

Handover management in wireless networks based on buffering and signaling

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Abstract

One of the main issues of Mobile IPv6 is handover latency that causes service disruption time. Although plenty of proposals significantly reduce the service disruption time provided the networks are well-overlapped, it is still recognizable in the handover between insufficiently overlapping networks or non-overlapping networks. In this paper, we propose a new scheme to minimize the service disruption in handover between domains. Our proposed scheme consists of new care-of address anticipation, buffering in access routers and signaling to invoke packet forwarding. In evaluation, we evaluate our scheme in the view of service disruption time, and finally, we clarify the effectiveness of our proposed scheme.

1. Introduction

Recently, IETF has been intensively working for the standardisation of Mobile IPv6, which enables mobility for mobile equipment. Mobile IPv6 specifies the operation of the IPv6[1] Internet with mobile nodes (MNs). Each MN is always identified by its home address, regardless of its current point of attachment to the Internet. While situated away from its home, an MN is also associated with a care-of address (CoA), which provides information about the MN's current location. IPv6 packets addressed to an MN's home address are transparently routed to its CoA. The protocol enables IPv6 nodes to cache the binding of the MN's home address with its CoA, and then send any packets destined for the MN directly to it at this CoA. To support this operation,

Mobile IPv6 defines extensions to IPv6 protocol. All IPv6 nodes, whether mobile or stationary can communicate with mobile nodes.[2]

However, Mobile IPv6 still contains some problems in handover since MN may encounter serious disruption of communication. To cope with this problem, plenty of researches have been proposed concerning layer 2 handover [3][4][5][6] and layer 3 handover [7][8][9]. However, though those proposals significantly reduce the service disruption time provided the networks are well-overlapped, the service disruption and packet losses are still recognizable in the handover between insufficiently overlapping networks or non-overlapping networks. The common problem is that those schemes simply discard packets in handover.

In this paper, we propose a new scheme to minimize the disruption in handover between domains, i.e. layer 3 handover. Our proposed scheme consists of new CoA (NCoA) anticipation, buffering in access routers (ARs) and signaling scheme to invoke packet forwarding. In evaluation, we evaluate our scheme in the view of service disruption time, and finally, we clarify the effectiveness of our proposed scheme.

2 Related Works

In this section, several related works are described. Researches on handover are categorized into 2 groups : layer 2 (L2) handover and layer 3 (L3) handover. L2 handover is the movement of MNs between access points (APs) belonging to a common subnet while L3 handover is the movement of MNs between APs belonging to a different domains. HAWAII [3] and Cellular IP [4]

represent the research on L2 handover. Those researches are focused on localizing the handover signaling. Although those schemes work well within the domain, they are not applicable when the CoA changes i.e. L3 handover.

When MN performs L3 handover, MN suffers handover latency, which includes the time for new prefix discovery on the new subnet, the time for NCoA establishment, and the time needed to notify the correspondents and home agent about the new locality of the MN. The major work for L3 handover is represented by the Route Optimization[7][8] and Fast Handover Protocol[9].

2.1 Route Optimization

One of the most generic solution for inter-domain mobility is route optimization. In [7], the basic concept of the route optimization is introduced though this draft is for MIPv4. This original concept is adopted to [8], and [9]. Foreign agent forwards the packets to the new foreign agent.

When an MN moves and registers with a new foreign agent (FA), the basic MIP protocol does not notify the MN's previous FA. IP datagrams intercepted by the home agent (HA) after the new registration are tunneled to the MN's NCoA, but datagrams in flight that had already been intercepted by the HA and tunneled to the old CoA when the MN moved are likely to be lost and are assumed to be retransmitted by higher-level protocols if needed. The old FA eventually deletes its visitor list entry for the MN after the expiration of the registration lifetime.

