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Transient Binding for Proxy Mobile IPv6
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Abstract

This document specifies a mechanism which enhances Proxy Mobile IPv6 protocol signaling to support the creation of a transient binding cache entry which is used for inter-MAG handover optimization. This mechanism is applicable to the mobile node's inter-MAG handover while using a single interface or different interfaces. The handover problem space using the Proxy Mobile IPv6 base protocol is analyzed and the use of transient binding cache entries at a mobility anchor is described. The specified extension to the Proxy Mobile IPv6 protocol ensures optimized forwarding of downlink as well as uplink packets between mobile nodes and the network infrastructure and avoids superfluous packet forwarding delay or even packet loss.

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1. Introduction

The IETF NetLMM WG is specifying Proxy Mobile IPv6 (PMIPv6) [I-D.ietf-netlmm-proxymip6] for network-based localized mobility management, which takes basic operation for registration, tunnel management and deregistration into account. This document specifies an extension to PMIPv6 to eliminate the risk of lost packets, which are sent by a mobile node towards the network infrastructure. These packets may get dropped by the mobile node's LMA due to an already updated binding cache entry (BCE) from the mobile node's handover target Mobility Access Gateway (MAG). Moreover, the extension suits MNs, which have multiple network interfaces implemented and hand over from one interface to the other while remaining anchored with their previously assigned Local Mobility Anchor (LMA).

According to the PMIPv6 base specification, an LMA updates a mobile node's BCE after having received the Proxy Binding Update (PBU) message from the mobile node's new MAG (nMAG). At the same time the LMA disables the forwarding entry towards the mobile node's previous MAG (pMAG). In case of an inter-technology handover, the mobile node's handover target interface must be configured according to the Router Advertisement being sent by the nMAG. Address configuration as well as possible access technology specific radio bearer setup may delay the complete set up of the mobile node's new interface before it is ready to receive or send data packets. In case the LMA prematurely forwards packets towards the mobile node's new interface, some packets may get lost or experience major packet delay.

This document specifies advanced binding cache management at LMAs according to well defined transient BCE states and use cases to adjust forwarding states at LMAs to different handover conditions. During a transient state, a mobile node's BCE refers to two co-existing proxy-Care-of-Address (pCoA) entries, one from the mobile node's pMAG, an other from its nMAG. A transient binding on an LMA can be controlled remotely, such as from a MAG, or by local information, such as events. This document specifies advanced binding cache control by means of a Transient Binding option, which can be used with Proxy Mobile IPv6 (PMIPv6) signaling, to support transient BCEs. Furthermore, this document specifies forwarding characteristics according to the current state of a binding to switch the forwarding tunnel at the LMA from the pMAG to the nMAG during inter-MAG handover according to the handover conditions. As a result of transient binding support, handover performance can be considerably improved to smooth an MN's handover without introducing major complexity into the system.

2. Conventions and Terminology

2.1. Conventions used in this document

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 [RFC2119].

2.2. Terminology and Functional Components

- IF - Interface. Any network interface, which offers an MN wireless or wired access to the network infrastructure. In case an MN has multiple interfaces implemented, they are numbered (IF1, IF2, ...)

- Inter-RAT handover. Handover between different radio access technologies.

- Transient Binding Cache Entry. A temporary state of the mobile node Binding Cache Entry which defines the forwarding characteristics of the mobile node forwarding tunnels to the nMAG and pMAG. A Transient BCE state is set up by means of including a Transient Binding option in the PBU and PBA. The LMA forwards the mobile node traffic according to current transient BCE characteristics as specified in this document. The change of Binding Cache Entry state is either controlled remotely by the MAGs or through a local process on the LMA. The transient state is transparent for pMAG and usage of the Transient Binding option is restricted to signalling between nMAG and LMA.

3. Analysis of the Problem Space

This section summarizes the analysis of the handover problem space for inter-technology handover as well as intra-technology handover when using the PMIPv6 base protocol.

3.1. Handover with a single interface

During an intra-technology handover, some of the MN's uplink traffic may still be in transit through the pMAG. In addition, in some active handoff scenarios, it is necessary to prepare the handover target MAG prior to completion of link layer handoff procedures. In some systems, the target MAG will be the recipient of uplink traffic prior to the completion of the procedure that would result in the PBU/PBA handshake. Currently and as per PMIPv6 base protocol [I-D.ietf-netlmm-proxymip6], the LMA forwards the MN's uplink traffic received from a tunnel only as long as the source IP address of the MN's uplink traffic matches the IP address of the mobile node's registered Proxy-CoA in the associated BCE. As a result, packets being forwarded by the MN's pMAG and arriving at the LMA after the LMA has updated the MN's BCE according to the received PBU from the nMAG will be dropped.

3.2. Handover between interfaces

In client based mobility protocols the handoff sequence is fully controlled by the MN and the MN updates its binding and associated routing information at its mobility anchor after IP connectivity has been established on the new link. On the contrary, PMIPv6 aims to relieve the MN from the IP mobility signaling, while the mobile node still controls link configuration during a handover. This introduces a problem during an MN's handover between interfaces. According to the PMIPv6 base protocol [I-D.ietf-netlmm-proxymip6], the Access Authentication and the Proxy Binding Update (PBU) are triggered in the access network by the radio attach procedure, transparently for the MN. Additional delay for the MN's new interface's address configuration is not considered. As a consequence, the immediate update of the MN's BCE after the PBU from the MN's new MAG has been received has impact to the performance of the MN's downlink traffic as well as its uplink traffic. Performance aspects of downlink as well as uplink traffic during a handover between interfaces is analyzed in the subsequent subsections.

