Network Working Group
Internet-Draft
Expires: August 5, 2006

H. Yokota
KDDI R&D Laboratories, Inc.
G. Dommety
Cisco Systems, Inc.

February 2006

Mobile IPv6 Fast Handovers for 3G CDMA Networks
draft-yokota-mipshop-3gfh-02.txt

Status of this Memo

Copyright Notice

Abstract

Mobile IPv6 is designed to maintain its connectivity while moving from one network to another. It is adopted in 3G CDMA networks as a way to maintain connectivity when the mobile node moves between access provider networks. However, this handover procedure requires not only movement detection, but also the acquisition of a new care-of address and the sending of a binding update message to the home agent before the traffic begins to direct to the new location.

During this period, packets destined for the mobile node will be lost, which may not be acceptable for real-time application such as Voice over IP (VoIP) or video telephony. This document specifies fast handover methods and selective bi-casting methods in the 3G context in order to reduce latency and packet loss during handover.

Table of Contents

1. Requirements notation 3
2. Introduction 4
3. Terminology 5
4. Network reference model for Mobile IPv6 over 3G networks . . . 6
5. Fast handover procedures 10
  5.1 Predictive fast handover 10
  5.2 Reactive fast handover 14
6. Selective bi-casting 18
  6.1 Bi-casting by the PAR to the MN with multiple interfaces (A-1) 20
  6.2 Bi-casting by the HA to the MN with multiple interfaces (A-2) 21
  6.3 Bi-casting by the PAR to the MN with a single interface (B-1) 22
  6.4 Bi-casting by the HA to the MN with a single interfaces (B-2) 24
  6.5 Message Format 26
    6.5.1 Simultaneous bindings flag and the HI message indication flag extensions to (F)BU message 26
    6.5.2 New mobility option for bi-casting lifetime 27
    6.5.3 New status code for simultaneous bindings 27
    6.5.4 New Option for vendor-specific information 28
  6.6 MN and AR/HA operations 29
7. Security Considerations 30
8. Conclusions 31
9. References 31
   Authors' Addresses 32
   Intellectual Property and Copyright Statements 33

1. Requirements notation

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [1].

2. Introduction

Mobile IPv6 allows mobile nodes (MNs) to maintain persistent IPv6 addresses while roaming around in IPv6 networks and it is adopted in 3G CDMA networks for handing off between different access provider networks [2]. During handover, however, the mobile node (MN) needs to switch the radio networks, to obtain a new Care-of Address (CoA) and to re-register with the home agent (HA), which causes a communication disruption. This is not desirable for real-time applications such as VoIP and video telephony. To reduce this disruption time or latency, a fast handover protocol for Mobile IPv6 [3] is proposed. In this proposal, there are two modes called "predictive" fast handover and "reactive" fast handover. This document first specifies how these fast handover modes can be applied in the 3G context and shows that several Mobile IPv6 bootstrapping procedures can be omitted. If the MN has more than one network interface, even smoother handover can be realized by transmitting packets destined for the MN to both networks, where the mobile node resides and will move to. This document defines this mechanism as selective bi-casting and shows several use cases with their handover procedures.

3. Terminology

This document refers to [2] for Mobile IPv6 fast handover terminology. Terms that first appear in this document are defined below:

Forward Pilot Channel:
A portion of the Forward Channel that carries the pilot. The Forward Channel is a portion of the physical layer channels transmitted from the access network to the MN.

Sector:
Part of the access network that provides one CDMA channel. The area covered by one base station may be split into several sectors.

Home Link Prefix (HLP):
The prefix address assigned to the home link where the MN should send the binding update message. This is one of the bootstrap parameters for the MN.

Packet Data Serving Node (PDSN):

An entity that routes MN originated or MN terminated packet data traffic. A PDSN establishes, maintains and terminates link layer sessions to MNs [2]. A PDSN can be the access router in the visited access provider network.

4. Network reference model for Mobile IPv6 over 3G networks

Figure 1 shows a simplified reference model of the Mobile IP enabled 3G networks. The home agent (HA) of the mobile node (MN) resides in the home IP network and the MN roams around the access provider networks. The home network and the access provider networks are managed by either the same or different operator(s). Prior to the Mobile IPv6 registration, the MN establishes a link-layer connection with the access router (AR), which is also called PDSN (Packet Data Serving Node) in 3G networks, of the access provider network to which the MN is attached. When the MN moves from one access provider network to another, a Mobile IPv6 handover is performed. The figure shows the situation, where the MN moves from the PAR (previous access router) to the NAR (new access router) and in the case of 3G networks, the PAR and the NAR are equivalent to the oPDSN (old PDSN) and the nPDSN (new PDSN).

```
                                  Home IP Network
                             +........................+
                             . +--------+  +--------+ .
                             . |   HA   |--|  AAA   | .
                             . +--------+  +--------+ .
                             +../......\..............+
                               /        \
             Access Provider Network   Access Provider Network
                  +.............+      +.............+
                  . +---------+ .      . +---------+ .
                  . |   PAR   | .      . |   NAR   | .
                  . | (oPDSN) | .      . | (nPDSN) | .
                  . +---------+ .      . +---------+ .
                  .   |    :|   .      .   :|    |   .
                  .   |    :|L2link  L2link:|    |   .
                  .   |    :|   .      .   :|    |   .
                  . +--+  +:--+ .      .  +:--+ +--+ .
                  . |BS|  |:BS| .      .  |:BS| |BS| .
                  . +--+  +:--+ .      .  +:--+ +--+ .
                  .        :|   .      .   :|        .
                  .      +----+ .      .  +----+     .
                  .      | MN |---------> | MN |     .
                  .      +----+ .      .  +----+     .
                  +.............+      +.............+
```

