(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 January 2011 (06.01.2011)

PCT

(10) International Publication Number
WO 2011/000871 A2

(51) International Patent Classification:
H04W 60/00 (2009.01) *H04L 29/08* (2006.01)

(21) International Application Number:
PCT/EP2010/059285

(22) International Filing Date:
30 June 2010 (30.06.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09290538.9 3 July 2009 (03.07.2009) EP

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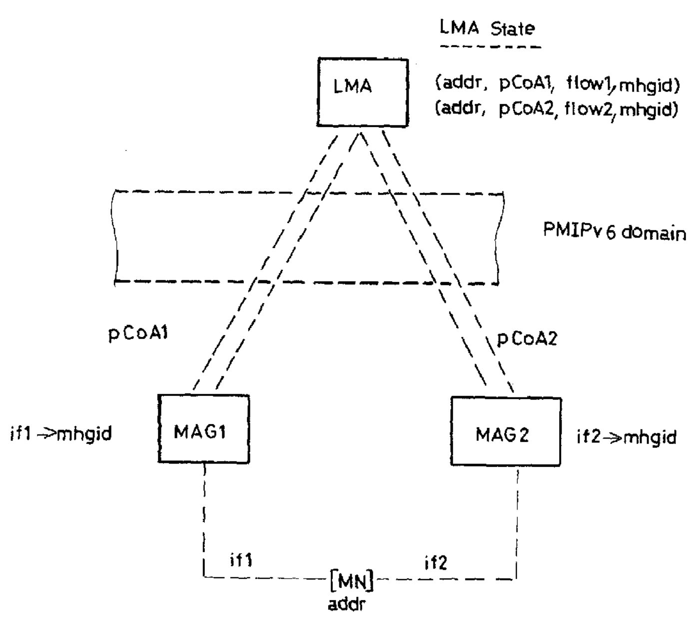
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) **Title**: ENHANCING NETWORK-BASED IP MOBILITY MANAGEMENT PROTOCOL TO PROVIDE MULTIHOMING SUPPORT

FIG-1



(57) Abstract: One object of the present invention is a method for enhancing a network-based IP mobility management protocol to provide multihoming support, said method including providing multihoming support based on multihoming group information, said information identifying a group of interfaces of a Mobile Node MN to be managed by a Local Mobility Anchor LMA on a Mobile Access Gateway MAG demand under a same mobility session.

WO 2011/000871 A2

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

ENHANCING NETWORK-BASED IP MOBILITY MANAGEMENT PROTOCOL TO PROVIDE MULTIHOMING SUPPORT

The present invention generally relates to mobile communication networks and systems, and to mobility management protocols in such networks and systems.

Detailed descriptions of mobile communication networks and systems, and mobility management protocols in such networks and systems, can be found in the litterature, such as in particular litterature published by standardisation bodies, such as IETF for IP mobility management.

Network - based IP mobility management protocols, such as in particular Proxy Mobile IPv6, PMIPv6 (as specified in RFC 5213) have a number of advantages as compared to host-based IP mobility management such as Mobile IPv6; however currently specified network-based IP mobility management protocols, such as in particular PMIPv6, fail to provide adequate multihoming support.

There is a need to provide such multihoming support, in particular for PMIPv6. More generally, there is a need to improve network-based IP mobility management protocols.

The present invention in particular addresses such needs.

These and other objects are achieved, in one aspect, in an embodiment, by a method for enhancing a network-based IP mobility management protocol to provide multihoming support, said method including providing multihoming support based on multihoming group information, said information identifying a group of interfaces of a Mobile Node MN to be managed by a Local Mobility Anchor LMA on a Mobile Access Gateway MAG demand under a same mobility session.

These and other objects are achieved, in another aspect, by entities, such as in particular Mobile Access Gateway MAG, and Local Mobility Anchor LMA, for performing such method.

These and other objects will become more apparent from the following description taken in conjunction with the accompanying drawings:

- figure 1 schematically illustrates multihomed Mobile Node with PMIPv6 extensions,

- figure 2 schematically illustrates mobility session extended for multihoming,

- figure 3 schematically illustrates initial multihoming setup,

- figure 4 schematically illustrates multihoming renewal,
- figure 5 schematically illustrates multihoming filters modification,
- figure 6 schematically illustrates multihoming interface removal,
- figure 7 schematically illustrates multihoming interface addition,
- figure 8 schematically illustrates multihoming option,
- figure 9 schematically illustrates FID Option Action values.

In one aspect, the present invention provides extensions to Proxy Mobile IPv6 in order to support multihomed mobile nodes (MN). These extensions are intended to permit such mobile nodes to send and receive IP packets on multiple interfaces in a simultaneous and possibly discriminated manner when attached to a PMIPv6 domain. A typical usage of these extensions is to perform downlink flow discrimination through multiple interfaces based on filtering rules (e.g. dedicate one MN interface to VOIP traffic and another MN interface to HTTP traffic). The proposed extensions to PMIPv6 attempt to increment in a backward compatible manner the current PMIPv6 specification.

