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Limiting the Length of BET for Tunnel-Based IP Fast Handover

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SUMMARY Next generation wired/wireless networks will be based on IP technology. In the IP based networks, it is crucially required to support seamless mobility especially for proving real-time services in the mobile environment. The conventional Mobile IP protocols cannot satisfy such seamless mobility requirements for real-time services. Therefore various extensions of Mobile IP are being proposed. In this paper, we propose a new handover scheme to enhance the existing tunnel-based fast handover method, which is a typical Mobile IP extension to support seamless mobility. It is shown that the proposed method reduces the traffic overhead in the networks. It is expected that the proposed method will be particularly useful in the IP-based networks in which there are a number of users simultaneously using the long-lived real-time services, or in the condition that the traffic overhead is considered as a critical performance measure.

key words: *Mobile IP, fast handover, bi-directional edge tunnel, seamless mobility*

1. Introduction

IP technology has been rapidly introduced in telecommunication networks as well as data networks with the explosive growth of Internet users and applications. With this trend, the future communication network is expected to evolve toward the IP-based network as called 'All-IP' network. One of the important issues to be addressed in the IP-based network is to provide the real-time services for mobile terminals in the mobile communication environment. Nowadays, the Mobile IP (MIP) is considered as a promising protocol for mobility support in an IP network. However, Mobile IP should do the registration to Home Agent (HA), whenever a mobile node changes its subnet (network point of attachment). This registration could typically cause the packet loss and latency which may not be acceptable for real-time services. Especially, the latency problem needs to be solved because the real-time services such as VoIP, which will be a promising service in the IP-based future networks.

A typical approach for seamless mobility support is the 'Fast Handover for MIP' (FMIP) scheme [1], [2]. The FMIP uses layer 2 trigger to decrease the handover latency. The FMIP may also establish the bi-directional tunnel between previous access router and next access router for reducing the data packet loss during handover.

The FMIP method using layer 2 triggers could further be classified into two types: anticipated handover and tunnel-based handover [2]. In the anticipated handover method, a mobile node performs the Mobile IP registration by using layer 2 triggers before the layer 2 handover is completed. Whereas, in the tunnel-based handover, the packets destined to the mobile node are forwarded through the bi-directional tunnel between old AR (Access Router) and next AR which was built previously using layer 2 triggers. A recent study in [3] has shown that the performance of the tunnel-based method is better than that of the anticipated method.

However it is noted that the tunnel-based handover may possibly induce the severe performance degradation when the length of the bi-directional edge tunnel (BET) becomes too long. This paper proposes an enhancement of the tunnel-based handover in FMIP, which ensures to prevent the BET from being too much longer.

This paper is organized as follows. Section 2 reviews the operations and problems of the tunnel-based handover method. In Sect. 3, we propose an enhanced tunnel-based handover method which could reduce the traffic overhead due to the longer BET. Section 4 describes the analysis of the performance for the proposed scheme. Finally we conclude this paper in Sect. 5.

2. The Existing Tunnel-Based Handover

In the tunnel-based handover, a mobile node (MN) maintains its Care of Address (CoA) even when it moves from old AR to new AR. That is, the BET between old AR and new AR will still be used by the MN to receive and transmit the data packets. The MN needs not configure a new CoA in the new AR's subnet. Accordingly the layer 3 registration with CN/HA is not performed in this method. The handover latency could be zero if the layer 2 information can be provided sufficiently earlier.

Table 1 shows the classification of the layer 2 triggers considered in the FMIP. The MN/Source/Target triggers can be viewed as the 'pre-triggers' to indicate imminent change of layer 2 attachment point to the MN, old AR(oAR), new AR(nAR), respectively. On the other hand, Link-Up and Link-Down are the triggers to indicate the completion of change of layer 2 attachment point. Link-Down is triggered when the link of MN to oAR is disconnected, whereas Link-Up is indicated when the MN makes a new link to nAR.

Based on the triggers specified in Table 1, the brief operations of the tunnel-based handover are described in

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Fig. 1.