Figure 1: Reference Model for Mobile IP

In 3G CDMA networks, pilot channels transmitted by base stations allow the MN to obtain a rapid and accurate C/I (carrier to interference) estimate. This estimate is based on measuring the strength of the Forward Pilot Channel or the pilot, which is associated with a sector of a base station (BS). The MN searches for the pilots and maintains those with sufficient signal strength in the pilot sets. The MN sends measurement results, which include the offsets of the PN (pseudorandom) code in use and the C/Is in the pilot sets, to provide the access network (AN) with the estimate of sectors in its neighborhood. There are several triggers for the MN to send those estimates, e.g. when the strength of a pilot in the pilot sets is higher enough than that of the current pilot, the MN sends the estimates to the access network. If the serving access network finds that the sector associated with the highest pilot strength belongs to a different AR, it attempts to close the connection with the MN. The MN then attempts to get a new traffic channel assigned in the new access network, which is followed by establishing a new connection with the new AR. The MN can continually search for pilots without disrupting the data communication and a timely handover is assisted by the network. If the air interface information can be used as a trigger for the handover between access routers, fast and smooth handover of Mobile IPv6 can be realized in 3G CDMA networks.

To assist the handover of the MN to the new AR, various types of information can be considered: the pilot sets, which include the candidates of the target sectors or BSs, the cell information where the MN resides, the serving nodes in the radio access network and the location of the MN if available. In this document, a collection of such information is called "handover assist information". In 3G networks, the link-layer address of the new access point defined in [3] may not be available. If this is the case, the handover assist information SHOULD be used instead.

Figure 2 shows the protocol sequence from the attachment to the network to the Mobile IPv6 registration. After the traffic channel is assigned, the MN first establishes a link-layer connection between itself and the access router. As the link-layer protocol, PPP can be considered and in this figure, a PPP handshake is depicted as an example. Then the MN registers with the HA by sending a Binding Update message. There are several parameters for using Mobile IPv6 such as the home address (HoA), the care-of address (CoA), the home agent address (HA) and the home link prefix (HLP). These addresses are required prior to sending a Binding Update and obtaining these values is called bootstrapping. One such method is proposed in [5], where the bootstrapping information is obtained during the link-layer establishment phase.


```
              MN                       AR             HA            AAA
```

```
        +--      |                    (PDSN)           |              |
        |        |         LCP          |              |              |
        |(1)     |<-------------------->|              |              |
        |        |     CHAP or PAP      | Access-Request/Accept       |
        |(2)     |<-------------------->|<---------|----------------->|
        |        |                +------------+   |   |              |
        |(3)     |                | HA,HLP,HoA |<--+   |              |
        |        |                +------------+       |              |
        |        |    IPv6CP(IF-ID)     |              |              |
        |(4)     |<--------|----------->|              |              |
    (a)<     +---------+   |            |              |              |
        |(5) | LL-addr |<--+            |              |              |
        |    +---------+                |              |              |
        |        |     RA(prefix)       |              |              |
        |(6)     |<-----|---------------|              |              |
        |     +-----+   |               |              |              |
        |(7)  | CoA |<--+               |              |              |
        |     +-----+                   |              |              |
        |        |   DHCPv6(HA,HLP,HoA) |              |              |
        |(8)     |<-----------|-------->|              |              |
        |    +------------+   |         |              |              |
        |(9) | HA,HLP,HoA |<--+         |              |              |
        |    +------------+             |              |              |
        *--      |                      | BU           |              |
    (b)          |------------------------------------>|Authentication|
                 |                      |              |  query/reply |
    (c)          |                      |              |<------------>|
                 |                      | BA           |              |
    (d)          |<------------------------------------|              |
                 |                      |              |              |
```

Figure 2: MIPv6 operation in 3G network

The procedure for the initial registration is as follows:

(a) The link-layer connection establishment and the bootstrapping phase

(a-1) The LCP configure-request/response messages are exchanged.

(a-2) CHAP or PAP authentication is conducted.

(a-3) The bootstrapping parameters are conveyed from the HA and stored in the AR (PDSN).

(a-4) Unique interface IDs are negotiated in IPv6CP.

(a-5) The MN configures its link-local address based on the obtained interface ID.

(a-6) A router advertisement containing the prefix is received by the MN.

(a-7) The MN configures its CoA based on the obtained prefix.

(a-8) DHCPv6 is used to obtain the bootstrap parameters such as the home agent address, the home link prefix and the home address.

(a-9) The MN configures its HoA based on the obtained parameters.

(b) A binding update is sent to the HA.

(c) The HA asks the AAA to authenticate the MN for the initial registration.

(d) The binding acknowledgment is sent back to the MN.

As is shown in Figure 2, it takes a considerable amount of time to establish a link-layer connection and all of the above sequences run every time the MN attaches to a new access network. It is therefore beneficial if packets on the fly to the MN are saved not only during the time period where the MN switches to the new radio channel but also during the time period where the MN establishes the link-layer connection.

5. Fast handover procedures

There are two modes defined in [3] according to the timing of sending FBU (Fast Binding Update); one is called "predictive mode," where the MN sends FBU and receives FBAck (Fast Binding Ack) on PAR (Previous Access Router)'s link and the other is called "reactive mode," where the MN sends FBU from NAR (New Access Router)'s link. In the predictive mode, the time and place the MN hands off is indicated sufficiently before the time it actually happens. In cellular systems, handovers are controlled by the network and the predictive mode is well applied although the reactive mode is possible as well. On the other hand, in wireless LAN networks, for example, the MN controls its handover and it is not easy to know where it moves to until it starts to scan the channels. In this case, the reactive mode is well applied.