Proxy Mobile IPv6 (PMIPv6), specified in [RFC5213], provides network based mobility management to hosts connecting to a PMIPv6 domain. PMIPv6 introduces two functional entities, the Local Mobility Anchor (LMA) and the Mobility Access Gateway (MAG). The MAG is the first layer-three hop detecting MN attachment and providing IP connectivity. The LMA is the entity assigning one or more HNP to the MN and is the topological anchor for all traffic from/to the MN. PMIPv6 allows a MN to connect to the same PMIPv6 domain through multiple interfaces (such MN being called multihomed MN). However in such a case, PMIPv6 requires each interface to be assigned a distinct IPv6 address and thus prevents from multihoming capabilities. IETF NETEXT Working Group “Multiple Interface Support with Proxy Mobile IPv6”, March 2009, studies how to support multihoming in PMIPv6 and identifies three possible models regarding IPv6 address management:

- unique prefix per interface
- unique address per interface
- shared address across interfaces.

It further describes topics associated with each model, in particular handover behavior and security aspects.

In the following description of an embodiment of the present invention, the shared address across interfaces model will be considered, as an example. In this example, the focus is intended to match the case where a multihomed MN is known by its Internet peers under the same address while the PMIPv6 domain it is attached to can perform, on its own criteria, packets delivery through the suited MN interface. As a consequence, only a single Home Network Prefix (HNP) is associated to a multihomed MN in a PMIPv6 domain. Other examples could be envisaged.

In the following description of an embodiment of the present invention, the interface "handover" or "mobility" terminology that can be perceived as confusing in the multihoming context (where MN interfaces are used simultaneously) will not be re-used. Instead, the concept of multihoming group (a logical set of interfaces of a MN) is introduced, and the support of elementary operations (addition, modification, removal) on a group entity for a MN is provided. Such terminology is expected to be more suited to the general multihoming paradigm. In the following description of an embodiment of the present invention , in an example, a default multihoming group (id=0) is defined to represent all interfaces of a given MN.

The functional usage of multihoming MN capabilities in a PMIPv6 domain is defined in a flexible and multi-purpose manner. This allows for various traffic processing in a PMIPv6 domain with multihomed MN such as (not limited to): traffic blocking, traffic load-balancing or traffic dissemination. To achieve this flexibility, the concept of "filter" is used to denote a unitary criteria that can be managed between a MAG and a LMA in relationship with a MN interface. Unitary filters can be added, deleted and modified on a per multihoming group basis. Flexibility is achieved by allowing an arbitrary filter syntax (or grammar) as proposed in IETF MEXT Working Group, “Flow bindings in Mobile IPv6 and Nemo Basic Support”, April 2009. The filter syntax is a matter of agreement between MAG and LMA entities.

Figure 1 depicts the general principles of PMIPv6 extensions for multihoming support as proposed in an embodiment of the present invention. When MN activates if1, MAG1selects the default multihoming group and perform proxy registration toward the LMA. MAG1 provides filters (flow1) during registration. LMA accepts proxy registration from MAG1 and allocates MN addr according to the shared address model.

Since proxy registration is requesting multihoming support, LMA stores MAG1 filters that come along with delivery to pCoA1.

When MN activates if2, MAG2 selects the default multihoming group and perform proxy registration toward the LMA. MAG2 provides filters (flow2) during registration. LMA accepts proxy registration from MAG2 and allocates MN addr according to the shared address model. LMA stores MAG2 filters that come along with delivery to pCoA2.

Later on, LMA receive IP packets destinated to MN addr. The LMA attempts to match each IP packet against filters (flow1, flow2) stored for the MN addr. When a filter match (flow1 or flow2), the LMA perform the action for the IP packet in the context of the matching flow. In particular if the IP packet is to be delivered, the LMA performs delivery using the pCoA associated to the filter (pCoA1 on flow1 or pCoA2 on flow2).

LMA behavior is extended to allow simultaneous transmission of downlink (DL) packets to the mobile node across multiple interfaces. No assumption is done on how the MN performs uplink (UL) packets transmission. The MN might either use a single interface for UL or select an interface according to existing or new mechanisms such as the ones being defined by the IETF MIF working group.

Both LMA and MAG behaviors are extended to provide enhanced Proxy Binding management for multihomed MN. LMA shall support Binding Control Entries (BCE) of multihomed type. This includes the capability to refer to a multihoming group id (mhgid) and a set of filters in a BCE. This also includes mechanism to allocate a unique HNP per MN when multihoming is used. LMA shall support or delegate the downlink packet processing and delivery according to flow specifications. Both MAG and LMA shall be able to manage flows on a per multihomed MN basis. Downlink flows are created/deleted/modified at LMA level on MAG request using PBU/PBA exchanges.