Route Optimization provides a means for the MN's previous FA to be reliably notified of the MN's new mobility binding, allowing datagrams in flight to the mobile node's previous FA to be forwarded to its NCoA. This notification also allows any datagrams tunneled to the MN's previous FA, from correspondent node (CN) with out-of-date binding cache entries for the MN, to be forwarded to its NCoA. Finally, this notification allows any resources consumed by the MN at the previous FA (such as radio channel reservations) to be released immediately, rather than waiting for its registration lifetime to expire.

In MIPv6, the basic concept of [7] was extended. Since MIPv6 does not have FA, this proposal uses the HA of previous network as a temporal HA of the MN in handover. When an MN connects to a new link and forms a NCoA, it may establish forwarding of packets from a previous CoA (PCoA) to this NCoA. To do so, the MN

sends a Binding Update to any HA on the link on which the PCoA is located, indicating this PCoA as the HA for the binding, and giving its NCoA as the binding's CoA. Such packet forwarding allows packets destined to the MN from nodes that have not yet learned the MN's NCoA, to be forwarded to the MN rather than being lost once the MN is no longer reachable at this PCoA.

This Binding Update is sent to a HA, albeit a temporary one. Nevertheless, the authentication requirements for Binding Updates from an MN to its HA apply. This means that the MN must employ IPsec ESP.

Although those schemes reduce the packet losses significantly, they still suffers handover latency due to the NCoA establishment and plenty of packet losses as later described in Section 3.2.

2.2 Fast Handovers for mobile IPv6

The Internet-Draft [9] proposes an extension of MIPv6 that allows an AR to offer services to an MN in order to anticipate the L3 handover. This protocol consists of three phases: handover initiation, tunnel establishment and packet forwarding. The overview of this protocol is described in Fig. 1.

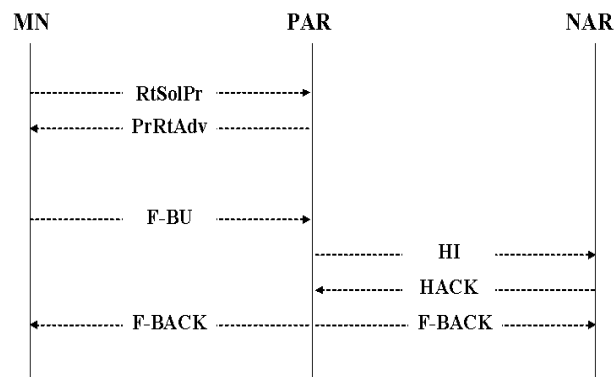


Figure 1. Fast Handover protocol overview

2.2.1 Handover Initiation

The protocol is initiated when an event, such as a decision to handover the MN to a new point of attachment, occurs. It is the MN that responds to such a trigger by requesting its AR to assist in handover by sending a Router Solicitation for Proxy (RtSolPr) message in which it includes the link-layer identifier of its prospective attachment point. In response to RtSolPr message, the previous AR (PAR) sends a Proxy Router Advertisement (PrRtAdv) message, which provides the

link-layer address, and network prefix information about the new AR (NAR). In the network-initiated handover, the PAR sends PrRtAdv message without the MN sending RtSolPr message. This procedure enables the MN to send packets immediately upon connecting to the NAR.

2.2.2 Tunnel Establishment and Packet Forwarding

After receiving a PrRtAdv message, the MN sends a Fast Binding Update (F-BU) to PAR. This F-BU message associates the MN's PCoA with NAR's IP address so that packets arriving at the PAR can be tunneled to the NAR. In response, the PAR sends a Handover Initiate (HI) message to the NAR. The HI message serves two purposes. First, it initiates establishing a bidirectional tunnel between the two routers so that the MN can continue to use PCoA for its existing sessions. Second, it serves to verify if NCoA can be used on NAR's link. In response to processing the HI message, the NAR sets up a host route for the MN's PCoA and responds with a Handover Acknowledge (HACK) message. When the NCoA could be used, the NAR begins to proxy that address for a short duration.