3.2.1. Issues with downlink traffic

Delaying availability of an MN's network interface can be caused by certain protocol operations that the MN needs to perform to configure its new interface and these operations can take time. In order to

complete the address auto-configuration on its new interface, the MN needs to send a router solicitation and awaits a router advertisement. Upon receiving a router advertisement from the new MAG, the MN can complete its address configuration and perform Duplicate Address Detection (DAD) [RFC4862] on the new interface. Only then the MN's new interface is ready to receive packets.

Address configuration can take more than a second to complete. If the LMA and the new MAG have already established a tunnel and the LMA starts forwarding data packets for the MN to the new MAG during this time, these data packets may get delayed or lost because the MN's new interface is not yet ready to receive data. However, delaying the PBU, which is sent from the new MAG to the LMA after the MN's new interface has attached to the network, is not possible, as the new MAG retrieves configuration data for the MN from the LMA in the PBA. With host-based mobility protocols, such as Mobile IPv6 [RFC3775], MNs can easily control when a binding is updated. This is different for network-based mobility management, where hosts are not involved in IP mobility management [RFC4831]

The aforementioned problem is exemplarily illustrated in Figure 1, which assumes that the HNP will be assigned under control of the LMA. Hence, the HNP option in the PBU, which is sent by the new MAG to the LMA, is set to ALL_ZERO. An MN has attached to the network with interface (IF) IF1 and receives data on this interface. When the MN's new interface IF2 comes up and is detected by the new MAG, the new MAG sends a PBU and receives a PBA from the LMA. If the LMA decides to forward data packets for the MN via the new MAG, the new MAG has to buffer these packets until address configuration of the MN's new interface has completed and the MN's new interface is ready to receive packets. While setting up IF2, the MN may not reply to address resolution signaling [RFC4861], as sent by the new MAG (A). If the MAG's buffer overflows or the MN cannot reply to address resolution signaling for too long, data packets for the MN are dropped and the MN can experience severe packet losses during an inter-technology handover (B) until IF2 is ready to receive and send data (C).

```
       +------+                  +----+      +----+                +---+
       |  MN  |                  |pMAG|      |nMAG|                |LMA|
       +------+                  +----+      +----+                +---+
       IF2 IF1                     |           |                     |
        |   |                      |           |                     |
        |   |- - - - - - - - - Attach          |                     |
        |   |                      |--------------PBU--------------->|
        |   |                      |<-------------PBA----------------|
        |   |--------RtSol------->|           |                     |
        |   |<-------RtAdv--------|           |                     |
        |  Addr.                   |           |                     |
        |  Conf.                   |           |                     |
        |   |<-------------------|=================data===========|--
        |   |                      |           |                     |
        |- - - - - - - - - - - - - - - - - Attach                   |
        |   |                      |           |----------PBU-------->|
        |   |                      |           |<---------PBA---------|
        |   |                      |           |<-====data===========|--
    [A]?|<-----------NSol--------------------|<-====data===========|--
        |   |                      |      [B] ?|<-====data===========|--
        |   |                      |          ?|<-====data===========|--
        |-----------RtSol------------------->|<-====data===========|--
        |<----------RtAdv--------------------|          :          |
     Addr.  |                      |           |          :          |
     Conf.  |                      |           |          :          |
        |<-----------NSol--------------------|          :          |
        |------------NAdv------------------>[C]                     |
       !|<-----------------------------------|======data===========|--
        |   |                      |           |                     |
        |   |                      |           |                     |
```

Figure 1: Issue with inter-RAT mobility.

Another risk for a delay in forwarding data packets from a new MAG to the MN's IF2 can be some latency in setting up a particular access technology's radio bearer or access specific security associations after the new MAG received the MN's HNP from the LMA via the PBA signaling message.

In case an access technology needs the MN's IP address or HNP to set up a radio bearer between an MN's IF2 and the network infrastructure, the responsible network component might have to wait until the nMAG has received the associated information from the LMA in the Proxy Binding Acknowledgment. Delay in forwarding packets from the nMAG to the MN's IF2 depends now on the latency in setting up the radio bearer.

A similar problem can occur in case the set up of a required security

association between the MN's IF2 and the network takes time and such set up can be performed only after the MN's IP address or HNP is available on the nMAG.

3.2.2. Issues with uplink traffic

In case of an inter-technology handover between two interfaces the MN may be able to maintain connectivity on IF1 while it is completing address configuration on IF2. Such HO mechanism is called make-before-break and can avoid UL packet loss in client based MIP. On the contrary, in a PMIP domain the attachment of the MN on IF2 will cause the nMAG to send a PBU to LMA and LMA will update the BCE for this mobility session of the MN. According to section 5.3.5 of the PMIPv6 base specification [I-D.ietf-netlmm-proxymip6], the LMA will drop all subsequent packets being forwarded by the MN's pMAG due to the updated BCE, which refers now to the nMAG as Proxy-CoA. Thus make-before-break handover is currently not supported by PMIP.