In an embodiment, it is proposed to extend PMIPv6 to support multiple proxy CoAs per mobility session possibly associated with downlink transmission criteria using the flow concept.

Upon MN attachment the MAG determines if the MN should be provided with multihoming service and, if so, selects the flow configuration that should be put in place for delivery through itself. The MAG can learn this information, for example through a policy store or using attachment- specific signalling. If the MAG determines that the MN can use the multihoming service it forms a PBU as per [RFC5213] and adds a Multihoming Option (as proposed in an embodiment of the present invention) and possibly one or several Flow Identifier option(s) as defined in the above –recalled MEXT document. The Multihoming option aims at identifying (MHGID) and parameterize the multihoming group to be managed (created/updated/deleted) by the LMA on MAG demand. The choice of identification of the multihoming group may follow the following rule: All PBUs with the same HNP and MHGID values belong to the same mobility session from the LMA perspective.

Figure 2 shows how the mobility session is extended to span the same HNP across multiple interfaces. This updates the text in [RFC5213] where each single interface is managed under a different mobility session. The MHGID, selected by MAG1 (corresponding to PCoA1) upon MN attachment, is stored at the LMA. When the MN attaches to MAG2 (corresponding to PCoA2) MAG2 selects its MHGID value. If both MAG1 and MAG2 MGHID and HNP values match then the LMA adds PCoA2 -- MHGID0 to the already existing mobility session.

The MAG treats the indication of multihoming as an explicit indication of adding flows to the PBU if any. Such flows can be learned for instance during MN access to the network.

Upon reception of a PBU containing indication for multihoming the LMA should perform a binding cache lookup and append the information to the found BCE. Filters, if present, are extracted from the PBU and processed by the LMA. The result of Filters processing is returned in the PBA by the LMA on an individual basis.

Examples of flow charts for multihoming setup, renewal, filters modifications and interface removal/addition will now be described.

Figure 3 shows Initial multihoming setup. Figure 3 shows the attachment of IF1 and subsequently the attachment of IF2. IF1 and IF2 belongs to the same multihoming group ID (i.e. the default multihoming group id 0).

Figure 4 shows Multihoming renewal: Figure 4 shows how binding renewal upon lifetime expiration is done.

Figure 5 shows Multihoming filters modification Filters can also be modified upon reception of an internal or external MAG trigger Figure 5. From the PMIPv6 point of view, filters modification is carried by binding renewal semantics (HI=5). The target multihoming group is set by the MAG in the multihoming option (MHGID field). This allows MAG to modify at any time the downlink filters it is responsible for.

Figure 6 shows Multihoming interface removal Figure 6 shows how to remove an interface from a multihoming group managed by a MAG for a given MN. The target multihoming group is set by the MAG in the multihoming option (MHGID field).

Figure 7 shows Multihoming interface addition Figure 7 addresses the case where the MN adds a third interface to the same multihoming group for a given MN. The target multihoming group is set by the MAG in the multihoming option (MHGID field).

The following extensions to the protocol options as defined in [RFC5213], as provided in an embodiment of the present invention, will now be described.

Figure 8 shows the Multihoming option. Following fields are provided:

Type TBA

Length 8-bit unsigned integer indicating the length of the option in octets, excluding the type and length fields. This field is set to 2.

MHGID : This 8 bit field identifies the multihoming group the PBU/PBA refer to. The value 0 is reserved to the default multihoming group which includes all interfaces of a MN. Only value 0 can be supported.

ACT

This 3-bit field is used to provide optional action to be performed by LMA upon removal of an interface from a multihoming group. The field shall only be set by the MAG when HI value in PBU is set to 4, otherwise the field shall be set to 0. The following bit values are currently defined:

000: Reserved
001: Remove filters
010: Keep filters

RFU (Reserved for Future Use)

This 5-bit field is unused for now. The value is initialized to 0 by the sender and is ignored by the receiver.

The following considerations on the ACT field may apply. If 001 (Remove filters) is set on interface removal, the LMA shall remove all filters currently configured. This might result in downlink traffic disruption. If 010 (Keep filters) is set on interface removal, the LMA shall arrange to re-instantiate filters configured on the removed interface to existing filters (if any) of other interfaces of the multihoming group if any. This allows to avoid downlink traffic disruption. The implementation of this action at LMA level can be specified. However, a filter that has been re-instantiated on a interface should be advertised by the LMA with a specific status of Flow identifier option whenever a MAG perform a filter operation the interface.