5.1 Predictive fast handover

Figure 3 shows the predictive mode of MIPv6 fast handover operation. When the MN finds a sector or a BS whose pilot signal is sufficiently strong, it initiates handover according to the following sequence:

(a) A router solicitation for proxy router advertisement is sent to the PAR.

(b) A proxy router advertisement containing the prefix in the NAR is sent back to the MN.

(c) The MN creates an NCoA (new CoA) and sends the Fast Binding Update (FBU) storing the NCoA to the PAR, which in turn sends the Handover Initiate (HI) to the NAR.

(d) The NAR sends the Handover Acknowledge (HAck) back to the PAR, which in turn sends the FBU acknowledgment (FBAck) to the MN.

(e) The PAR starts forwarding packets toward the NCoA and the NAR captures and buffers them.

(f) The connection associated with the PAR is closed and the traffic channel is assigned in the new access network.

(g) The MN establishes the link layer connection with or without authentication.

(h) The MN sends the Fast Neighbor Advertisement (FNA).

(i) The NAR starts delivering packets to the MN.

(j) The MN sends the BU to the HA.

(k) The HA sends the BA back to the MN.

(l) The HA starts delivering packets to the MN via the NAR.

```
         MN            PAR             NAR            HA             AAA
         |    RtSolPr   |               |              |              |
    (a)  |------------->|               |              |              |
         |    PrRtAdv   |               |              |              |
    (b)  |<-------------|               |              |              |
         |      FBU     |      Hl       |              |              |
    (c)  |------------->|-------------->|              |              |
         |     FBack    |     HAck      |              |              |
    (d)  |<-------------|<--------------|              |              |
         |              |forward packets|              |              |
    (e)  |              |==============>|              |              |
         |              |         +-----------+        |              |
         |              |         | buffering |        |              |
         |              |         +-----------+        |              |
    (f) handover        |               |              |              |
         |              | link layer connection        |              |
    (g)  |/----------------------------\|/...........................\|
         |\----------------------------/|\.........................../|
         |             FNA              |              |              |
    (h)  |----------------------------->|              |              |
         |       deliver packets        |              |              |
    (i)  |<=============================|              |              |
         |              |    BU         |              |              |
    (j)  |------------------------------------------->|              |
         |              |    BA         |              |              |
```

```
 (k)  |<-------------------------------------------|                    |
      |       deliver packets       |              |                    |
 (l)  |<============================|<=============|                    |
```

Figure 3: MIPv6 Fast handover operation (predictive mode)

It is assumed that the NAR can be identified by the PAR leveraging the handover assist information from the MN. To perform the predictive mode, the FBAck MUST be received by the MN before the connection with the current access network is closed. If the MN fails to send the FBU before handover, it SHOULD fall back to the reactive mode. Even if the MN successfully sends the FBU, its reception by the PAR may be delayed for various reasons such as congestion. If the NAR receives the HI triggered by the delayed FBU after the reception of the FNA ((c) comes after (h)), then the NAR

SHOULD send the HAck with handover not accepted.

In (a), RtSolPr MUST include the MN and the New Access Point Link-Layer Address (LLA) options according to [3]. As for the MN-LLA option, the only available identifier is the interface ID, so it SHOULD be used for the MN-LLA. As for the New AP-LLA, the handover assist information may be applied. Since the LLA is assumed to be an IEEE identifier, even if the length field of the LLA option is in units of 8 octets, the actual length can be obtained by knowing that the length of an IEEE identifier is 6 octets. If the interface ID of the MN is generated in the EUI-64-based format, the MN-LLA can be constructed from it. However, if the LLA is not well-known, the length of the LLA becomes ambiguous. If this is the case, it is necessary to use a new option defined in Section 6.5.4 and the corresponding length in it.

In (b), PrRtAdv MUST include options for the LLA, IP address and prefix of the NAR. The PAR SHOULD be able to identify the NAR from the handover assist information provided by the MN.

There are several ways to configure a unique IP address for the MN. If a globally unique prefix is assigned per each link as introduced in [5], the MN can use any interface ID except that of the other peer to create a unique IP address. If this is the case, however, the PAR cannot provide the MN with a correct prefix for the new network since such a prefix is selected by the NAR and provided in the router advertisement ((a-6) in Figure 2). Still, the NCoA MUST be included in the FBU for the PAR to resolve the IP address of the NAR, so that the MN configures a temporary NCoA with the prefix of the NAR and the correct NCoA MUST be assigned by the NAR. Therefore, in (c), the PAR MUST send the HI with the S flag set when it receives the FBU from the MN. On the other hand, if more than one MN connected to an AR share the same prefix, each MN MUST have a unique interface ID. Unless it is guaranteed that each MN connected to the network including a roaming case is preconfigured with a unique interface ID, it MUST be agreed or provided by the NAR via the HI/Hack exchange.

In [3], the FNA MUST include the LLA of the MN, but the point-to-point link layer connection makes it unnecessary. The only required information is the NCoA to check if there is a corresponding buffer, thus in (h), the function of the FNA can be realized in several ways.