A further issue for uplink packets arises from differences in the time of travel between nMAG and LMA resp. pMAG and LMA. Even if the MN stops sending packets on IF1 before the PBU is sent (i.e. before it attaches IF2 to nMAG), uplink packets from pMAG may arrive at LMA after the PBU from nMAG. Such situation can in particular occur when the MN's previous link has a high delay (e.g. a GSM link) and is slow compared to the handover target link. This characteristic is exemplarily illustrated in Figure 1. All packets forwarded from pMAG that arrive at the LMA after the PBU from nMAG has been processed have to be dropped according to section 5.3.5 of the PMIPv6 base specification [I-D.ietf-netlmm-proxymip6].

```
      +------+              +-----+                   +---+
      |  MN  |              |nMAG|                   |LMA|
      +------+              +-----+                   +---+
      IF2 IF1                  |                         |
       |   |\                  |                         |BCE exists
       |   |   \               |                         | for pMAG
       |- -|- - - - \- - - - Attach                      |
       |   |          s\       |---------PBU----------->|BCE update
       |   |              l\ |<--------PBA------------| for nMAG
       |   |                  o\                         |
       |   |                   |    w\                   |
       |   |                   |        l\               |
       |   |                   |            i\           |
       |   |                   |               n \       |packet dropped
       |   |                   |                  k --->| as BCE has only
       |   |                   |                         | entry for nMAG
       |   |                   |                         |
       |   |                   |                         |
```

Figure 2: Uplink traffic issue with slow links.

3.3. Demand for a common solution

To reduce the risk of packet loss, some settings on an MN could be chosen appropriately to speed up the process of network interface configuration. Also tuning some network parameters, such as increasing the buffer capability on MAG components, could improve the handover performance. However, some network characteristics, such as access link delay or bearer setup latency, cannot be easily fine tuned to suit a particular handover scenario. Preferable is a general solution based on a simple extension to the PMIPv6 base protocol, which performs well in different handover situations.

This document specifies transient BCEs as extension to the PMIPv6 base protocol. Set up and configuration of a transient BCE can be performed by means of standard PMIPv6 signaling messages between a MAG and an LMA component having a new Transient Binding option included. The specification of transient BCEs covers support for three clearly distinguished use cases to suit various handover scenarios and to improve handover performance for both, inter- and intra-technology handover. As a result of using transient BCEs, excessive packet buffering at a handover target MAG is not necessary and packet losses and major jitter during an MN's handover can be avoided.

4. Use of Transient Binding Cache Entries

4.1. General Approach

The use of transient BCEs during an MN's handover enables controlled forwarding of uplink and downlink traffic to harmonize handover performance characteristics with the capabilities of the handover source and target access networks. Updating of an MN's BCE at an LMA is split into different phases before and after the radio setup and IP configuration being associated with the MN's handover from a pMAG to a nMAG.

During an inter-technology handover, the LMA shall on one hand be able to accept uplink packets of the MN as soon as the MN has finalized address configuration at the new IF2 and may start using the new interface for data traffic, i.e. the PBU for the uplink shall be done before the radio setup procedure is finalized. But, to allow the MN to keep sending its data traffic on IF1 during the handover, uplink packets with the previously existing binding on IF1 shall still be accepted by the LMA until the MN detaches from pMAG with IF1 and the pMAG has deregistered the MN's attachment at the LMA by means of sending a PBU with lifetime 0. This is of particular importance as sending the registration PBU from the nMAG is transparent to the mobile node, i.e. the MN does not know when the PBU has been sent. On the other hand, switching the downlink path from the pMAG to the nMAG shall be performed at the LMA only after completion of the IP configuration at the MN's IF2 and after a complete setup of the access link between the MN and the nMAG. How long this takes depends on some interface specific settings on the MN as well as on the duration of the target system's radio layer protocols, which is transparent to the LMA but may be known to MAGs.

Thus, the use of a transient BCE during an MN's handover splits into a configuration phase and an activation phase. As a result of the MN's attachment at the nMAG, the first PBU from the MN's nMAG performs configuration at the LMA and the nMAG. The LMA enters the nMAG as a further forwarding entry to the MN's BCE without deleting the existing forwarding entry and marks the BCE state as 'transient'. After reception of the PBA, the nMAG enters the MN's configuration data, such as the assigned HNP, into its BUL and marks the MN's binding with the LMA as 'transient', which serves as an indication to the nMAG that the transient BCE needs activation. During the transient state, the LMA accepts uplink packets from both MAGs, the pMAG and the nMAG, for forwarding. To benefit from the still available downlink path from pMAG to MN, the LMA forwards downlink packets towards the pMAG until the transient BCE gets activated. Such downlink forwarding characteristic is denoted as 'Late path switch' (L).

Decision about classification of an MN's BCE as transient can be done either by the nMAG or the LMA. In case the nMAG takes the decision to perform a handover according to the transient BCE specification, the MN's nMAG includes the Transient Binding option in the PBU. In case the LMA receives a PBU from the nMAG which has no Transient Binding option included, it may still take the decision to create a transient BCE for the MN. In such case, the LMA includes the Transient Binding option in the PBA message to notify the nMAG about the classification of the MN's BCE as transient. Description of a detailed mechanism how a nMAG or an LMA decides to use a transient BCE is out of scope of this document. The detailed use of the Transient Binding option is described in Section 4.4 and Section 4.5.

A transient BCE can be activated by different means, such as a timeout at the LMA, a PBU from the nMAG, which has no Transient Binding option attached or a deregistration PBU from the pMAG. As soon as the MN's BCE gets activated, the LMA switches the forwarding path for downlink packets from the pMAG to the nMAG. This specification considers an optional state during the activation (A), which keeps the forwarding entry to the pMAG for some more time as a transient BCE, solely to ensure forwarding of delayed uplink packets from the pMAG.