Figure 9 shows the Flow Identifier Option

The FID option defined in the above-recalled MEXT document can be used to manage downlink packet delivery across interfaces of a multihomed MN. The option might be used by a MAG to create/modify/delete filter(s) on the LMA for a particular multihoming group of a MN. Upon successful processing and installation of filter(s) at LMA level an individual status (Status field) shall be returned to the MAG by the LMA. The LMA should later evaluate packets destinated to a MN through filters installed by MAG(s) that are proxying the MN under the same mobility session. The LMA can perform the action(s) associated to the matching filter(s).

In case, the LMA re-instantiates flows on a multihoming interface group toward a MAG for a given MN, the LMA can perform the following processing:

- Allocate a unique FID to the re-instantiated filter within the context of existing filters for the multihoming group of the MN toward the target LMA
- Set the PRO field to a new reserved value (2: flow binding re-instantiated by LMA) of [MEXT] as proposed by the current specification
- Copy FID-PRI and Action fields from the original filter into the re-instantiated filter

Since no notification mechanism is currently defined between MAG and LMA in [RFC5213], re-instantiated filter(s) will be returned by LMA only on MAG demand. This might happen when MAG renews PBU or create/modify/delete its own filters.

The format of the option is briefly recalled hereafter. In an embodiment, it is proposed to extend the PRO field value in order to add the (2: flow binding re-instantiated by LMA) predefined value. The full specification of the option can be found in the above-recalled MEXT document.

MAG behavior in an embodiment of the present invention will now be described. The MAG upon MN attachment performs all the steps as per [RFC5213]. In addition to this it performs the following checks. The MAG learns if the MN is requesting a HNP as part of a new mobility session or if it is requesting to attach a new interface as part of an already existing mobility session. The MAG retrieves the MHGID from e.g. MN's profile as well as filters. The MAG can learn filters for example in an access-specific manner or alternatively via other infrastructure support.In any case the MAG encodes the PBU including at least the Multihoming option as specified before and possibly one or more FID option(s).

The MAG can modify or delete filters attached to a multihoming group by sending a PBU carrying the filter operation(s) to be performed. It shall analyze individual results according to what is returned by the LMA. In addition, MAG should be prepared to handle filters that has been re-instantiated by LMA when MN has disconnected an interface belonging to the same multihoming group.

When MAG proxying a MN detects the MN has detached the related interface, MAG stops proxying the MN by sending a PBU with lifetime set to 0 and includes the multihoming option that identifies the target multihoming group of the detached interface as well as removal behavior regarding filters. MAG waits for successful PBA to release the MN access.

LMA behavior in an embodiment of the present invention will now be described. The LMA should be modified in the BCE and conceptual data structures.

BCE modifications: The LMA binding cache lookup method should be extended to accommodate multihoming support. In case the LMA processes the Multihoming Option it SHOULD update existing mobility session as defined in [RFC5213]. In addition to this it performs the following checks.

If the Multihoming option is present in the PBU, the LMA allocates/updates/deletes the mobility session and the multihoming group ID it refers to. Flow filters received in the PBU are created/modified/deleted for the target Multihoming group ID and a result shall be return on an individual filter basis.

In addition, the LMA handles removal of interfaces from multihoming group according to MAG instructions. In particular, if a MAG instructs a LMA to remove an interface from a multihoming group but to keep filters, the LMA should re-instantiate filters on existing interface(s) of the multihoming group according to its own mechanisms. If a LMA does not support multihoming extension (as a whole) or specific multihoming option, as proposed by embodiments of the present document, it may return a status code in PBA as defined in [RFC5213]. The later specification might be extended to include multi-homing specific statuses, such as:

MH_NOT_SUPPORTED_BY_LMA

MH_FILTERS_REINSTANCIATION_NOT_SUPPORTED_BY_LMA

In one aspect , in an embodiment, the present invention provides a method for improvement of a network-based IP mobility management protocol, said protocol running between Mobile Access Gateway MAG and Local Mobility Anchor LMA, said method including providing multihoming support, based on multihoming group information exchanged between MAG and LMA, said information identifying a group of interfaces of a Mobile Node MN to be managed by LMA on MAG demand under a same mobility session.

In addition to a method for improvement of a network-based IP mobility management protocol (examples of which have been decribed above), the present invention also has for its object different entities, such as in particular Mobile Access Gateway MAG and Local mobility Anchor LMA comprising, in an embodiment, means for performing such method.

The detailed implementation of the above-mentioned means does not raise any special problem for a person skilled in the art, and therefore such means do not need to be more fully disclosed than has been made above, by their function, for a person skilled in the art.

A person of skill in the art would readily recognize that steps of various above-described methods can be performed by programmed computers. Herein, some embodiments are also intended to cover program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machine-executable or computer-executable programs of instructions, wherein said instructions perform some or all of the steps of said above-described methods. The program storage devices may be, e.g., digital memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. The embodiments are also intended to cover computers programmed to perform said steps of the above-described methods.