After it receives a HACK message, the PAR sends a Fast Binding Acknowledgment (F-BACK) message to the MN. The F-BACK message confirms whether the NCoA could be used, only after which the MN must use the NCoA on the new link.

Although this scheme significantly reduces the handover latency, some extensions are necessary unless the networks are overlapped enough to perform Fast Handover protocol. From the other point of view, this scheme requires MN for additional protocol procedure other than MIPv6 protocol. Therefore, some second best protocol without any modification to MN should also be considered.

3 Proposed Scheme

Our proposed scheme consists of the following 3 parts: NCoA anticipation, Buffering and packet forwarding.

3.1 NCoA anticipation

Although the Fast Handover protocol is not applicable on the network that does not have sufficient overlapping, the anticipation of the NCoA mentioned in Section 2.2 significantly reduces the

handover latency. Therefore, the extension to the Fast Handover protocol is introduced here.

When the MN or the network realized that the connectivity to the MN is below a certain threshold value, the MN sends RtSolPr as described in the protocol even though the MN still does not acquire the link-layer identifier of its prospective attachment point.

In this case, the PAR need to inform information concerning an available list of corresponding neighborhood AR since the MN did not inform the link-layer identifier of its prospective attachment point. The neighborhood ARs are obtained by the following procedure: When an MN came into an AR's service area by handover, the MN informs the AR the PAR information. The message to inform the PAR information might be Fast Binding Update message, ICMP handover information message, Binding Update message or some L2 messages depending on the policy and the protocol of the network. The obtained information about PAR is stored inside the AR for each BSs with reasonable timeout values and is used as the neighborhood ARs information. This information may also depend on the policy of the network administration.

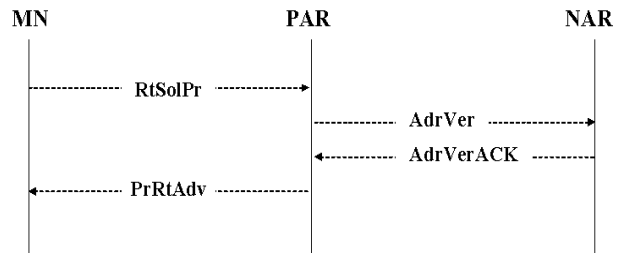


Figure 2. AdrVer and AdrVerACK messages

In the insufficiently overlapping networks or non-overlapping networks, it is possible that the MN cannot send F-BU message before the handover or that the MN cannot receive F-BACK message before the handover even though MN can send F-BU before the handover. Since MN cannot use NCoA until it receives F-BACK message, the waiting time for the F-BACK message causes service disruption time. Therefore, the MN needs to acquire NCoA before handover. When PAR receives RtSolPr, the PAR send address verification (AdrVer) message that includes the candidate NCoA decided by the PAR to NARs. Upon receiving the AdrVer message, the possible NARs reserve the NCoA for the MN. If the requested NCoA is already reserved, the NAR may assign and reserve another NCoA for the MN. Then the NAR responds with the AdrVer acknowledgement (AdrVerACK) message, which

includes the authenticated PAR. Upon receiving those AdrVerAck messages from the possible NARs, the PAR sends PrRtAdv message with a set of NCoAs to the MN.

Since the possibility of an interface identifier duplication on the same subnet is very low, reserving NCoA on several network might not affect on those networks. However, this scheme using AdrVer to reserve the CoA before F-BU should be applied only for the case that the RtSolPr message contains no link-layer identifier of its prospective attachment point. In that case, the Fasthandover Protocol may be performed instead of our proposed scheme.

3.2 Buffering and Packet Forwarding

With the scheme mentioned in [7], [8], and [9], handover goes very smoothly if the related 2 networks are well-overlapped. However, these schemes do not take care of those packets sent to the MN before the establishment of tunnel.