- Since the establishment of the link layer connection in (g) indicates readiness of data communication on the MN side, the NAR immediately checks if there is a buffer that has packets destined for the NCoA and starts delivering if any. (elimination of FNA)

- The FNA equivalent information can be conveyed in the phase of the link layer connection, e.g. by conveying the NCoA in a PPP IPCP with vendor specific extension as defined in [6]. Only when this message is received by the NAR, it checks if there is a buffer for the NCoA. (L2 implementation of FNA)

- The MN sends the FNA as defined in [3] with the LLA of the MN, which may be derived from the EUI-64 based interface ID. (standard implementation of FNA)

When PPP IPCP option is used as the means for the L2 implementation of FNA, it SHOULD be confirmed that the NAR supports this option, otherwise it may cause a longer delay by the Configure-Reject message.

The primary benefit of this mode is that the packets destined for the MN can be buffered at the NAR, and packet loss due to handover will be much lower than that of the normal MIPv6 opration. Regarding the bootstrapping, the following benefits can be obtained, too:

- o Since the HA, HLP and HoA are not changed during the fast handover, bootstrapping information is not required.

- o Since the NCoA including the interface ID can be obtained or configured via the fast handover procedures, a router advertisement is not required.

Therefore, as shown in Figure 4, bootstrapping procedures (a-3) to (a-9) can be omitted from the standard MIPv6 operation in Figure 2. Also, if the security policy permits, the NAR can know the MN by the NAI in the PPP link setup and the authentication in (2) may be omitted. Note that another authentication is conducted in the MIPv6 registration phase and presumably the same AAA is referred to.


```
                  MN          oPDSN       nPDSN        HA          AAA
          +--     |           (PAR)       (NAR)         |           |
          |       |        LCP  |           |           |           |
          | (1)   |<----------------------->|           |           |
          |       |        CHAP |           | Access-Request/Accept |
          | (2)   |<----------------------->|<-------|------------->|
          |+...................................+     |  |           |
          |.      |       +------------+    |  .     |  |           |
          |.(3)*  |       | HA,HLP,HoA |<------------+  |           |
          |.      |       +------------+    |  .        |           |
          |.      |                         |  .        |           |
```

```
          |.      |    IPv6CP(IF-ID)        |  .        |           |
          |.(4)*  |<---------|------------->|  .        |           |
      (a)< .     +---------+  |  |          |  .        |           |
          |.(5)*| LL-addr |<-+  |           |  .        |           |
          |.     +---------+    |           |  .        |           |
          |.      |                         |  .        |           |
          |.      |       RA(prefix)        |  .        |           |
          |.(6)*  |<---------|--------------|  .        |           |
          |.     +-----+      |  |          |  .        |           |
          |.(7)*| CoA |<-----+  |           |  .        |           |
          |.     +-----+        |           |  .        |           |
          |.      |                         |  .        |           |
          |.      |    HCPv6(HA,HL,HoA)     |  .        |           |
          |.(8)*  |<---------|------------->|  .        |           |
          |.     +-----+      |  |          |  .        |           |
          |.(9)*| HoA |<-----+  |           |  .        |           |
          |.     +-----+        |           |  .        |           |
          |+...................................+        |           |
          *--     |             |           |           |           |
```

Figure 4: Procedures that can be omitted in the link-layer connection

5.2 Reactive fast handover

When the MN cannot receive the FBAck on the PAR's link or the network does not support the predictive fast handover, the reactive fast handover can be applied. To support the predictive fast handover, the PAR must accurately resolve the address of the NAR from the lower layer information such as the link-layer address of the new access point or the base station, which is not always feasible in some cases. To minimize packet loss in this situation, the PAR instead of the NAR can buffer packets for the MN until the MN regains connectivity with the NAR. The NAR obtains the information of the PAR from the MN on the NAR's link and receives packets buffered at the PAR. In this case, the PAR does not need to know the IP address of the NAR or the NCoA and just waits for the NAR to contact the PAR.

However, since the PAR needs to know when to buffer packets for the MN, the PAR obtains the timing of buffering from the MN via the FBU or the lower layer signaling, e.g. an indication of the release of the connection with the MN. Details of the procedure are as follows:

(a) A router solicitation for proxy router advertisement MAY be sent to the PAR.

(b) The proxy router advertisement MAY be sent to the MN, but the prefix of the NAR MAY not be included.

(c) The MN sends the FBU or the access network indicates the close of the connection with the MN by the lower layer signaling. The PAR MAY start buffering packets destined for the PCoA.

(d) The connection associated with the PAR is closed and the traffic channel is assigned in the new access network.

(e) The MN establishes the link layer connection. Since the IP address of the MN is guaranteed to be unique, the MN SHOULD not perform DAD

(f) The MN sends the Fast Binding Update (FBU) to the NAR either or not being encapsulated by the Fast Neighbor Advertisement (FNA).

(g) The NAR decapsulates the FBU if encapsulated and sends it to the PAR.

(h) The PAR sends the Handover Initiate (HI) to the NAR with the Code set to 1.

(i) The NAR sends the Handover Acknowledge (HAck) back to the PAR.

(j) The PAR sends the FBAck to the NAR.

(k) If the PAR buffers packets destined for the PCoA, it starts forwarding them as well as newly arriving ones to the NAR.

(l) The NAR delivers the packets to the MN.

(m) The MN sends the BU to the HA.

(n) The HA sends the BA back to the MN.