CLAIMS

1. A method for enhancing a network-based IP mobility management protocol to provide multihoming support, said method including providing multihoming support based on multihoming group information, said information identifying a group of interfaces of a Mobile Node MN to be managed by a Local Mobility Anchor LMA on a Mobile Access Gateway MAG demand under a same mobility session.

2 . A method according to claim 1, including a step of:

- upon attachment of a MN, MAG sending to LMA a Proxy Binding Update PBU including a Multihoming Option carrying said multihoming group information.

3 . A method according to claim 1, including a step of:

- upon attachment of a MN, MAG determining if the MN is provided with multihoming service, and if so, sending to LMA a Proxy binding Update PBU including a Multihoming Option carrying said multihoming group information.

4. A method accpording to claim 2 or 3, including a step of:

- upon attachment of a MN, MAG sending to LMA a Proxy Binding Update PBU including a Multihoming Option and Flow Identifier Option(s).

5 . A method according to any of claims 1 to 4, including a step of:

- upon reception from a MAG of a Proxy Binding Update PBU including multihoming group information, LMA performing a binding cache lookup and appending the information to the found Binding Cache Entry BCE.

6. A method according to any of claims 1 to 5, wherein the choice of identifier MHGID of a multihoming group is such that all Proxy Binding Updates PBUs sent by MAG to LMA with same Home Network Prefix and MHGID values belong to the same mobility session from LMA perspective.

7. A method according to any of claims 1 to 6, wherein a default multihoming group (id=0) is defined to represent all interfaces of a MN.

8. A method according to any of claims 1 to 7, including providing support of elementary operations on a group entity for a MN.

9. A method according to claim 8, wherin said elementary operations include at least one of following operations: initial multihoming setup, multihoming renewal, multihoming filters modification, multihoming interface removal, multihoming interface addition.