In the figure, it is assumed that a MN moves from oAR to nAR(1), nAR(2), . . . , nAR(k), successively. Firstly, oAR takes the role of anchor AR when the MN moves from oAR to nAR(1). oAR and nAR(1) establish the BET by exchanging the HI (Handover Initiate) and HACK (Handover Acknowledgement) messages. If there are the packets destined to the MN after establishing the BET, then oAR intercepts and forwards them to nAR(1). If a MN is going to send packets to CN, they are forwarded to oAR through nAR. After that, if the MN moves toward nAR(2), nAR(1) informs nAR(2) about oAR (such as IP address, layer 2 address) by using the HTT(Handover To Third) message. After nAR(2) establish a BET with oAR. oAR removes the existing BET between oAR and nAR(1). Now the data packets destined to the MN are forwarded to nAR(2) through oAR. This procedure will be continued until the MN doesn't require fast handover no longer.

As described above, the tunnel-based handover method seems to be simple and to reduce the handover latency due to layer 3 registration. In fact, the tunnel-based handover is considered as a strong candidate for the MIPv6 fast handover.

However, it is noted that the exisitng tunnel-based handover may cause severe problem when the fast change of the layer 2 attach point is repeated and thus the length of BET becomes long. In this case, the number of routers on the path between anchors AR and new AR will get larger, which tends to increase unnecessary traffic in the backbone network and the possibility of failure for the nodes on the path.

Table 1 Layer 2 triggers.

L2 Trigger	*Recipient*	*When ?*	*Parameters*
MN Trigger	MN	Sufficiently before L2 HO	nAR IP Addr. ID
Source Trigger	oAR	Sufficiently before L2 HO	nAR IP Addr. ID MN IP Addr. ID
Target Trigger	nAR	Sufficiently before L2 HO	oAR IP Addr. ID MN IP Addr. ID
Link-Up	MN or nAR	When radio link between MN & nAR is established	nAR IP or L2 Addr.
Link-Down	oAR	When radio link between MN & oAR is lost	MN IP Addr. ID

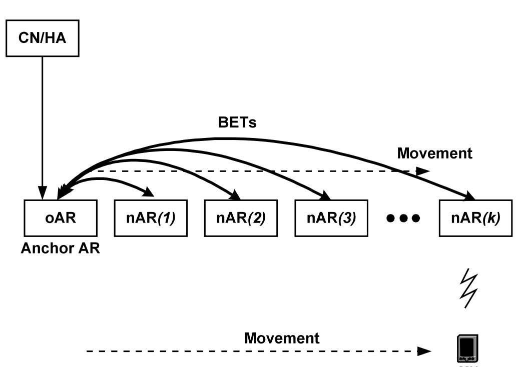


Fig. 1 Existing tunnel-based handover method.

3. The Proposed Scheme to Limit the BET Length

In this paper, we propose an enhancement scheme for the tunnel-based handover method. To limit the length of BET, we propose that the anchor AR is forced to exchange its role with a pre-specified AR, if the pre-defined condition is satisfied. That is, all ARs are grouped by a pre-defined (positive) number and the grouping is done logically rather than physically. In order to configure such groups, some factors could be used; for example, the frequency of AR changes, the hop count of BET, and so on. In this paper, the hop count of BET is considered. That is, if the hop count of BET is greater than the pre-defined number p, the current anchor AR will hand its role over to a new AR. As a result, the length of BET can always be limited and maintained to be below the specified value p.

Figure 2 shows the structure of the proposed tunnel-based handover method. In the figure, oAR counts the number of hops of the BET (denoted by k) according to MN's movement from the anchor AR, as shown in Fig. 3.

When the hop count k reaches the pre-defined number p, the oAR send a message to request nAR(p) to change the corresponding anchor AR. Then the p-th AR is set as the new anchor AR. After receiving this requesting message, the MN sends the binding update (BU) message to the CN/HA through nAR(p) regardless of the existence of the MN within its coverage. After that, nAR(p) will maintain its BET with both oAR and the subsequent nAR(p+1) or nAR(p+2), and so on until the packets destined to the MN are forwarded to nAR(p), not oAR by successful BU. This