The use of a transient BCE for an inter-technology handover is exemplarily illustrated in Figure 3. The MN attaches to the PMIPv6 network with IF1 according to the procedure described in [I-D.ietf-netlmm-proxymip6]. The MN starts receiving data packets on IF1. When the MN activates IF2 to prepare an inter-technology handover, the nMAG receives an attach indication and sends the PBU to the LMA to retrieve configuration information for the MN (e.g. HNP). The LMA is able to identify an inter-technology handover by means of processing the HI option coming along with the PBU sent by the nMAG. As in this example the nMAG includes the Transient Binding option in the PBU to control the transient BCE at the LMA, the LMA updates the MN's BCE according to the transient BCE specification described in this document and marks the state of the BCE as 'transient' [A].

As a result of the transient BCE, the LMA keeps using the previous forwarding information towards the pMAG binding as forwarding information until the transient BCE gets activated. The LMA acknowledges the PBU by means of sending a PBA to the nMAG. The nMAG has now relevant information available, such as the MN's HNP, to set up a radio bearer and send a Router Advertisement to the MN. While the MN's BCE at the LMA has transient characteristic, the LMA forwards uplink packets from the MN's pMAG as well as from its nMAG. The nMAG may recognize when the MN's IF2 is able to send and receive data packets and sends an updating PBU to the LMA without including the Transient Binding option, which results in activation of the MN's

transient BCE [B]. From that moment, downlink packets will be forwarded towards the MN's IF2 via the nMAG [C].

```
 +------+                 +----+      +----+                +---+
 |  MN  |                 |pMAG|      |nMAG|                |LMA|
 +------+                 +----+      +----+                +---+
 IF2 IF1                     |           |                     |
  |   |                      |           |                     |
  |   |- - - - - - - - - Attach          |                     |
  |   |                      |---------------PBU--------------->|
  |   |                      |<--------------PBA----------------|
  |   |--------RtSol------->|           |                     |
  |   |<-------RtAdv--------|           |                     |
  |  Addr.                   |           |                     |
  |  Conf.                   |           |                     |
  |   |<------------------->|==================data============|<---
  |   |                      |           |                     |
  |- - - - - - - - - - - - - - - - - Attach                    |
  |   |                      |           |----PBU(transient)--->|
  |   |                      |           |<---PBA(transient)---[A]
  |------RAT Configuration-------------|                     |
  |   |<--------------------|==================data============|<---
  |-------RtSol-(optional)------------->|                     |
  |<-----------RtAdv--------------------|                     |
Addr. |                      |           |                     |
Conf  |                      |           |                     |
  |------------NSol-------------------->|---------PBU-------->[B]
  |   |                      |           |<---------PBA----------|
  |<-----------------------------------|========data=========[C]<--
  |   |                      |           |                     |
  |   |                      |           |                     |
  |   |                      |           |                     |
```

Figure 3: Late path switch with PMIPv6 transient BCEs.

An example of using a transient BCE for intra-technology handover is illustrated in Figure 4. When the nMAG receives the indication that the MN is moving from the pMAG's access network to the nMAG's area, the nMAG sends a PBU on behalf of the MN to the MN's LMA. In this PBU, the nMAG includes the MN-ID, the HNP, and the interface ID as per PMIPv6 base protocol [I-D.ietf-netlmm-proxymip6].

Furthermore, the nMAG indicates an intra-technology handover by means of the HI option and includes the Transient Binding option to indicate to the LMA that this registration should result in a transient BCE. The nMAG sets the value of the transient BCE lifetime to a value that is dependent on the deployment and operator specific

[D].

After the nMAG receives an indication that the MN has completed the handover process and the data path is ready to move the tunnel completely from the pMAG to the nMAG, the nMAG SHOULD send a PBU to allow the LMA to activate the MN's BCE to a regular BCE and to switch the data path completely to be delivered through the new Proxy-CoA. In this case, the nMAG sends a PBU with the MN-ID, Interface ID, HNP and at the same time indicates an intra-technology handover by means of the HI option. The nMAG does not include the Transient Binding option again, as shown in Figure 4 [E].

In the event that the nMAG receives downlink traffic destined to the MN from the LMA after sending a PBU with Transient Binding option included, the nMAG MUST deliver the downlink traffic to the MN. In this case, the nMAG SHOULD send a PBU to ensure that the transient BCE has been activated.

```
        +-----+      +----+      +-----+                  +-----+
        | MN  |      |pMAG|      |nMAG|                   | LMA |
        +-----+      +----+      +-----+                  +-----+
           |            |            |  bi-directional       |
           |            |<<<<<<<<========================>>>>>>>>|<-->
           |            |            |                         |
           |            |            |                         |
     [Handoff Event]    |            |                         |
           |      [MN HO Event]      |                         |
           |            |     [HO Event Acquire]               |
           |            |            |                         |
    [LL Attach to       |            |                         |
         nMAG]          |            |----PBU (transient)----->|
           |            |            |                        [D]
           |            |            |<-----PBA(transient)-----|
           |            |            |                         |
           |            |          bi-directional              |
           |            |<<<<<<<<========================>>>>>>>>|<-->
           |            |            |                         |
           |            |            |      uplink only        |
           |            |            |>>>>>>===========>>>>>>>>|-->
           |            |            |                         |
           |            |      [HO Complete]                   |
           |            |            |----------PBU----------->|
           |            |            |                        [E]
           |            |            |<---------PBA -----------|
           |            |`           |                         |
           |            |            |<<<<<<<<=========>>>>>>>>|<-->
           |            |            |                         |
```

Figure 4: Transient BCE support for an intra-technology handover

The current specification of transient BCEs covers three use cases. Each use case characterizes a particular transition and walk through the transient forwarding state model during an MN's handover. Each state implies a dedicated characteristic regarding forwarding entries, in which forwarding rules for uplink traffic are maintained separately from downlink traffic. Use case 1 implies a late downlink path switch from the pMAG to the nMAG. Use case 2 implies a late downlink path switch as well as a subsequent intermediate activation state to ensure forwarding of delayed uplink packets at the LMA even after activation of the transient BCE has been initiated. Use case 3 does not perform late path switching, but ensures forwarding of delayed uplink packets from the pMAG while the MN is already able to send and receive packets through the nMAG. The following section describes these use cases in more detail.