10. A Mobile Access Gateway MAG, comprising means for performing a method according to any of claim 1 to 9.

11. A Local Mobility Anchor LMA, comprising means for performing a method according to any of claim 1 to 9.

FIG_1

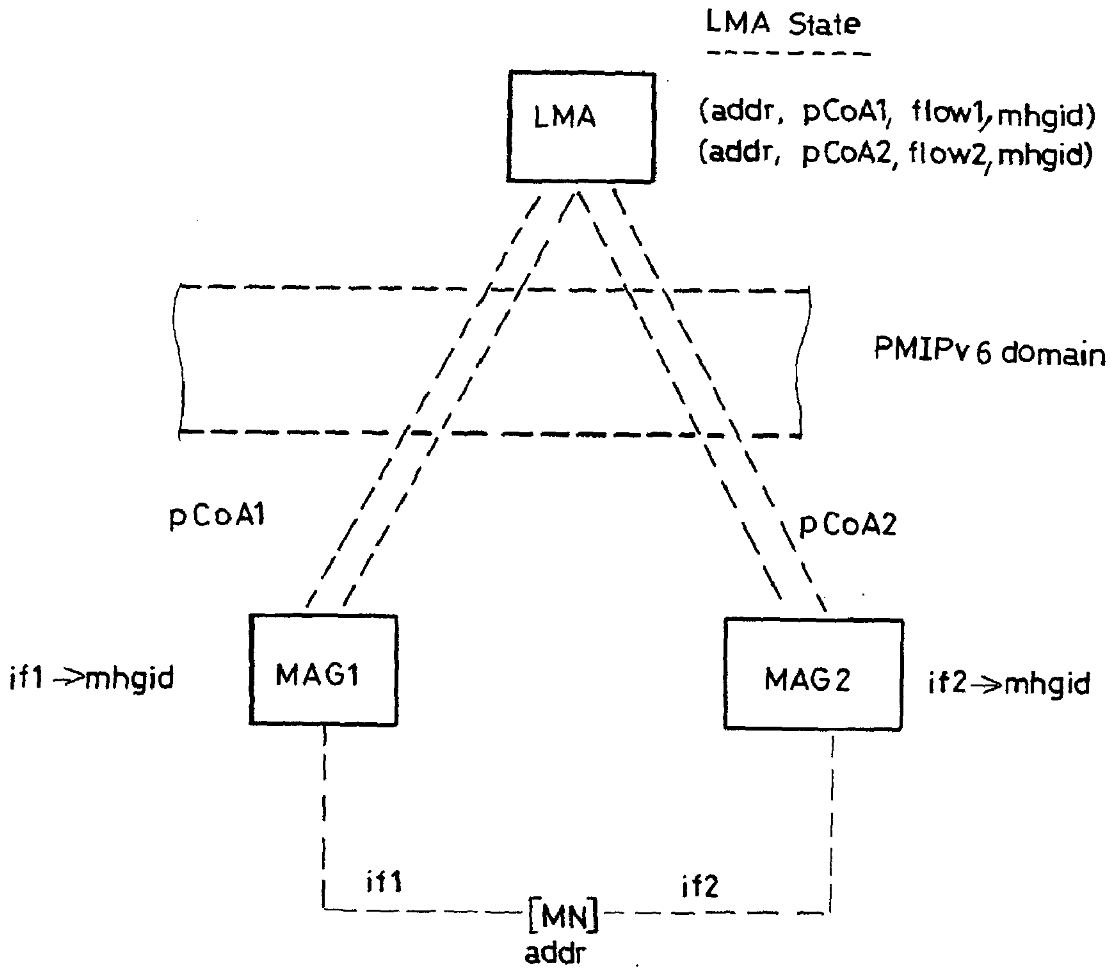

LMA State
LMA
(addr, pCoA1, flow1, mhgid)
(addr, pCoA2, flow2, mhgid)
PMIPv 6 domain
pCoA1
pCoA2
if1 ->mhgid
MAG1
MAG2
if2->mhgid
if1
if2
[MN]
addr

FIG_2

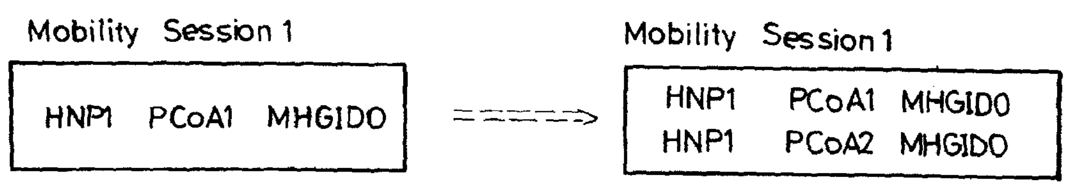

Mobility Session 1
HNP1 PCoA1 MHGID0
Mobility Session 1
HNP1 PCoA1 MHGID0
HNP1 PCoA2 MHGID0