(o) The HA starts delivering packets to the MN via the NAR.

```
         MN           oPDSN           nPDSN            HA            AAA
         |            (PAR)           (NAR)            |              |
         |   RtSolPr    |               |              |              |
    (a)  |------------->|               |              |              |
         |   PrRtAdv    |               |              |              |
    (b)  |<-------------|               |              |              |
         | FBU/lower-layer sig.         |              |              |
    (c)  | . . . . . . >|               |              |              |
         |        +-----------+         |              |              |
         |        | buffering |         |              |              |
         |        +-----------+         |              |              |
    (d) handover        |               |              |              |
         |              | link layer connection        |              |
    (e)  |/----------------------------\|/...........................\|
         |\----------------------------/|\.........................../|
         |        FNA[FBU]/FBU          |              |              |
    (f)  |----------------------------->|              |              |
         |              |     FBU       |              |              |
    (g)  |              |<--------------|              |              |
         |              |      HI       |              |              |
    (h)  |              |-------------->|              |              |
         |              |     HAck      |              |              |
    (i)  |              |<--------------|              |              |
         |              |     FBack     |              |              |
    (j)  |              |-------------->|              |              |
         |              |forward packets|              |              |
    (k)  |              |==============>|              |              |
         |        deliver packets       |              |              |
    (l)  |<=============================|              |              |
         |              |     BU        |              |              |
    (m)  |-------------------------------------------->|              |
         |              |     BA        |              |              |
    (n)  |<--------------------------------------------|              |
         |        deliver packets       |              |              |
    (o)  |<=============================|<=============|              |
```

Figure 5: MIPv6 Fast handover operation (reactive mode)

To indicate the PAR to buffer packets destined for the PCoA, in (c), the MN SHOULD not include information on the NCoA in the FBU and the PAR SHOULD accept it. Or, when the PAR is indicated that the session with the MN has been closed by the lower layer signaling when the PAR attempts to send the FBAck, the PAR MAY start buffering.

An L2-based fast handover is possible as defined in [7] by extending the L2 link from the previous access network to the new access network via the PAR and the NAR. The timing of the fast handover trigger is the same as the reactive fast handover method (without

buffering) in this section. In the case of the L2-based fast handover, however, once the L2 link is extended to the new location, it is maintained until the MN becomes inactive (dormant) and the link is released. As long as the L2 link is extended, the path, on which packets are conveyed, is not optimal in length. In the case of Mobile IPv6 fast handover, when the new location is registered with the HA, the packets are directed to the NAR.

6. Selective bi-casting

If the MN has the capability to receive more than one radio signal, even smoother handover can be realized. This situation happens when, for instance, the MN can receive multiple channels of the same radio system at the same time, or the MN has multiple interfaces of different radio systems such as 3G and WiFi. Especially, when the MN is running a real-time and interactive application, long-time buffering at the PAR or NAR is not always beneficial for the MN. If this is the case, it will be helpful to deliver packets destined for the MN via both the old and new points of attachment at the same time during handover. Even if the MN has only a single interface, the above function has some benefits when the timing of handover cannot be acquired precisely in advance. This type of use case was originally proposed in [9]. Mobile IPv4 allows simultaneous bindings [8] and bi-casting is realized by retaining the old care-of address in the binding cache and sending packets destined for the MN towards both the old and new care-of addresses. Since bi-casting consumes double the network resources, it must be limited to smooth handover. In this document, bi-casting used for a short period of time for smooth handover is called "selective bi-casting." Figure 6 shows that the simultaneous bindings and bi-casting are performed at the PAR, which copies packets destined for the MN and transmits them not only to the old point of attachment but also to the new point of attachment via the NAR. The above operation is more effective when the predictive fast handover is applied because in the case of the reactive fast handover, all the actions are taken after the MN has moved to the new location. By that time, it is not necessary to deliver packets to the old point of attachment. As another scenario, Figure 7 shows that simultaneous bindings are performed at the HA. This scenario is likely to happen when the MN is connected to multiple different networks such as 3G and WiFi at the same time. Also, if the access networks in Figure 1 are operated by different providers, it may be difficult for the ARs in these networks to cooperate with each other. In this case as well, the HA must handle simultaneous bindings and bi-casting.


```
                   +----------+
                   |    HA    |
                   +----------+
                     /
                    /
             +------/-+      +--------+
             |  PAR --|------|-- NAR  |
             +------|-+      +-|------+
                    |          |
                    |          |
               +----|+        +|----+
               | BS ||        || BS |
               +----|+        +|----+
                    \         /
                     \     | /
                      >    |<
                     +------+
                     |  MN  |-->
                     +------+
```

Figure 6: Selective bi-casting scenario 1

```
                   +----------+
```

```
                                |    HA    |
                                +----------+
                                  /      \
                                 /        \
                         +------/-+      +-\------+
                         |  PAR | |      | | NAR  |
                         +------|-+      +-|------+
                                |          |
                                |          |
                           +----|+        +|----+
                           | BS ||        || BS |
                           +----|+        +|----+
                                \          /
                                 \     | /
                                  >    |<
                                  +-------+
                                  |  MN   |-->
                                  +-------+
```

Figure 7: Selective bi-casting scenario 2

From the above observations, selective bi-casting can be categorized from the following viewpoints:

[No. of interfaces on the MN]
   (A) multiple interfaces
   (B) single interface

[the node where bi-casting is performed]
   (1) at the PAR
   (2) at the HA

The procedures for each combination are described in the following section.

6.1 Bi-casting by the PAR to the MN with multiple interfaces (A-1)

As shown in Figure 8, the MN has two interfaces with the link layer addresses: LLA1 and LLA2. This case is typical of handover between different access systems such as 3G and WiFi. Details of the sequence are as follows:

(a) The interface with LLA1 acquires the global IP address PCoA.

(b) The MN sends the BU to the HA from the link with PCoA with S=0 and N=0 (the default behavior), which are defined in Section 6.5.1, and receives the BA from the HA.

(c) The MN receives packets destined for PCoA from the link with LLA1 via the PAR.

(d) When the MN detects that handover is imminent, it opens the interface with LLA2 and acquires the global IP address NCoA.