4.2. Specified Use Cases for Transient BCEs

4.2.1. Use case 1

In some systems, PMIPv6 is supported for providing network based mobility between the Serving Gateway (MAG) and the PDN-GW (LMA). In such system and during active inter-MAG handoff, it is critical to reduce handoff latency and packet loss for real-time applications such as VoIP. In such case, the LMA is required to forward the mobile node uplink traffic from the nMAG without completely switching the tunnel from the pMAG.

A context transfer mechanism may be used to provide the nMAG with the mobile node's current session information, that is anchored at the local mobility anchor, e.g. LMA IP address, allocated HNP, GRE keys, etc. This information with the specific link layer events informs the MAG of the mobile node movement and attachment which allows the nMAG to send a PBU to the local mobility anchor to create a transient BCE which allows uplink traffic from the proxy CoA that is hosted at the nMAG without switching the tunnel from the pMAG. During the lifetime of the transient BCE, the LMA continues to accept uplink traffic from both previous and new MAG while forwarding downlink traffic to the pMAG only. While during an inter-technology handover the MN is possibly able to receive downlink traffic via the pMAG, the mechanism used in the pMAG's access network to forward downlink traffic to the current location of the mobile node in the nMAG's access network during an intra-technology handover is out of scope.

When the nMAG receives an indication that the inter-MAG handoff process has completed, the nMAG sends another PBU without including a Transient Binding option to update the mobile node's transient BCE to a regular PMIPv6 BCE with bi-directional capabilities. This mechanism is used by the LMA as an indication to switch the tunnel to point to the nMAG, which results in a smoother handover for the MN.

4.2.2. Use case 2

Similar to use case 1, a transient BCE can be utilized for MNs with dual radio capability. Such MNs are still able to send and receive data on the previous interface during the new address configuration. Forwarding between nMAG and pMAG is not required, but it has to be avoided that the LMA immediately starts forwarding downlink data packets to the nMAG. This is enabled by a PBU which has the Transient Binding option included, so that it is not necessary that MN and LMA synchronize the point in time for switching interfaces and activating the BCE.

When the handover is finalized, the nMAG sends a second PBU without

including the Transient Binding option and the LMA activates the MN's BCE. This PBU may overtake packets-on-the-fly from MN to LMA via pMAG (e.g. if the previous interface was of type GSM or UMTS with up to 150msec uplink delay). The LMA has to drop all these packets from the pMAG due to the activation of the MN's BCE. This can be avoided by another transient BCE state for uplink packets from pMAG, that is characteristic to this use case and created by the PBU from nMAG and terminated by a preconfigured lifetime.

4.2.3. Use case 3

This use case applies when an MN performs a handover from its pMAG to a nMAG and can neither maintain its connection to the pMAG to receive downlink packets nor the network ensures forwarding of downlink packets from the MN's previous to its new point of attachment. The MN's nMAG sends a PBU with the Transient Binding option included to the LMA, which results in a transient BCE for the MN. The LMA starts forwarding downlink packets towards the nMAG, which represents the MN's new Proxy-CoA. The key characteristic of the MN's transient BCE in this use case is that the LMA accepts uplink packets from the MN's pMAG as well as from its nMAG for a certain period to forward them into the network infrastructure. This ensures forwarding of delayed uplink packets, which are still on the way from the pMAG to the LMA.

The LMA activates the MN's BCE after a pre-configured lifetime of the transient BCE or after it has received a deregistration PBU (lifetime = 0) from the pMAG. After the MN's BCE state has turned from transient state to active state, the LMA deletes the forwarding entry to the pMAG and performs forwarding of the MN's uplink and downlink packets only from and to the Proxy-CoA being associated with the MN's nMAG.

4.3. Impact to Binding Management

The use of a transient BCE requires temporary maintenance of two forwarding entries in the MN's BCE at the LMA, one referring to the MN's pMAG, the other referring to its nMAG. Forwarding entries are represented according to [I-D.ietf-netlmm-proxymip6] and comprise the interface identifier of the associated tunnel interface towards each MAG, as well as the associated access technology information. Each forwarding entry is assigned a forwarding rule to admit and control forwarding of uplink and downlink traffic to and from the associated MAG. Hence, according to this specification, a forwarding entry can have either a rule that allows only forwarding of uplink traffic from the associated MAG, or a rule that allows bidirectional forwarding from and to the associated MAG. The interface identifier and access technology type info can be taken from the PBU received at the LMA and linked to each forwarding entry accordingly.

MAGs should maintain the status of an MN's binding and the lifetime associated with a transient BCE at the LMA in their binding update list. This is in particular important in case a new MAG needs to explicitly activate a binding after the associated MN's new interface has proven to be ready to handle IP traffic.