FIG_3

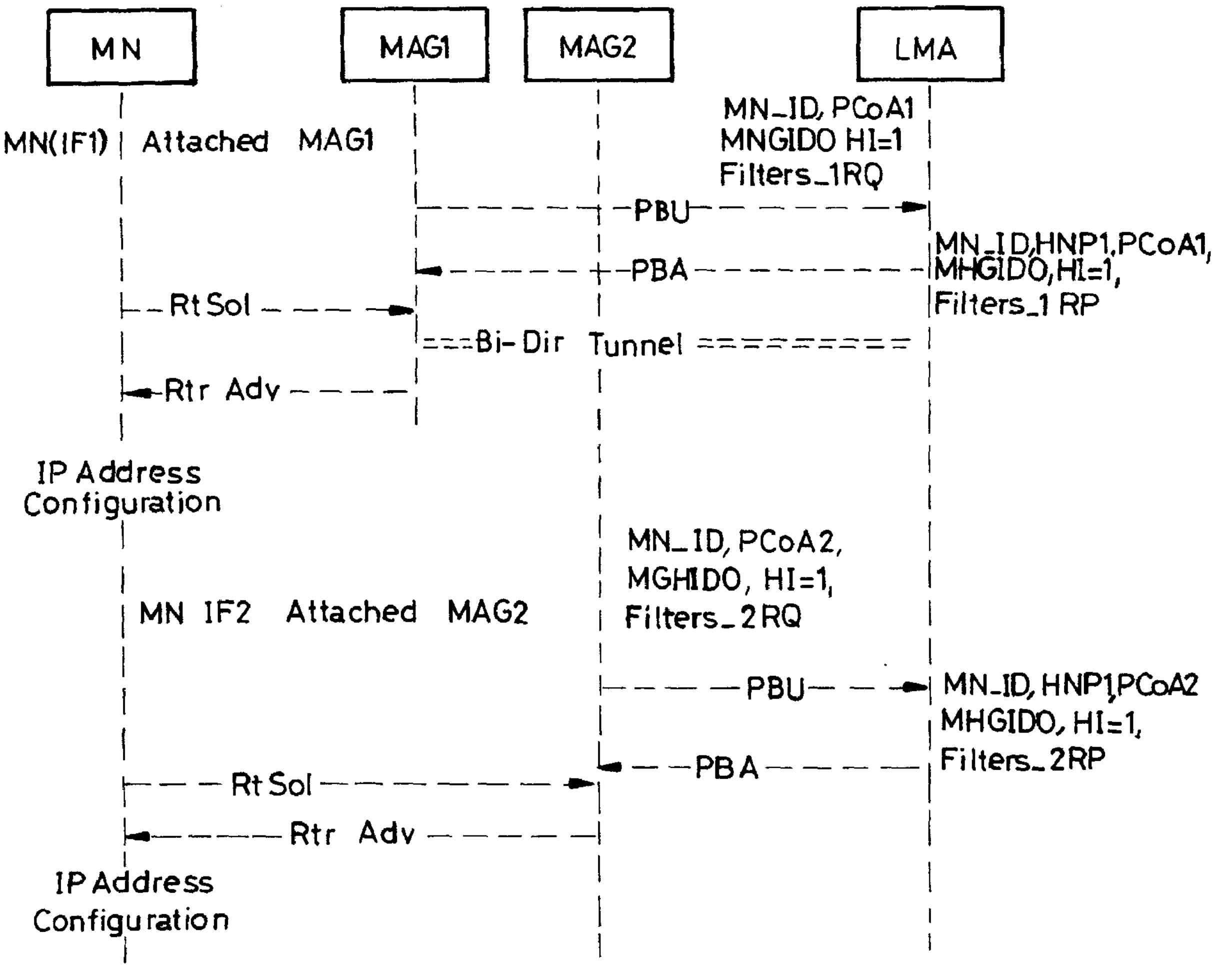

MN
MAG1
MAG2
LMA
MN(IF1) Attached MAG1
MN_ID, PCoA1
MNGIDO HI=1
Filters_1RQ
PBU
PBA
MN_ID,HNP1,PCoA1,
MHGIDO,HI=1,
Filters_1 RP
Rt Sol
Bi-Dir Tunnel
Rtr Adv
IP Address
Configuration
MN_ID, PCoA2,
MGHIDO, HI=1,
Filters_2RQ
MN IF2 Attached MAG2
PBU
MN_ID, HNP1,PCoA2
MHGIDO, HI=1,
Filters_2RP
PBA
Rt Sol
Rtr Adv
IP Address
Configuration

FIG_4

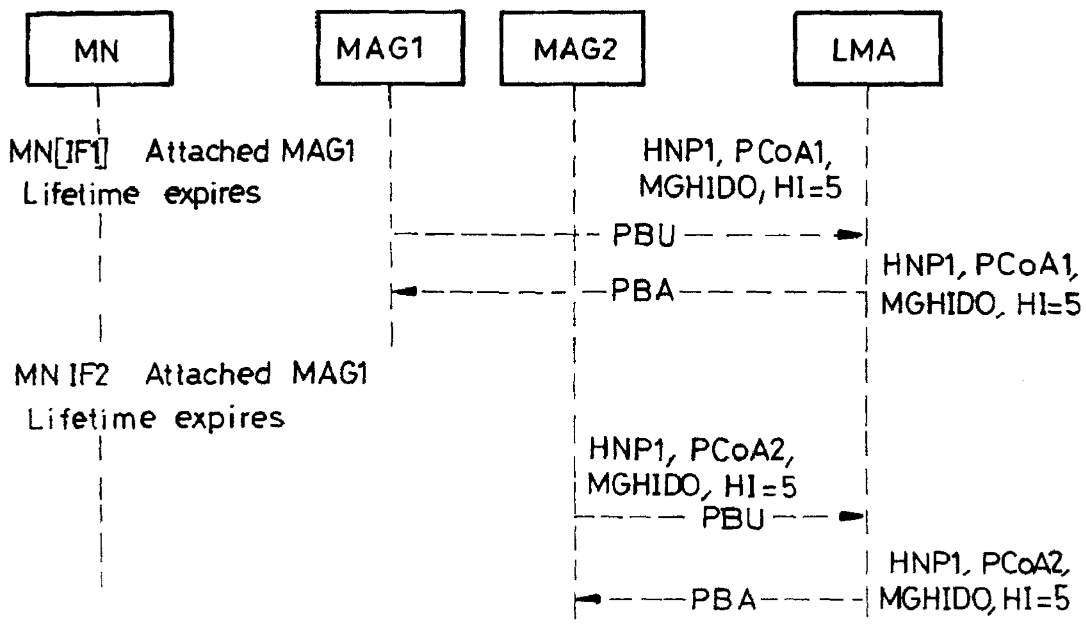

MN
MAG1
MAG2
LMA
MN[IF1] Attached MAG1
Lifetime expires
HNP1, PCoA1,
MGHIDO, HI=5
PBU
HNP1, PCoA1,
MGHIDO, HI=5
PBA
MN IF2 Attached MAG1
Lifetime expires
HNP1, PCoA2,
MGHIDO, HI=5
PBU
HNP1, PCoA2,
MGHIDO, HI=5
PBA