(e) The MN inserts NCoA into the FBU and sends it with S=1 and N=0 from the link with PCoA to the PAR.

(f) The MN receives the FBack from the PAR.

(g) The PAR sends packets destined for PCoA directly to the link with LLA1 and also forwards them to the NAR. The forwarded packets are received by the MN on the link with NCoA.

(h) When the MN is ready to use the link with LLA2 as the primary one, it sends the BU to the HA with S=0 and N=0.

(i) The MN starts to receive packets via the NAR.

As shown in this example, since the NCoA is assigned on the link with

LLA2 and the NAR has the neighbor cache entry (NCE) for the NCoA, there is no need to send the HI from the PAR. To suppress sending the HI, a new flag 'N' is defined in the FBU. Also, to indicate the PAR to bi-cast packets, a new flag 'S' is defined in the FBU. If the MN requests selective bi-casting and the valid NCoA has been assigned, the MN SHOULD send the FBU to the PAR with the S flag set and the N flag unset requesting bi-casting but not sending the HI. If the PAR receives this FBU, it SHOULD not send the HI to the NAR.

```
   +..MN..+
  LLA1   LLA2            PAR                  NAR                  HA
   |      |               |                    |                    |
```

```
        |link-layer connection |                  |                  |
   (a)  |/--------------------\|                  |                  |
        |\--------------------/|                  |                  |
        |      |               BU(S=0,N=0)/BA                        |
   (b)  |<---------------------------------------------------------->|
        |      |               |                  |                  |
   (c)  |<=====================|<====================================|
        |      |       link-layer connection      |                  |
   (d)  |      |/--------------------------------\|                  |
        |      |\--------------------------------/|                  |
        |     FBU(S=1,N=0)     |                  |                  |
   (e)  |--------------------->|                  |                  |
        |        FBack         |                  |                  |
   (f)  |<---------------------|                  |                  |
        |      |               |                  |                  |
   (g)  |<====================+|<====================================|
        |      |              +=================>+|                  |
        |      |<================================+|                  |
        |      |               |                  |                  |
        |      |               BU(S=0,N=0)/BA                        |
   (h)  |      |<--------------------------------------------------->|
        :      |               |                  |                  |
   (i)  :      |<=================================|<=================|
```

Figure 8: Combination (A-1)

6.2 Bi-casting by the HA to the MN with multiple interfaces (A-2)

This case happens when the access network where the PAR belongs and the one where the NAR belongs are administrated by different providers or are different access systems. The cellular network is typically a closed network and the ARs can access external nodes only via the HA. If this is the case, the PAR and the NAR cannot directly communicate with each other. Details of the sequence of this case are shown in Figure 9 and below:

(a) through (d) are the same as those in the case (A-1).

(e) The MN sends the BU to the HA from the link with NCoA with S=1 and N=0, which means that the MN requests the HA to bi-cast but not to send the HI.

(f) The HA forwards packets destined for the MN to both the PAR and the NAR. Those packets can be received by the MN on either one or both of the links.

(g) When the bi-casting lifetime, which is defined in Section 6.5.2, is expired, packets are forwarded only to the NAR.

```
        +..MN..+
       LLA1   LLA2            PAR                NAR                 HA
        |      |               |                  |                  |
        |link-layer connection |                  |                  |
   (a)  |/--------------------\|                  |                  |
        |\--------------------/|                  |                  |
        |      |                BU(S=0,N=0)/BA    |                  |
   (b)  |<----------------------------------------------------------->|
        |      |               |                  |                  |
   (c)  |<=====================|<====================================|
        |      |       link-layer connection      |                  |
   (d)  |      |/--------------------------------\|                  |
        |      |\--------------------------------/|                  |
        |      |               |                  |                  |
        |      |                   BU(S=1,N=0)/BA                    |
   (e)  |      |<---------------------------------------------------->|
        |      |               |                  |                  |
   (f)  |<=====================|<====================================|
        |      |<=================================|<=================|
        :      |               |                  |                  |
   (g)  :      |<=================================|<=================|
```

Figure 9: Combination (A-2)

6.3 Bi-casting by the PAR to the MN with a single interface (B-1)

This case is typical of handover with the same access system within the same provider network. Details of the sequence of this case are shown in Figure 10 and below:

(a) through (c) are the same as those in the case (A-1).

(d) The MN sends the RtSolPr to the PAR.

(e) The MN receives the PrRtAdv with a valid NCoA from the PAR.

(f) The MN sends the FBU with S=1 and N=1 to the PAR.

(g) The PAR sends the HI to the NAR. The 'U' bit MUST not be set if the 'S' bit of the FBU is set.

(h) The PAR receives the HAck with a valid NCoA from the NAR.

(i) The PAR sends the FBack both to the MN and the NAR.

(j) The PAR sends packets destined for PCoA directly to the MN and also forwards them to the NAR.

(k) The MN moves to the new access network and configures NCoA by establishing the link-layer connection. At this point, the MN can receive the forwarded packets from the NAR.

(l) The MN sends the BU with S=0 and N=0 to the HA.

(m) The MN starts to receive packets only via the NAR.