4.4. MAG operation

In case of a handover, the MN's nMAG may decide to control the MN's handover at the LMA according to any of the three use cases for transient BCEs described above. In such case, the nMAG includes the Transient Binding option in the PBU message it sends to the MN's LMA. If the nMAG wants the LMA to perform a late path switch, it sets the L-flag of the Transient Binding option to 1. If the nMAG wants the LMA to enter a temporary activation state after the activation of a transient BCE has been initiated to follow use case 2, the nMAG sets the A-flag along with the L-flag in the Transient Binding option to 1. Otherwise, the nMAG may set the L-flag to 1 and the A-flag to 0 to perform a handover according to use case 1. In case the nMAG does not control the LMA to perform a late path switch, but wants to ensure temporary forwarding of uplink traffic at the LMA from the pMAG and from the nMAG according to the use case 3, it sets the L-flag to 0 and the A-flag to 1. The nMAG SHOULD NOT use the Transient Binding option with both flags set to 0. In any case where the nMAG includes the Transient Binding option in the PBU with the L-Flag set to 1, it MUST set the Lifetime field of the Transient Binding option to a value larger than 0 to propose a maximum lifetime of the transient BCE. The chosen lifetime value for the Transient Binding option SHOULD be smaller than the chosen lifetime value for the PBU registration. If the L-Flag of the Transient Binding option is set to 0, the timer SHALL be set to 0. Other fields and options of the PBU are used according to [I-D.ietf-netlmm-proxymip6]

In case the nMAG does not include a Transient Binding option but the LMA decides to perform a handover according to any of the three use cases for transient BCEs, the nMAG may receive a Transient Binding option along with the PBA from the LMA as a result of the PBU it sent to the LMA.

In case the nMAG receives a PBA with a Transient Binding option, it SHOULD link the information about the transient BCE use case and the associated transient BCE lifetime with the MN's entry in the BUL. Only in case the L-flag of the Transient Binding option is set to 1, the nMAG MAY activate the MNs transient BCE before expiration of the transient BCE lifetime by means of sending an updating PBU to the LMA without including a Transient Binding option. All fields of the PBU MAY be set according to the procedure for binding lifetime extension described in section 5.3.3 of [I-D.ietf-netlmm-proxymip6]. In case

the lifetime of a transient BCE expires or the LMA approves the activation of a transient BCE as a result of PBU sent by the nMAG, the nMAG MUST delete all information associated with a transient BCE from the MN's BUL entry.

In any case where the nMAG decides to add a Transient Binding option to the PBU, the amount of Transient Binding options per message is limited to one.

A MAG, which serves to an MN already as pCoA and the LMA has already a binding for the MN referring to this MAG, SHALL NOT include a Transient Binding option in any subsequent PBU being associated with the MN's registration.

4.5. LMA operation

4.5.1. Configuration of a transient BCE

In case the LMA receives a handover PBU from a MN's nMAG which has no Transient Binding option included and the associated MN's BCE is active and not in transient state, the LMA MAY take the decision to use a transient BCE and inform the nMAG about the transient BCE characteristics by means of including a Transient Binding option in the PBA. In such case, configuration of the MN's transient BCE is done according to the description in this section and the selected use case. Otherwise, the LMA processes the PBU according to the PMIPv6 base protocol [I-D.ietf-netlmm-proxymip6] and performs normal update of the MN's BCE, which represents an active BCE after the LMA has sent the PBA back to the nMAG after a successful registration.

In case the PBU from the nMAG has a Transient Binding option included, the LMA must identify the use case of the transient BCE registration according to the L-flag and the A-flag settings in the Transient Binding option. In case the LMA finds the L-flag set to 1, but the A-flag set to 0, the LMA configures the MN's transient BCE and the forwarding rules to support use case 1. Accordingly, the LMA performs a late path switch and forwards downlink packets for the MN towards the MN's pMAG, whereas uplink packets being forwarded from both Proxy-CoAs, the MN's pMAG as well as from its nMAG, will be routed by the LMA. The LMA sets the lifetime of the transient BCE according to the lifetime indicated by the nMAG in the Transient Binding option's lifetime field or may decide to reduce the lifetime according to its policy. If the lifetime value in the Transient Binding option exceeds the lifetime value associated with the PBU message, the LMA MUST reduce the lifetime of the transient BCE to a value smaller than the registration lifetime value in the PBU message. In case of a successful transient BCE registration, the LMA sends a PBA with a Transient Binding option back to the nMAG. The

L-flag and the A-flag of the Transient Binding option included in the PBA are set according to the values received in the PBU, whereas the lifetime field is set to the value finally chosen by the LMA.

In case the LMA finds the L-flag and the A-flag set to 1, the LMA configures the MN's transient BCE and the forwarding rules to support use case 2. Accordingly, the LMA performs a late path switch and forwards downlink packets for the MN towards the MN's pMAG, whereas uplink packets being forwarded from both Proxy-CoAs, the MN's pMAG as well as from its nMAG, will be routed by the LMA. In addition, the LMA marks the transient BCE to enter a temporary activation phase after the LMA receives an indication to activate a transient BCE. The LMA sets the lifetime of the transient BCE according to the lifetime indicated by the nMAG in the Transient Binding option's lifetime field or may decide to reduce the lifetime. If the lifetime value in the Transient Binding option exceeds the lifetime value associated with the PBU message, the LMA MUST reduce the lifetime of the transient BCE to a value smaller than the registration lifetime value in the PBU message. In case of a successful transient BCE registration, the LMA sends a PBA with a Transient Binding option back to the nMAG. The L-flag and the A-flag of the Transient Binding option included in the PBA are set according to the values received in the PBU, whereas the lifetime field is set to the value finally chosen by the LMA.

