous access networks has a quite different capacity and coverage. For example, WLAN, WiBro, 3G networks provide different bandwidths to a user, and thus a drastic change in a bandwidth may occur when the MN performs the vertical handover on these heterogeneous access networks. The latency of the vertical handover is longer since it may need an authentication procedure when the MN enters into a new access network. Thus, it should be required to adjust quickly real-time traffics in Mobile IPv6 based vertical handovers.

In order that the CN can adjust quickly real-time traffics according to the new link’s available bandwidth of the MN in Mobile IPv6 based vertical handovers, the CN have to recognize quickly the handover situation of the MN. In Mobile IPv6 based vertical handovers, the handover situation can be recognized by the link specified CoA and defined by three as follows;

- a horizontal handover in homogeneous access network
- an upward vertical handover from a smaller access network with higher bandwidth to a large access network with lower bandwidth
- a downward vertical handover from a larger access network to a smaller access network

Assume that the MN communicates with the CN using available bandwidth for the current link. In real-time communication, when the MN moves to the new link, it creates a link specified CoA using the new link’s interface identifier. Then, the MN performs the binding procedure with its home agent to register its link specified CoA.

Then, for the Mobile IPv6 registration procedure between the MN and the CN, the return routability (RR) procedure is performed to enable the CN to obtain some reasonable assurance that the MN is in fact addressable at its claimed link specified CoA as well as at its home address. Only with this assurance is the CN able to accept binding update from the MN which would then instruct the CN to direct that MN’s data traffic to its claimed link specified CoA. For the RR, the Home Test Init (HoTI) and Care-of Test Init (CoTI) messages are sent at the same time. The procedure requires very little processing at the correspondent node, and the Home Test (HoT) and Care-of Test (CoT) messages can be returned quickly, perhaps nearly simultaneously. As shown in Fig. 1, the CoTI message uses the link specified CoA as the source address and the CoT message uses the link specified CoA as the destination address. Thus, the CN can recognize the new link of the MN from the CoTI message with link specified CoA in RR procedure and can prepare quickly to adjust real-time traffic amount or pattern sent to the MN according to the new link’s available bandwidth.

On the other hand, in the existing scheme [9], the CN (i.e. TCP sender) can recognize the MN’s (i.e. TCP receiver’s) handover situation using the handover option field in TCP header in the transport layer (L4). In addition, in comparison with the proposed scheme, the existing scheme requires additional operations such as RR procedure with CoT message exchange and authorizing binding procedure with binding update (BU) and the binding acknowledgement (BA) message exchange until the CN recognizes the MN’s handover situation. However, as shown in [7][8], these additional operations to recognize handover situation are somewhat time-consuming and computationally burdensome since cryptographic functions for authentication and encryption require considerable computation and CPU processing time, which might introduces the binding latency. Especially, this might be serious when MN or CN is an embedded mobile platform whose processing capability,

