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Abstract

According to the current Mobile IPv6 specification, a mobile node may have several care-of addresses, but only one, termed the primary care-of address, can be registered with its home agent and the correspondent nodes. However, for matters of cost, bandwidth, delay, etc, it is useful for the mobile node to get Internet access through multiple access media simultaneously, in which case multiple active IPv6 care-of addresses would be assigned to the mobile node. We thus propose Mobile IPv6 extensions designed to register multiple care-of addresses bound to a single Home Address instead of the sole primary care-of address. For doing so, a new identification number must be carried in each binding for the receiver to distinguish between the bindings corresponding to the same Home Address. Those extensions are targeted to NEMO (Network Mobility) Basic Support as well as to Mobile IPv6.

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1. Introduction

A mobile node should use various type of network interfaces to obtain durable and wide area network connectivity. The assumed scenarios and motivations for multiple points of attachment, and benefits for doing it are discussed at large in [[ID-MOTIVATION](#)].

IPv6 [[RFC-2460](#)] conceptually allows a node to have several addresses on a given interface. Consequently, Mobile IPv6 [[RFC-3775](#)] has mechanisms to manage multiple ``Home Addresses'' based on home agent's managed prefixes such as mobile prefix solicitation and mobile prefix advertisement. But assigning a single Home Address to a node is more advantageous than assigning multiple Home Addresses because applications do not need to be aware of the multiplicity of Home Addresses. If multiple home addresses are available, applications must reset the connection information when the mobile node changes its active network interface (i.e. change the Home Address).

According to the Mobile IPv6 specification, a mobile node is not allowed to register multiple care-of addresses bound to a single Home Address. Since NEMO Basic Support [[RFC-3963](#)] is based on Mobile IPv6, the same issues apply to a mobile node acting as a mobile router. Multihoming issues pertaining to mobile nodes operating Mobile IPv6 and mobile routers operating NEMO Basic Support are respectively discussed [[ID-MIP6ANALYSIS](#)] and [[RFC-4980](#)] in Monami6 and NEMO Working Group.

In this document, we thus propose a new identification number called Binding Unique Identification (BID) number for each binding cache entry to accommodate multiple bindings registration. The mobile node notifies the BID to both its Home Agent and correspondent nodes by means of a Binding Update. Correspondent nodes and the home agent record the BID into their binding cache. The Home Address thus identifies a mobile node itself whereas the BID identifies each binding registered by a mobile node. By using the BID, multiple bindings can then be distinguished.

2. Terminology

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 [[RFC-2119](#)].

Terms used in this draft are defined in [[RFC-3775](#)], [[RFC-3753](#)] and [[RFC-4885](#)]. In addition or in replacement of these, the following terms are defined or redefined:

Binding Unique Identification number (BID)

The BID is an identification number used to distinguish multiple bindings registered by the mobile node. Assignment of distinct BID allows a mobile node to register multiple binding cache entries for a given Home Address. The BID is conceptually assigned to a binding in a way it cannot be duplicated with another BID. The zero value and a negative value MUST NOT be used. After being generated by the mobile node, the BID is stored in the Binding Update List and is sent by the mobile node by means of a sub-option of a Binding Update. A mobile node MAY change the value of a BID at any time according to its administrative policy, for instance to protect its privacy. An implementation must carefully assign the BID so as to keep using the same BID for the same binding even when the status of the binding is changed. More details can be found in [Section 5.1](#).

Binding Unique Identifier sub-option

The Binding Unique Identifier sub-option is used to carry the BID.

Bulk Registration

A mobile node can register multiple bindings at once by sending a single binding update. The mobile node does not necessarily put all the available care-of addresses in the binding update, but several care-of addresses. A mobile node can also replace all the bindings available at the home agent with the new bindings by using the bulk registration. The bulk registration is supported only for home registration and deregistration as explained in [Section 5.5](#). A mobile node MUST NOT perform bulk registration with correspondent nodes.