In case the LMA finds the L-flag of the received Transient Binding option set to 0 but the A-flag set to 1, the LMA configures the MN's transient BCE and the forwarding rules to to support use case 3. Accordingly, the LMA forwards downlink packets for the MN towards the MN's nMAG, whereas uplink packets being forwarded from both Proxy-CoAs, the MN's pMAG as well as from its nMAG, will be routed by the LMA. The LMA sends a PBA with a Transient Binding option included back to the nMAG. The L-flag and the A-flag of the Transient Binding option included in the PBA are set according to the values received in the PBU, whereas the lifetime field is set to 0 by the LMA.

In any case where the LMA finds the L-flag of the received Transient Binding option set to 1, but the lifetime field of the Transient Binding option is set to 0, the LMA MUST ignore the Transient Binding option and process the PBU according to [I-D.ietf-netlmm-proxymip6]. After the PBU has been processed successfully, the LMA sends back a PBA with the status field set to PBU_ACCEPTED_TB_IGNORED.

In case the LMA finds the L-flag as well as the A-flag of the received Transient Binding option set to 0, the LMA MUST ignore the Transient Binding option and process the PBU according to the PMIPv6 base protocol [I-D.ietf-netlmm-proxymip6]. After the PBU has been processed successfully, the LMA sends back a PBA with the status

field set to PBU_ACCEPTED_TB_IGNORED.

In case the LMA receives a PBU with a Transient Binding option included from a MAG which serves already as pCoA to the associated MN, the LMA MUST ignore the Transient Binding option and process the PBU according to [I-D.ietf-netlmm-proxymip6]. After the PBU has been processed successfully, the LMA sends back a PBA with the status field set to PBU_ACCEPTED_TB_IGNORED.

In any case where the LMA adds a Transient Binding option to the PBA, the amount of Transient Binding options per message is limited to one.

4.5.2. Activation of a transient BCE

When the LMA receives a PBU from an MN's nMAG which has no Transient option included, the LMA should check whether the MN's BCE is in any of the specified transient states. If the MN's BCE is not transient, the LMA performs processing and BCE update according to the PMIPv6 base protocol [I-D.ietf-netlmm-proxymip6]. When the LMA receives a PBU from the MN's pMAG and the MN's BCE is not transient, the LMA performs protocol operation and an update of the MN's BCE according to the PMIPv6 base protocol [I-D.ietf-netlmm-proxymip6].

When the LMA receives a PBU from the MN's nMAG which has no Transient option included but the MN's BCE is in a transient state or the LMA receives a local event trigger due to expiration of MN's transient BCE, the LMA should check whether the forwarding rules for the associated MN are set to route the MN's downlink traffic to the MN's pMAG. If the forwarding entry for downlink packets refers to the MN's pMAG, the LMA must update the forwarding information to forward downlink packets towards the MN's nMAG. After the forwarding path has been switched, the LMA must update the MN's BCE accordingly. If the transient BCE indicates that the LMA must consider an activation phase after leaving a transient BCE has been initiated, the LMA must keep both forwarding entries for the pMAG and the nMAG for uplink packets and perform forwarding of packets it receives from both Proxy-CoAs. If the activation phase can be omitted, the LMA sets the state of the MN's BCE to active and deletes any forwarding entry referring to the MN's pMAG. The LMA must delete any scheduled timeout event for the MN which are associated with a transient BCE.

When the LMA receives a deregistration PBU from the MN's pMAG, which has the registration lifetime set to 0 and the MN's BCE is in transient state, the LMA must update the forwarding rules for the MN and switch the downlink traffic path from the pMAG to the nMAG. Furthermore, the LMA sets the state of the MN's BCE to active and removes any forwarding entry towards the pMAG from the MN's BCE,

irrespective whether or not the transient BCE was configured to enter a temporary activation state.

When the LMA receives a local event trigger due to expiration of a timer which has been set to ACTIVATIONDELAY and scheduled to terminate the activation state of an MN's transient BCE, the LMA sets the state of the MN's BCE to active and removes any forwarding entry towards the pMAG from the MN's BCE.

4.5.3. Forwarding state diagram

Figure 5 illustrates the forwarding state diagram for the three transient BCE use cases based on the assumption that the nMAG controls the use of a transient BCE during an MN's handover by means of including a Transient Binding option in the PBU message.

The same diagram applies for the case that the LMA takes the decision to use any of the specified transient BCE use cases. The LMA indicates the use of a transient BCE by means of including the Transient Binding option in the PBA it sends back to the MN's nMAG. As the forwarding characteristics according to the transient BCE states is independent of whether a MAG or an LMA takes the decision to use a transient BCE during a handover, LMA-initiated use and indication of a transient BCE is not explicitly covered in the diagram.

According to this specification, each BCE has a state associated, which can be either 'Active' or any of the specified transient states 'Transient-L', 'Transient-LA' or 'Transient-A'. In case a BCE is in state 'Active', the information in a BCE and associated forwarding conforms to [I-D.ietf-netlmm-proxymip6]. Any of the transient states implies that the transient BCE has two forwarding entries, which are denoted as pMAG and nMAG in the forwarding state diagram. The forwarding diagram includes information about the forwarding rule along with each forwarding entry. This rule indicates whether a forwarding entry is meant to perform forwarding only for Uplink (Ul) traffic or to perform bi-directional forwarding for Uplink (Ul) and Downlink (Dl) traffic.

State transitions can be triggered as a result of processing a received PBU or by a local timeout event on the LMA. Presence of a Transient Binding option in a PBU is indicated by 'Topt' as argument to a PBU or PBA respectively. As a further argument to a PBU message, the source of the message is indicated, which can be either the MN's nMAG or its pMAG. The values of the Transient Binding option flags are indicated in brackets as argument to the Topt.