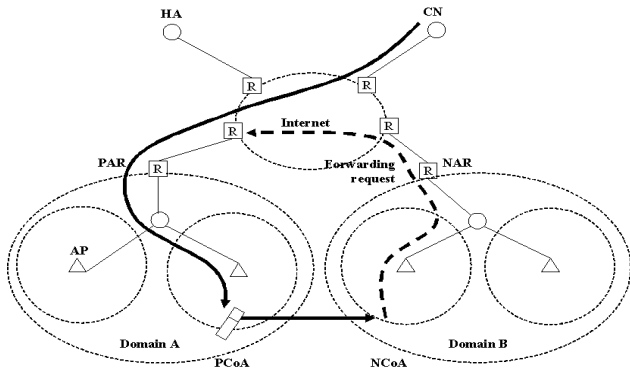


Figure 3. Lost packets in handover

In the network described in Fig. 3, the MN cannot receive those packets sent from PAR to PCoA, which arrive to the AP after the MN has left Domain A. This situation continues until the PAR is requested to forward packets. Those packets are simply discarded inside the network. Although those lost packets are reduced if the network is somehow overlapping, the lost packets should be avoided as much as possible in any case.

In this section, we propose a new scheme that takes care of the lost packets before the establishment of tunnel, especially for the handover between networks that have insufficient overlapping for Fast Handover. The PAR replicates the packets destined to the MN and saves the replicated packets into its buffer. The detailed procedures are described as follows:

[buffering request]

When the possibility of handover is detected, the MN sends buffering request message to the PAR. Since the handover does not occur as soon as the possible better network is temporarily detected, the MN still has some time before the actual handover. That enables the PAR to prepare the handover. In a network-controlled handover, those procedures are not required since PAR realizes the possibility of handover without the MN requesting it.

The message was invoked by the L2 trigger, which should be defined depending on the each network. It is possible that this buffering request message is included inside the RtSolPr message.

[buffering start]

Upon receiving the buffering request message, the PAR starts buffering. The scheme to determine the buffering size is described in Section 3.3. Insofar as the buffering request message is valid, the PAR keeps buffering. However, since the buffering request message is a stateless message, the PAR stops buffering provided the timeout expires. The network or MN may retransmit the buffering request message when necessary.

After this point, the procedure in handover varies depending on the network. Each detailed procedure is described below. If the networks are sufficiently overlapping and support Fast Handover, the MN performs the Fast Handover procedure. If the networks are sufficiently overlapping, but NAR do not support Fast handover, the MN takes the procedure described in Section 3.2.1. If the networks are not sufficiently overlapping, the MN takes the procedure described in Section 3.2.2. If the networks are not sufficiently overlapping and the MN only supports Mobile IPv6 protocol, the MN takes the procedure described in Section 3.2.3.

3.2.1 Overlapping network without NAR support (Scheme 1)

Although the Fast Handover protocol works effectively, the protocol requires NAR to create host route before handover [9]. To achieve that, the NAR should be known by PAR some times before the handover since the F-BACK message should be sent to the MN (Preferred to the PCoA). If the PAR receives RtSolPr message without any information of MN's prospective attachment point, the networks for handover might not have enough overlapping to achieve Fast Handover protocol. Or if NAR does not support the Fast Handover protocol while PAR supports it, the MN takes this scheme. Fig. 4 shows the procedure of this scheme.