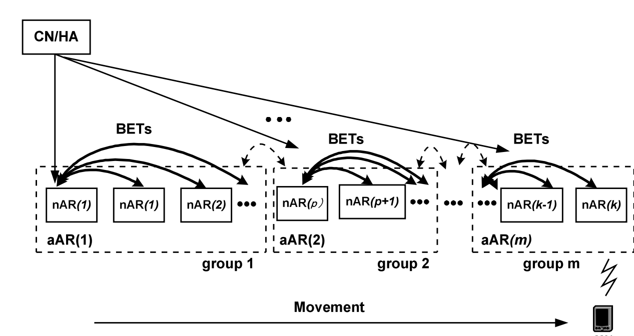
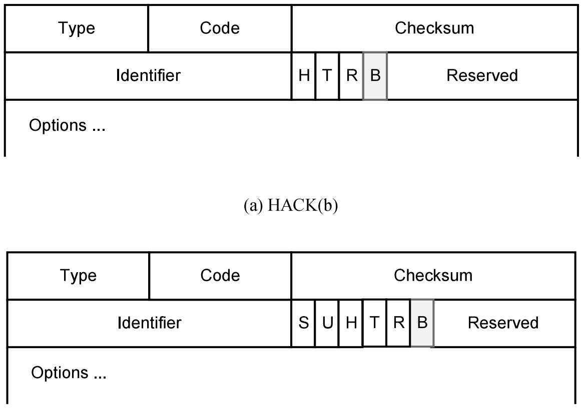


Fig. 2 Proposed enhancement of the tunnel-based handover.

- k=k+1 if currnet AR is a new one, which the MN has not passed by
- k=k-1 if current AR is not a new one, which the MN has already passed by
- k=0 if aAR is changed

where, k is the hop count of BET, an integer

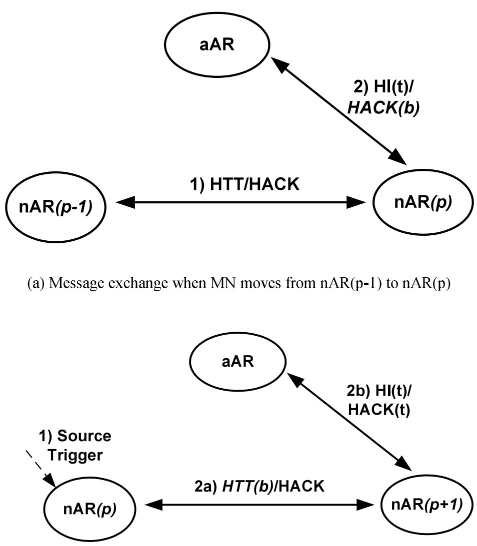
Fig. 3 Algorithm for calculation of hop counts of BET.



(a) HACK(b)

(b) HTT(b)

Fig. 4 Message format of HACK(b) and HTT(b).



(a) Message exchange when MN moves from nAR(p-1) to nAR(p)

(b) Message exchange when MN moves from nAR(p) to nAR(p+1)

Fig. 5 The exchange of the role as anchor AR.

is done for preventing packet loss and keeping the real-time property during the exchange of anchor AR. When a mobile node receives the packets through the nAR(p), the current nAR now removes the BET between oAR and current nAR. This procedure is repeated each time the hop counts of BET(k) becomes p.

In the proposed tunnel-based handover, any new message is not defined, except the messages to exchange the anchor role to nAR(p) and nAR($p+1$). These messages can be defined easily by using the existing HACK and HTT message of the existing tunnel-based protocol. We have named theses messages as HACK(b) and HTT(b). The format of HACK(b)/HTT(b) is shown in Fig. 4.

Only one difference with the existing HACK message is the B bit which was a bit in the reserved field in the existing message. If a AR receives HACK(b) message with B bit set to 1, the AR has to take a role of anchor AR and MN send BU to CN/HA through the AR, as described above.

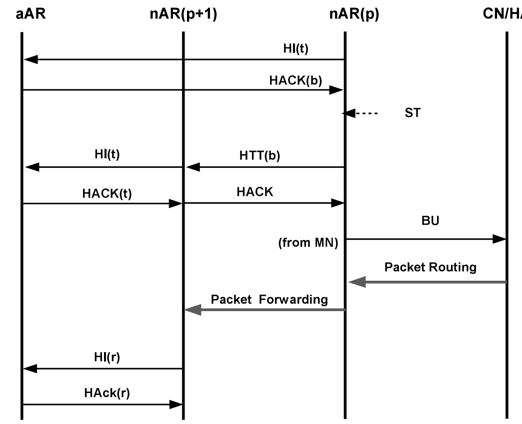


Fig. 6 Timing diagram of the proposed tunnel-based handover method.