The diagram refers to two timeout events. TIMEOUT_1 is set according

to the Lifetime value in a Transient Binding option, whereas TIMEOUT_2 is set to ACTIVATIONDELAY (see Section 7 for the default value).

The three specified use cases for a transient BCE are reflected in the diagram. Use case 1 implies going through state Transient-L to support a late path switch. State Transient-LA is entered to support use case 2, which considers an activation state Transient-A. Use case 3 neither enters state Transient-L nor state Transient-LA, but enters state Transient-A directly.

```
                                           +----------+
                                           | No Entry |
                                           +----------+
                                                |
                                                | PBU(pMAG)
                                                V
                                         +----------------+
                PBU(nMAG)                |    Active      |
    +------------------------------------|                |
    |                                    |  pMAG [Dl,Ul]  |
    |                                    +----------------+
    |           PBU(nMAG, Topt[L=1,A=0])   |    |       |
    |           +--------------------------+    |       |
    |           |                               |       |PBU(nMAG,
    |           |       PBU(nMAG, Topt[L=1,A=1])|       |Topt[L=0,A=1])
    |           V                               V       |
    |    +--------------+          +--------------+     |
    |    | Transient-L  |          | Transient-LA |     |
    |    |              |          |              |     |
    |    | pMAG [Dl,Ul] |      +---| pMAG [Dl,Ul] |     |
    |    | nMAG [Ul]    |      |   | nMAG [Ul]    |     |
    |    +--------------+      |   +--------------+     |
    |           |              |           |            |
    |           |   PBU(pMAG,  |           |            |
    |           |   lifetime=0)|  PBU(nMAG)|TIMEOUT_1   |
    |           |              |           |            |
    |           |              |           V            V
    |           |              |          +--------------+
    |           |              |          | Transient-A  |
    |  PBU(nMAG)|TIMEOUT_1     |          |              |
    |           |              |          | nMAG [Dl,Ul] |
    |           |PBU(pMAG,     |          | pMAG [Ul]    |
    |           | lifetime=0)  |          +--------------+
    |           |              |                 |
    |           |              |    PBU(pMAG,    |
    |           |              |     lifetime=0) | TIMEOUT_2
    |           |              |                 V
    |           |              |          +--------------+
    |           |              +--------->|    Active    |
    |           +------------------------>|              |
    +------------------------------------>| nMAG [Dl,Ul] |
                                          +--------------+
```

Figure 5

4.6. MN operation

Operation of MN to support handover and choosing appropriate settings for a transient BCE is out of scope of this specification. The same applies to mechanisms for the nMAG to detect the presence of any of the use cases for transient BCEs, e.g. the simultaneous usage of two interfaces during the handover. One solution is that the MN signals its intent for transient bindings to the MAG, either using radio layer protocols between MN and MAG or with dedicated IP-based signalling.

This document focuses on extensions required in the MAG and in the LMA. Other documents address issues of the MN operation with PMIPv6, such as [I-D.premec-netlmm-intertech-handover] and [I-D.sarikaya-netlmm-itho].

It is further out of the scope of this document how the MN can perform address configuration of the same IP address for two simultaneously attached interfaces.

4.7. Status values

This section specifies the following PBA status value for transient binding cache entry support. This status value must be smaller than 128 and adds to the set of status values specified in [I-D.ietf-netlmm-proxymip6].

- o PBU_ACCEPTED_TB_IGNORED: [IANA] The LMA has processed and accepted the PBU, but the attached Transient Binding option has been ignored.

5. Message Format

5.1. Transient Binding option

This section describes the format of the Transient Binding option, which can be present in a Proxy Binding Update message and a Proxy Binding Acknowledge message.

The Transient Binding option can be included in a PBU message which is sent by a MN's nMAG as a result of a handover. In such case, the nMAG controls the transient BCE on the LMA and specifies the associated use case by means of setting the L-flag and the A-flag accordingly. Alternatively, the LMA may attach the Transient Binding option in a PBA for two reasons. Either it replies to a received PBU with an attached Transient Binding option to approve or correct the transient BCE lifetime, or it notifies the nMAG about its decision to enter a transient BCE without having received a Transient Binding option from the nMAG in the associated PBU beforehand.

The format of the Transient Binding option is as follows.

```
     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    | Reserved  |A|L|   Lifetime    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6

Type: Identifies the Transient Binding option. To be assigned by IANA.

Length: 8-bit unsigned integer indicating the length of the option in octets, excluding the Type and the Length fields.

L-Flag: Indicates that the LMA applies late path switch according to the transient BCE state. It the L-flag is set to 1, the LMA continues to forward downlink packets towards the pMAG. In case the L-flag is set to 0, the LMA will switch the downlink path immediately to the nMAG after the PBU has been processed.

A-Flag: Indicates that the LMA must enter the Transient-A state before entering Active state when set to 1. The LMA omits the Transient-A state during activation of a transient BCE state when set

to 0.

Lifetime: Lifetime of a Transient-L state in multiple of 100ms. In case the L-Flag of the Transient Binding option is set to 1, the Lifetime field MUST be set to a non-zero value.

6. Security Considerations

Signaling between MAGs and LMAs as well as information carried by PBU and PBA messages is protected and authenticated according to the mechanisms described in [I-D.ietf-netlmm-proxymip6].

In case MAGs or LMAs make use of a further protocol interface to an external component, such as for support of transient BCE control, the associated protocol must be protected and information must be authenticated.

7. Protocol Configuration Variables

LMA values:

- o 'ACTIVATIONDELAY' : This value is set by default to 2000 ms and can be administratively adjusted.

8. Contributors

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9. Normative References

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