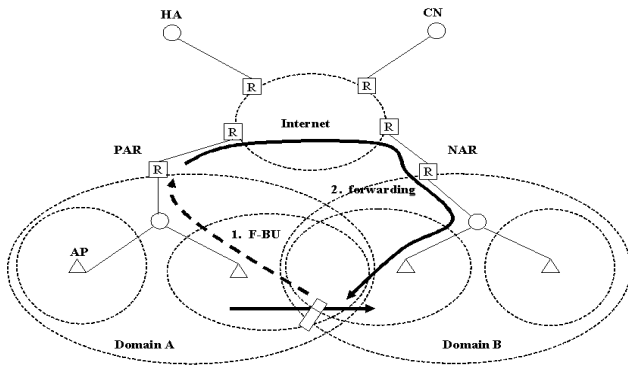


Figure 4. Scheme 1

The MN informs the handover to PAR by sending F-BU message just before the handover. If the handover is initiated by MN, the MN needs to acquire the link-layer identifier of MN's prospective attachment point by this time. Then the MN puts NCoA inside the F-BU message. Upon receiving the message, the PAR starts forwarding packets to the NCoA by encapsulation instead of forwarding them to the NAR. If the handover is initiated by network, the F-BU message is optional. If the MN cannot send F-BU message directly due to the insufficient network overlapping, the MN utilizes the scheme 2 or the scheme 3 described later.

As described in [9], The MN cannot send any packet to CN with NCoA until the MN finishes binding update procedure. When MN sends packets to CN before finishing binding update procedure, the from field should be PCoA and then, the IP packet is encapsulated in another IP packet whose from field is NCoA and whose destination field is PAR. Upon receiving the encapsulated packet, the PAR decapsulates the packet and sends the inside IP packet to the CN. This also applies to scheme 2 and scheme 3.

3.2.2 Non-overlapping Network with NAR support (Scheme 2)

This scheme is used when neither Fast Handover protocol nor scheme 1 is available due to the networks' insufficient overlapping. Fig. 5 shows the procedure of this scheme.

The PAR might detect the MN's handover though this detection is not the concerning of this paper. If a PAR detects the handover, the PAR stops sending packets destined to the PCoA while the PAR still continues buffering those packets.

Upon obtaining the NCoA, the MN sends Binding Update message of Mobile IPv6. In this message, the mobile node adds the information of PAR address in the mobility options field. If the

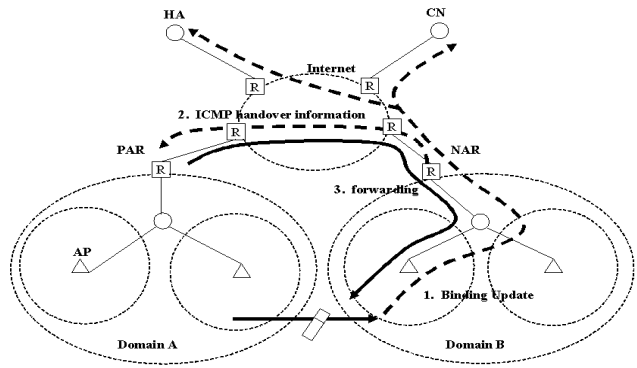


Figure 5. Scheme 2

NAR cannot recognize the new option defined in this document, the option is silently ignored, and normal Mobile IPv6 procedure is performed.

When the NAR intercept the binding update message from MN to home agent (HA), the NAR sends ICMP handover information message to the PAR. Upon receiving the ICMP handover information message, the PAR starts forwarding the packets to NCoA preceded by the buffered packets.

3.2.3 Non-overlapping network with general MN (Scheme 3)

This scheme is used when neither Fast Handover protocol nor scheme 1 is available due to the networks' insufficient overlapping. When MN does not support any extra protocol extension, this scheme should be used. Fig. 6 shows the procedure of this scheme.

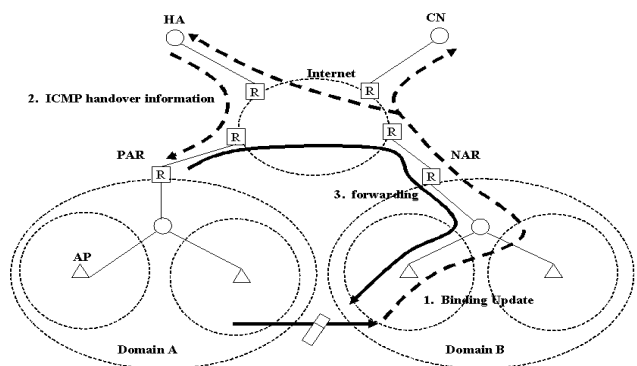


Figure 6. Scheme 3

As with Scheme 2, the PAR might detect the MN's handover though this detection is not the concerning of this paper. If a PAR detects the handover, the PAR stops sending packets destined to the PCoA while the PAR still continues buffering those packets.