In (g), it is necessary that the PAR sends the HI to the NAR to create the neighbor cache entry (NCE) for the NCoA on the NAR.

```
       MN                     PAR                NAR                 HA
        |                      |                  |                  |
        |link-layer connection |                  |                  |
   (a)  |/--------------------\|                  |                  |
        |\--------------------/|                  |                  |
        |                      BU(S=0,N=0)/BA                        |
   (b)  |<---------------------------------------------------------->|
        |                      |                  |                  |
   (c)  |<=====================|<====================================|
        |       RtSoIPr        |                  |                  |
   (d)  |--------------------->|                  |                  |
        |       PrRtAdv        |                  |                  |
   (e)  |<---------------------|                  |                  |
        |     FBU(S=1,N=1)     |                  |                  |
   (f)  |--------------------->|                  |                  |
        |                      |        HI        |                  |
   (g)  |                      |----------------->|                  |
        |  (new link)          |       HAck       |                  |
   (h)  |      |               |<-----------------|                  |
        |      |  FBAck        |       FBack      |                  |
   (i)  |<---------------------|----------------->|                  |
        |      |               |                  |                  |
   (j)  |<====================+|<====================================|
        |.....>|              +=================>+|                  |
        :      |<================================+|                  |
        :      |               |                  |                  |
        :      |       link-layer connection      |                  |
   (k)  :      |/--------------------------------\|                  |
        :      |\--------------------------------/|                  |
        :      |                  BU(S=0,N=0)/BA                     |
   (l)  :      |<--------------------------------------------------->|
        :      |               |                  |                  |
   (m)  :      |<=================================|<=================|
```

Figure 10: Combination (B-1)

6.4 Bi-casting by the HA to the MN with a single interfaces (B-2)

This case is typical of handover with the same access system between different provider networks. Details of the sequence of this case are shown in Figure 11 and below:

(a) through (d) are the same as those in the case (A-3).

(e) The MN receives the PrRtAdv without a valid NCoA from the PAR.

(f) The MN sends the FBU with S=1 and N=1 to the HA.

(g) The HA sends the HI to the NAR. The 'U' bit MUST not be set if the 'S' bit of the FBU is set.

(h) The HA receives the HAck from the NAR.

(i) The HA sends the FBack to the MN and the NAR.

(j) The HA sends packets destined for the MN to both the PAR and the NAR. They can be received by the MN on either one or both of the links.

(k) The MN moves to the new access network and configures NCoA by establishing the link-layer connection. At this point, the MN can receive the forwarded packets from the NAR.

(l) The MN sends the BU with S=0 and N=0 to the HA.

(m) The MN starts to receive packets only via the NAR.

(k) The MN moves to the new access network and configures NCoA by establishing the link-layer connection. At this point, the MN can receive the forwarded packets from the NAR.

(l) The MN sends the BU with S=0 and N=0 to the HA.

(m) The MN starts to receive packets only via the NAR.

In (e), by receiving the PrRtAdv without a valid NCoA (the Code is typically 2), the MN judges that the PAR does not have information on the NAR or can not send the HI directly to the NAR. Then the MN sends the FBU to the HA.

In (g), it is necessary that the HA sends the HI to the NAR to make the NCE for the NCoA on the NAR.


```
        MN                     PAR                NAR                  HA
         |                      |                  |                   |
         |link-layer connection |                  |                   |
   (a)   |/--------------------\|                  |                   |
         |\--------------------/|                  |                   |
         |                      BU(S=0,N=0)/BA                         |
   (b)   |<----------------------------------------------------------->|
         |                      |                  |                   |
   (c)   |<=====================|<======================================|
         |       RtSoIPr        |                  |                   |
   (d)   |--------------------->|                  |                   |
         |       PrRtAdv        |                  |                   |
   (e)   |<---------------------|                  |                   |
         |                        FBU(S=1,N=1)                         |
   (f)   |------------------------------------------------------------>|
         |                      |                  |        HI         |
   (g)   |                      |                  |<------------------|
         |                      |                  |       HAck        |
   (h)   |  (new link)          |                  |------------------>|
         |      |               |                  |       FBack       |
   (i)   |      |               |     FBack        |<------------------|
         |<------------------------------------------------------------|
         |      |               |                  |                   |
   (j)   |<=====================|<======================================|
         |      |<=================================|<==================|
         |.....>|       link-layer connection      |                   |
   (k)   :      |/--------------------------------\|                   |
         :      |\--------------------------------/|                   |
```

```
       :      |                 BU(S=0,N=0)/BA                     |
   (l) :      |<-------------------------------------------------->|
       :      |               |                  |                 |
   (m) :      |<=================================|<=================|
```

Figure 11: Combination (B-2)