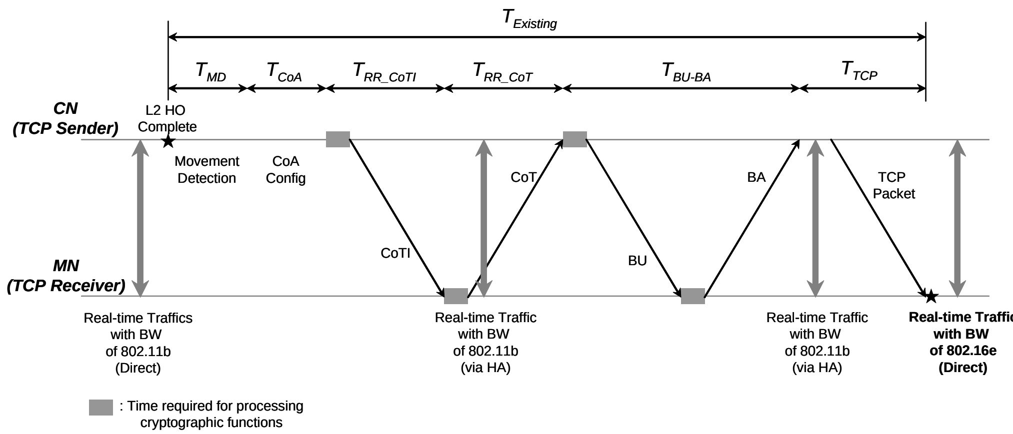

Fig. 5. Operation procedure for existing mechanism

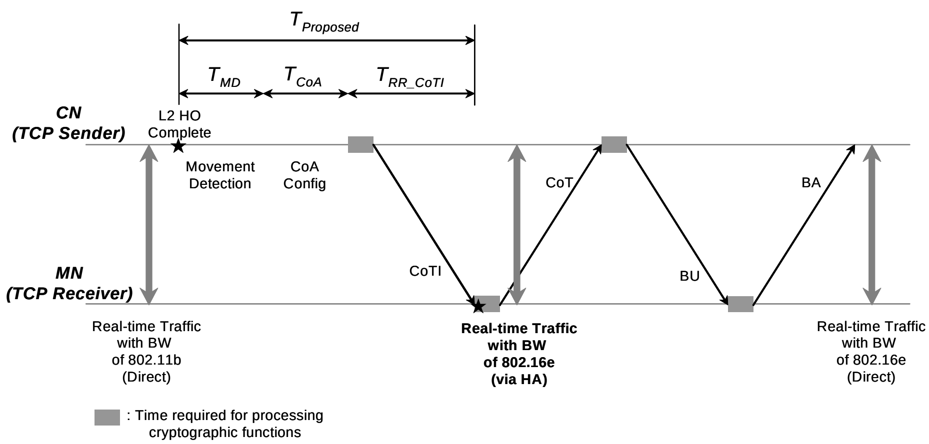

Fig. 6. Operation procedure for proposed mechanism

power and resource are limited. Thus, in the existing scheme, the CN can adjust real-time traffics after somewhat long time has passed from the link layer (L2) handover of the MN.

Therefore, in the proposed scheme, the CN recognizes more quickly the MN's handover situation than the existing scheme in [6], since the RR procedure in the network layer (L3) precedes TCP packet resolution in the transport layer (L4). Therefore, the proposed scheme can be expected to adjust more quickly real-time traffics according to the new link's available bandwidth of the MN than the existing scheme.

4. A Guideline for Adjusting Real-time Traffic

This paper has focused on only how can the CN recognize quickly the MN's handover situation. The specific method for adjusting real-time traffics is out of the scope of this paper and thus one of existing TCP control methods in [1]-[6] can be adopted. In this paper, only a guideline for the congestion control is provided for improving TCP performance during vertical handover. The main task of congestion control in vertical handovers is to freeze TCP during handover and to restart its data transmission with the appropriate congestion window size (*cwnd*) after handover. Since the network environment is drastically changed in a new access network after the vertical handover, it improves performance to estimate the available bandwidth, rather than to start with the same bandwidth as before the vertical handover.

As mentioned before, handover situations are defined by a horizontal handover, an upward vertical handover, a downward vertical handover. If the horizontal handover is occurring, the CN resumes data transmission at the CA state with the same *cwnd* as before handover, since the MN moves into the same access network. When the upward vertical handover is occurring, TCP suffers from significant throughput degradation because of the buffer overflows. Moreover, the upward vertical handover contains another aspect to result in the buffer overflow.

In this case, the congestion window size control and the transmission rate control can be used. When the downward vertical handover is occurring, TCP suffers from significant degradation of link utilization. To maintain the high link utilization after the handover, it is necessary to increase *cwnd* up to the bandwidth-delay product (BDP).

5. Analytical Result

Fig. 5 and 6 show the overall operation procedure for the proposed scheme and the existing one, respectively. In these figures, it is assumed that the MN moves from ‘IEEE 802.11b’ with link type value ‘0xF0’ to the ‘IEEE 802.16e’ with link type value ‘0xD0’.

As shown in these figures, to present the analytical result, the following parameters are considered for estimating the delay time to recognizing handover situation from L2 handover.

T_{MD} : Time required for movement detection

T_{CoA} : Time required for CoA configuration

T_{RR_CoTI} : Time required for CoTI operation in RR (one way delay from MN to CN + processing cryptographic functions)

T_{RR_CoT} : Time required for CoT operation in RR (one way delay from CN to MN + processing cryptographic functions)

T_{BU-BA} : Time required for BU and BA operation (round trip delay between MN and CN + processing cryptographic functions)

T_{TCP} : Time required for TCP packet transmission (one way delay from MN to CN)

Then, the analytical comparison of the delay time to recognizing handover situation from L2 handover between the proposed scheme and the existing scheme can be shown as follows:

▫ *Proposed scheme* :

$$T_{Proposed} = T_{MD} + T_{CoA} + T_{RR\_CoTI}$$

▫ *Existing scheme :*

$$T_{Existing} = T_{MD} + T_{CoA} + T_{RR\_CoTI} + T_{RR\_CoT} + T_{BU-BA} + T_{TCP}$$

Above analytical results show that the CN can recognize more quickly the MN’s handover situation than the existing scheme in [6]. Therefore, it is expected that the proposed scheme can adjust quickly real-time traffics than the existing one.

6. Conclusion

This paper has proposed the new scheme which allows the CN to recognize the handover situation of the MN for Mobile IPv6 based vertical handovers. The proposed scheme might be helpful for quick adjusting real-time traffics between two nodes when a drastic change in a bandwidth occurs due to vertical handovers in heterogeneous access networks that have a quite different capacity and coverage. Firstly, this paper has defined newly the CoA configuration specified by the new link of the MN in Mobile IPv6. Secondly, this paper has given a new method for the CN to recognize the handover situation of the MN using the RR procedure with the link specified CoA in the network layer. For improving TCP performance during vertical handover, the guideline for the congestion control has been provided. Finally, the analytical result has shown the CN recognizes more quickly the MN’s handover situation than the existing scheme.

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