Upon obtaining the NCoA, the MN sends Binding Update message of Mobile IPv6 as defined in Mobile IP protocol. When the HA receives the binding update message from MN, the HA sends ICMP handover information message to the PAR. Upon receiving the ICMP handover information message, the PAR starts forwarding the stream to NCoA preceded by the buffered stream.

This scheme is effective provided the HA is very close to both PAR and NAR. In the current draft of Mobile IPv6, one MN can contain multiple HAs. To find the suitable HA for this handover, the possible HAs and ARs have to exchange information periodically. And the router advertisement of the NAR may contain the preferred HA's information.

This scheme has another option. When the buffering request message was sent, the PAR can start forwarding packets to the MN's HA instead of starting buffering. Then, the HA starts buffering. In this situation, when the HA receives Binding Update message from NCoA, the HA starts forwarding the buffered stream.

In both options, this scheme does not require any notification of both PCoA and NCoA from MN like F-BU (scheme 1) and ICMP handover information (scheme 2) since HA has already known both addresses.

Table 1. Requirements (MN handover)

Protocol	Modification for Network	Modification for MN
Fast Handover	PAR, NAR	RtSolPr, F-BU
Scheme 1	PAR	F-BU
Scheme 2	PAR, NAR	(Option to Binding Update)
Scheme 3	PAR, HA	—

Table 2. Requirements (network handover)

Protocol	Modification for Network	Modification for MN
Fast Handover	PAR, NAR	—
Scheme 1	PAR	—
Scheme 2	PAR, NAR	(Option to Binding Update)
Scheme 3	PAR, HA	—

As the end of this chapter, the list of protocol extension requirements is summarized in Table 1 for MN-initiated handover and in Table 2 for network-initiated handover. The Option to Binding Update at Scheme 2 is not necessary provided the MN successfully achieved the NCoA prediction described in Section 3.1.

3.3 Buffer size

There are several ways to determine the buffer size of PAR. One of the easiest ways to determine the buffer size is determining it manually beforehand. For instance, according to the contract between subscribers, the operator decides the size. However, too much buffering does not give us any advantage since audiovisual stream has strict timestamp to be decoded.

The other way to determine the buffer size is determining it dynamically. Although we have to use normal IPv6 handover procedure when handover between two networks occurs at the first time, we can use the previous handover information when the handover occurs again. The buffer size depends on how large those networks are overlapping. The larger the degree of overlapping, the smaller size is the buffer. The smaller the degree of overlapping, the larger size is the buffer. The buffer size issue should be studied more for the future work.

If the buffer does not have any spared buffer for new handover, the MN simply proceed to the normal handover process like mobile IPv6.

4 Evaluation

In this section, our proposed scheme is evaluated. Although NCoA anticipation mentioned Section 3.1 is very effective to lessen the L3 handover latency, we don't evaluate it here since the effectiveness was obvious from [7]. The difference between them is whether the scheme is for the overlapping network or not. Here, we evaluate the effectiveness of the buffering and the comparison between those proposed signaling schemes.

4.1 Buffering Efficiency

To evaluate our buffering scheme, we evaluated the buffer model of MN when using a streaming application with playout buffer. Fig. 7 shows the comparison between the proposed scheme and the conventional scheme in the view of buffer model. Here, t_0 denotes the time that the MN leaves the previous mobile network, and t_1 denotes the time that the MN receives the first data packet in the new mobile network. The MN decodes the packets so long as the MN has some packets to be decoded in its buffer. The MN decodes packets according to the time stamp of the packets in its buffer. Fig. 7 assumes that the incoming stream is constant bit rate (CBR) traffic in the unit of packet, and that the MN decodes packets with CBR in the unit of byte.