6.5 Message Format

6.5.1 Simultaneous bindings flag and the HI message indication flag extensions to (F)BU message

When the MN requests simultaneous bindings and bi-casting to the HA or the PAR, the MN sets the newly defined simultaneous bindings flag in the Binding Update (BU) [10] or FBU, respectively. To suppress sending the HI when it is unnecessary, the HI message indication flag is defined in the (F)BU as well.


```
                                 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                 |          Sequence #           |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |A|H|L|K|S|N|    Reserved      |           Lifetime            |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                                                               |
  .                                                               .
  .                        Mobility options                       .
  .                                                               .
  |                                                               |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

S: Simultaneous bindings. If the 'S' bit is set, the mobile node is requesting that the HA or the PAR retain its prior mobility bindings and bi-cast packets destined for the MN.

N: Indication to send the HI. On the condition that the 'S' bit is set, if the 'N' bit is set, the receiver (the PAR or the HA) SHOULD send the HI to the NAR, otherwise the receiver SHOULD not send the HI. If the 'S' bit is not set, the 'N' bit MUST be ignored.

If the 'S' bit is supported, the 'N' MUST also be supported. When S=0 and N=0, the AR and the HA perform according to [3] and [10], respectively (the default behavior).

6.5.2 New mobility option for bi-casting lifetime

The MN may request how long the HA or the PAR should retain the simultaneous bindings (and therefore bi-casting) by attaching the following mobility option in the binding update message:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                |  Type = T.B.D |   Length = 2  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Bi-casting Lifetime     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Bi-casting Lifetime:
The time period when the PAR or the HA retains the previous CoA (PCoA).

6.5.3 New status code for simultaneous bindings

If the AR or the HA receives more (fast) binding update messages with

different CoAs for the same HoA than it can support, it should send a binding acknowledgement message with the following status code:

Status T.B.D.
too many simultaneous mobility bindings

6.5.4 New Option for vendor-specific information

If the lower layer information of the new point of attachment is not represented as the Link-Layer Address, the following option SHOULD be used. The primary purpose of this option is to convey the handover assist information described in Section 4.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Length     |  Option-Code  |   VS-Length   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          VS-Value...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type   T.B.D.

Length   The size of this option in 8 octets including the Type, Length, Option-Code and VS-Length fields.

Option-Code   Indicates the particular type of vendor-specific information. This value is administrated by the vendor or organization that uses this option.

VS-Length   The size of the VS-Value field in octets.

VS-Value   Zero or more octets of vendor-specific information data.

This option MUST be understood by the sender (typically the MN) and the receiver (typically the AR or the HA). If nodes in between do not support this option, they SHOULD treat this option as opaque and MUST not drop it.

Depending on the size of the VS-Value field, appropriate padding MUST be used to ensure that the entire option size is a multiple of 8 octets. The VS-Length is used to disambiguate the size of the VS-Value.

6.6 MN and AR/HA operations

In order to enable bi-casting, the MN sends a BU or FBU by setting the 'S' flag to the HA or the PAR, respectively. When the PAR/HA allows bi-casting, a successful (F)Back is returned and bi-casting is started. The MN can request a desirable bi-casting lifetime to the PAR/HA with the bi-casting lifetime option in the (F)BU. If the requested lifetime is acceptable, the PAR/HA sends an (F)Back with the accepted bi-casting lifetime, which is determined by the policies of the PAR/HA. When bi-casting is performed at the HA, the MN is likely to receive duplicate packets from multiple interfaces. In the case of audio or video applications, it may be necessary to synchronize the bi-cast flows coming from different access networks so that the user does not have to experience a communication disruption. This may take longer than just the time for a handover. If this is the case, the MN may request a longer bi-cast lifetime. After the flows are synchronized and successfully switched on the application level, the MN may explicitly de-register the PCoA by sending an (F)BU with the lifetime field being zero. On the side of the PAR/HA, the maximum value of the bi-casting lifetime must be configured and even if the MN does not request a bi-casting lifetime or does not successfully de-register the PCoA, it is deleted after the maximum value of the bi-casting lifetime elapses.

7. Security Considerations

The security considerations for Mobile IPv6 fast handover are described in [3]. When a 3G network is considered, the PAR and the NAR have a trusting relationship and the links between them and those between the ARs and the MN are usually secured. When the MN is authenticated at the phase of the link-layer connection, the AR can distinguish the authenticated users from the others. This may be not the case, however, if the access networks are operated by different providers.

8. Conclusions

The handover performance of the standard Mobile IPv6 is not sufficient for real-time communications that are not resilient to packet loss. The Mobile IPv6 fast handover methods are effective for these applications. This document specifies how these methods can be applied to 3G networks. By introducing fast handover, not only are more packets saved which otherwise would be dropped, but also some of the bootstrapping parameters can be omitted at the link establishment phase, which can expedite the handover process. For interactive real-time applications, in which excessive buffering is inappropriate, selective bi-casting is also proposed. By retaining the PCoA and the NCoA in the binding cache, packets destined for the MN are transmitted to both the old and new points of attachment at the same time, whereby the applications on the MN can choose which flow to adopt considering the media continuity.

9. References

[1] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[2] 3GPP2 TSG-A, "Interoperability Specification (IOS) for cdma2000 Access Network Interfaces Part 1 Overview", A.S0011-C v.1.0, February 2005.

[3] Koodli, R., Ed., "Fast Handover for Mobile IPv6", RFC 4068, July 2005.

[4] 3GPP2 TSG-X, "cdma2000 Wireless IP Network Standard: Introduction", X.P0011-001-D v.0.5, November 2004.

[5] 3GPP2 TSG-X, "cdma2000 Wireless IP Network Standard: Simple IP and Mobile IP services", X.P0011-002-D v.0.5, November 2004.

[6] Simpson, W., "PPP Vendor Extensions", RFC 2153, May 1997.

[7] 3GPP2 TSG-X, "cdma2000 Wireless IP Network Standard: Packet Data Mobility and Resource Management", X.P0011-003-D v.0.5, November 2004.

[8] Perkins, C., Ed., "IP Mobility Support for IPv4", RFC 3344, August 2002.

[9] Malki, K., "Simultaneous Bindings for Mobile IPv6 Fast Handovers", draft-elmalki-mobileip-bicasting-v6-05.txt, October 2003.

[10] Johnson, D., "Mobility Support in IPv6", RFC 3775, June 2004.

Authors' Addresses

Hidetoshi Yokota
KDDI R&D Laboratories, Inc.
2-1-15 Ohara, Fujimino
Saitama, 356-8502
JP

Phone: +81 49 278 7894
Fax: +81 49 278 7510
Email: yokota@kddilabs.jp

Gopal Dommety
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134
US

Phone: +1 408 525 1404
Email: gdommety@cisco.com

Intellectual Property Statement

Disclaimer of Validity

Copyright Statement

Acknowledgment

Funding for the RFC Editor function is currently provided by the Internet Society.