Figure 5 illustrates the operations for exchange of anchor AR. In the figure, the source trigger is assumed. An aAR counts the hop counts of BET. If the number becomes $p-1$ and aAR receives HI(t), then aAR replies with HACK(b) so as to request nAR(p) to do a role of anchor AR as shown in Fig. 5(a). After that, when an MN is going to move from nAR(p) to nAR(p+1) and receives a prehandover trigger (source or target trigger), nAR(p) sends the HTT(b) message to nAR(p+1), which includes the information for requesting the exchange of anchor AR as well as for aAR as shown Fig. 5(b). HI(t) and HACK(t) were already defined in [1] and 't' indicates that these message were initiated by target AR (i.e. nAR) in [3].

The AR receiving HTT(b) establish BET with nAR(p) as well as aAR. Then MN sends the binding update message toward CN/HA through nAR(p). These two BETs are maintained even though the AR serving MN is changed, until the BU is succeeded and forwarded packets destined to MN arriving at current AR serving MN through nAR(p). It is for supporting the real-time property even during changing anchor AR. Current AR, receiving the forwarded packets destined to MN through nAR(p), removes the BET with aAR. Now the anchor AR in BET is changed from aAR to nAR(p). The procedure is repeated whenever the hop count of BET (k) becomes p.

Figure 6 shows the timing diagram of the proposed tunnel-based handover method.

4. Performance Comparisons

This section describes analytical comparison of the performance between the existing and proposed schemes. Throughout the analysis, we assume the following condition for simplicity:

- Each normal router (NR, i.e. not Access Router) in the backbone network is connected to two ARs as shown in Fig. 7;
- The movement of a mobile node is linear (i.e. unidirectional);
- A mobile node moves toward the CN.

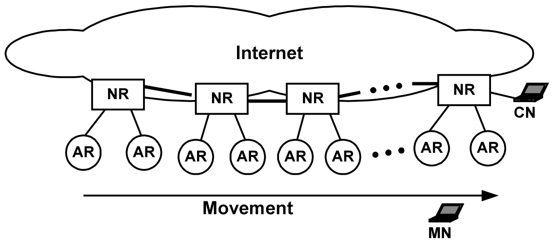


Fig. 7 Network architecture for analysis.

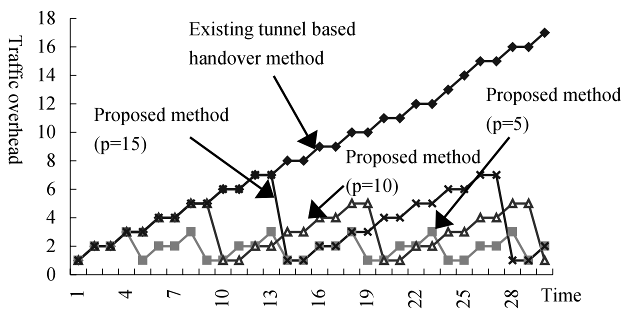


Fig. 8 Comparison of traffic overhead.

Figure 8 compares the existing tunnel-based handover and the proposed enhanced methods in terms of the traffic overhead required. The results in the figure were obtained by simply calculating the traffic amount required for each scheme, based on the movement pattern of the MN in the network of Fig. 6. The traffic overhead in the figure means the number of routers required to forward packet between CN and MN.

In the figure, the proposed method induces lower traffic overhead than the existing method. If we choose a lower value of p, the traffic overhead will be more decreased. However, the value of p should be chosen carefully by considering the network environment, since an excessively low value of p may require more frequent signaling.

5. Conclusions

In this paper, we have proposed a new handover scheme to enhance the existing tunnel-based handover method. The proposed method shows better performance by reducing the traffic overhead in the backbone network. It is expected that the proposed method will be more useful in the networks in which there are a number of subscribers using long-lived real-time services, or in the condition of traffic overhead is considered a serious performance measure.

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