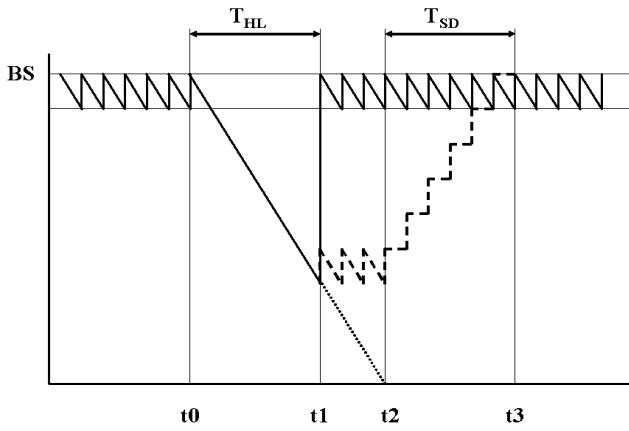


Figure 7. Buffer model with sufficient playout

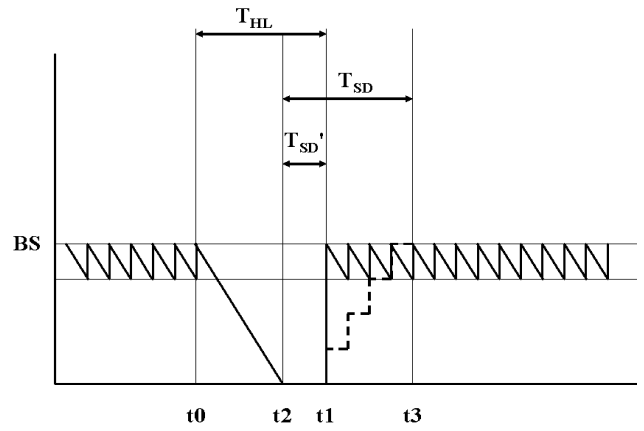


Figure 8. Buffer model with insufficient playout

The dashed line in Fig. 7 shows the conventional scheme. At t_2 , the MN has no packets to decode though the buffer still contains packets. This is because the packets that the MN contains are those ones that should be decoded after t_3 . Therefore, during the time between t_2 and t_3 , the MN does not decode any packet and it stores the received packets. As can be seen, the non-decoding period denoted as T_{SD} is the service disruption time for the conventional scheme.

The solid line in Fig. 7 shows the proposed scheme. Although the original traffic from CN to MN is CBR, the forwarded traffic from PAR to MN is a burst stream since the PAR sends the buffered packets as soon as possible. Here, the transmission time for those burst packets were considered as 0 second for simplicity. As can be seen, this proposed scheme has no service disruption time.

If we denote the disruption time for the proposed scheme as T'_{SD} , those values are equal to the equation 1. Here, T_{HL} denotes the time between t_0 and t_1 , which is the total handover latency.

$$\begin{cases} T_{SD} = T_{HL} \\ T'_{SD} = 0 \end{cases} \quad (1)$$

However, if the buffer became empty before t_1 , i.e. if $BS > b_{out} \times T_{HL}$, our proposed scheme also suffers from service disruption. Here, b_{out} is the bitrate of CBR traffic. But even in that case, the duration of service disruption time is significantly reduced compared to the conventional scheme.

Fig. 8 shows the case of the insufficient buffer. When the handover delay is too long compared to the buffer size, or when the stream has a small playout buffer, this situation occurs. The service disruption time for conventional scheme and pro-

posed scheme is described in equation 2.

$$\begin{cases} T_{SD} = T_{HL} \\ T'_{SD} = T_{HL} - \frac{BS}{b_{out}} \end{cases} \quad (2)$$

Although the service disruption time for conventional scheme is always T_{HL} , the one for proposed scheme is nought or no more than T_{HL} .