FIG_5

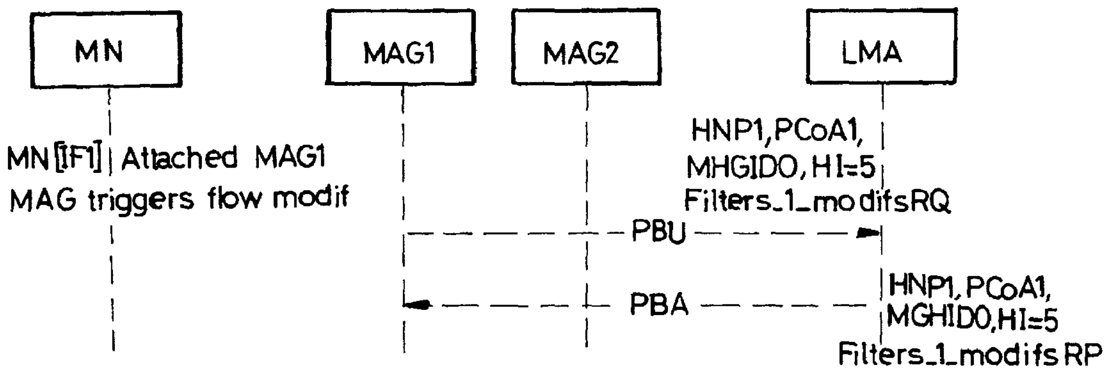


FIG_6

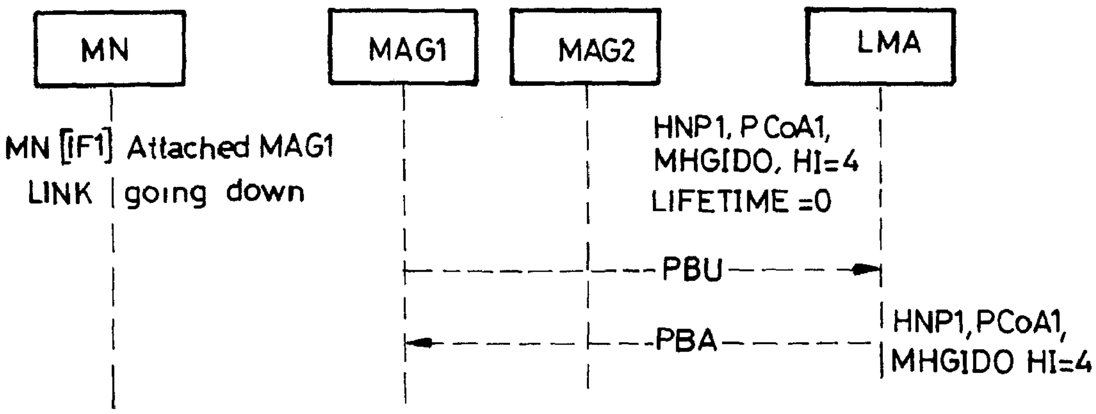


FIG_7

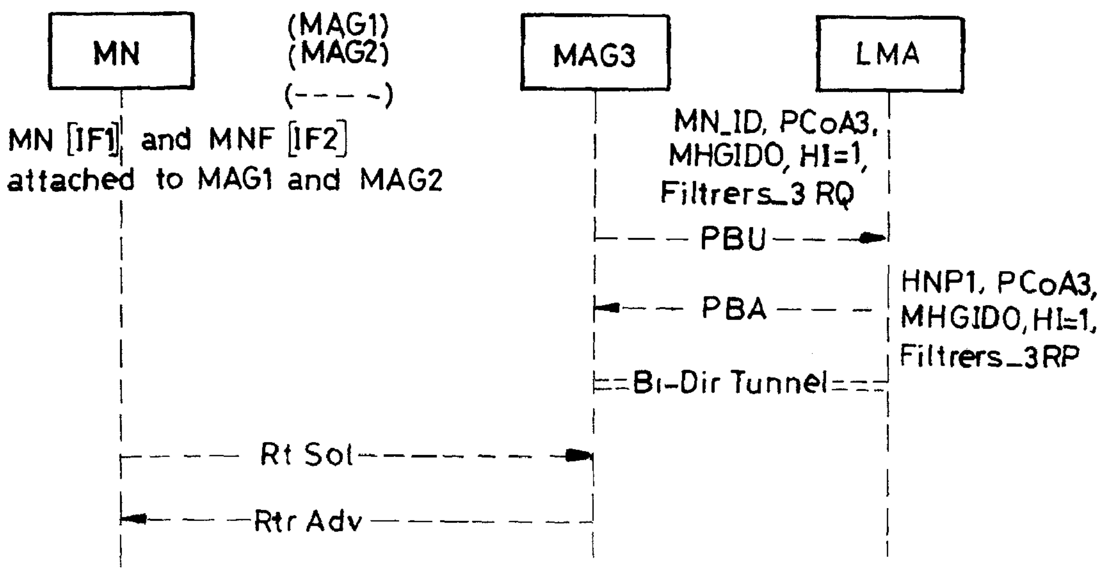


FIG_8

```
 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     |     MHGID     | ACT |   RFU   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

FIG_9

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Option type   |  Option Len   |              FID              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    FID-PRI     |    Action     |Rsvd |  PRO   |    Status      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```