4.2 Signaling Delay

The topology we assume for the case study is shown in the figure 9.

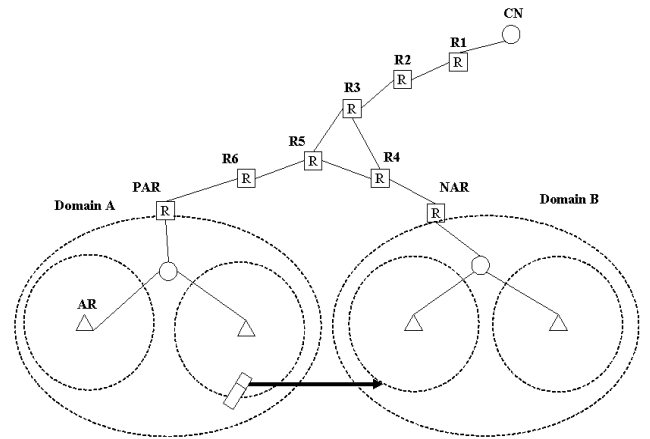


Figure 9. Topology for the case study

Here, each node causes 10msec queuing, and the bitrate is 10Mbps for each wired network and 1Mbps for each wireless network. Now, MN is receiving CBR traffic from CN to MN. We assume the MN is small mobile like mobile phone or mobile communicator that has only a small-resolution screen and a small buffer.

The topology shown in the figure 9 causes packet losses and service disruption time in handover as calculated in Table 3.

Table 3. Disruption time for each scheme

Protocol	Disruption time
Fast Handover	60msec
Scheme 1	60msec
Scheme 2	100msec
Scheme 3_1	100msec
Scheme 3_2	60msec

Here, Scheme 3 assumes that the router R5 works as an HA in this evaluation. Scheme 3_1 is the scheme that the buffering is performed inside the PAR (option 1) while Scheme 3_2 is the scheme that the buffering is performed inside the HA (option 2).

As can be seen, if MN can send message from the previous network to PAR (Fast Handover, Scheme 1), the disruption time is much shorter than the one in the case that MN sends the message from the new network to PAR. Therefore, it is natural that MN first tries to proceed in the Fast Handover scheme or Scheme 1. The option 2 of Scheme 3 can significantly reduce the disruption time even though the request message was sent from the new network. But to obtain the advantage of this scheme, MN needs to find the HA between PAR and NAR. The HA should be between PAR and NAR. The closer to NAR the HA is, the less disruption time does the MN suffer. However, the farther from PAR the HA is, the more network resource consumption occurs. There is a trade-off between disruption time and network resource consumption. For instance, if the NAR can work as HA of the MN, the disruption time is significantly reduced. However, the network resource between PAR and NAR is getting crowded even if the actual handover does not occur. Indeed, if the handover does not occur at all, the forwarded packets to the HA simply waste of the network resources.

5 Conclusion

To enable smooth inter-domain handover for mobile IP, we proposed a scheme consisting of NCoA anticipation, a buffering scheme and signaling schemes to invoke the packet forwarding. A case study shows the efficiency of our buffering scheme. Likewise, the effectiveness of our signalling scheme was shown by calculating the reduction of the disruption time. Even if the

MN supports only Mobile IPv6 without any extensions, the MN can benefit from our buffering scheme. Although our proposed scheme is described based on Mobile IPv6, it is also applicable to Mobile IPv4. Our scheme is completely compatible with Mobile IPv6, and other proposals concerning micromobility are also applicable to our proposal. Although this paper clarified the basic efficiency of our inter-domain handover scheme, we still need future work, with topics such as dynamic HA protocol, home computer working as a HA, authentication issues, simulation experiments with random number of mobile nodes.

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