3. Protocol Overview

A new identification number (BID) is introduced to distinguish multiple bindings pertaining to the same Home Address. Once a mobile node gets several IPv6 global addresses on interfaces, it can register these addresses with its home agent. If the mobile node wants to register multiple bindings, it MUST generate a BID for each care-of address and record the BID into the binding update list. A mobile node can manage each binding independently owing to BID. The mobile node then registers its care-of addresses by sending a Binding Update with a Binding Unique Identifier sub-option. The BID MUST be included in the Binding Unique Identifier sub-option. After receiving such Binding Update and Binding Unique Identifier sub-option, the home agent MUST copy the BID from the Binding Unique Identifier sub-option to the corresponding field in the binding cache entry. Even if there is already an entry for the mobile node's home address, the home agent MUST register a new binding entry for the BID stored in the Binding Unique Identifier sub-option. The mobile node registers multiple care-of addresses either independently in individual Binding Updates or multiple at once in a single Binding Update.

If the mobile host wishes to register its binding with a correspondent node, it must operate return routability operations. The mobile host MUST manage a Care-of Keygen Token per care-of address. If it is necessary (ex. Care-of Keygen token is expired), the mobile host exchanges CoTI and CoT for the relative care-of addresses. When the mobile host registers several care-of addresses to a correspondent node, it uses the same BID as the one generated for the home registration's bindings. The binding registration step is the same as for the home registration except for calculating authenticator by using Binding Unique Identifier sub-option as well as the other sub-options specified in [\[RFC-3775\]](#). For simplicity, the bulk registration is not supported for correspondent nodes in this document.

If the mobile node decides to act as a regular mobile node compliant with [\[RFC-3775\]](#), it just sends a Binding Update without any Binding Unique Identifier sub-options (i.e. normal Binding Update). The receiver of the Binding Update deletes all the bindings registering with a BID and registers only a single binding for the mobile node. Note that the mobile node can continue to use BID even if only a single binding is active at some time.

The BID is used as a search key for a corresponding entry in the binding cache in addition to the Home Address. When a home agent and a correspondent node check the binding cache database for the mobile node, they search a corresponding binding entry with the Home Address

and BID of the desired binding. If necessary, a mobile node can use policy and filter information to look up the best binding per sessions, flow, packets, but this is out of scope in this document and is currently discussed in Monami6 WG. If there is no desired binding, it searches the binding cache database with the Home Address as specified in Mobile IPv6. The first matched binding entry may be found, although this is implementation dependent.

A mobile node carefully operates the returning home. The Home Agent needs to defend a mobile node's home address by the proxy NDP for packet interception, while the mobile node defends its home address by regular NDP to send and receive packets at the interface attached to the home link. Two nodes, Home Agent and Mobile Node, compete ND state. This will cause address duplication problem at the end. If the proxy neighbor advertisement for the Home Address is stopped, packets are always routed to the interface attached to the home link. On the other hand, packets are never routed to the interface attached to the home link when the proxy is active.

When a mobile node wants to return home with interface attached to the home link, it MUST de-register all the bindings by sending a Binding Update with lifetime set to zero as described in [[RFC-3775](#)] and [[RFC-3963](#)]. The mobile node does not put any Binding Unique Identifier sub-option in this Binding Update. The receiver deletes all the bindings from its binding cache database. On the other hand, a mobile node does not want to return home and keeps the interfaces attached to the foreign links active, when one of its interfaces is attached to its home link. The mobile node disables the interface attached to the home link and keeps using the rest of interfaces attached to foreign links. In this case, the mobile node sends a de-registration Binding Update including the BID for the interface attached to the home link. The receiver of the de-registration Binding Update deletes only the relative binding entry from the binding cache database. The home agent does not stop proxying neighbor advertisement as long as there are still bindings for the other interfaces. It is important to understand that this scenario is not the most efficient because all the traffic from and to the mobile node is going through the bi-directional tunnel, whereas the mobile node is now accessible at one hop from its home agent.

In the above two cases, a mobile node cannot use interfaces attached to both home and foreign links simultaneously. If the proxy NDP is disabled, the main problem can be solved. In the Multiple Care-of Address Registration, the elimination of Proxy NDP enables that Mobile Node and Home Agent maintain multiple bindings for the interfaces attached to the home link and the foreign links. The mobile node sends the binding update with H flag set for the interface attached to the home link. The detail operation can be

found in [Section 5.5](#).

4. Mobile IPv6 Extensions

This section summarizes the changes to Mobile IPv6 necessary to manage multiple bindings bound to a same Home Address.

4.1. Binding Cache Structure and Binding Update List

The BID is required in the binding cache and binding update list structure.

4.2. Message Format Changes

4.2.1. Binding Unique Identifier sub-option

The Binding Unique Identifier sub-option is included in the Binding Update, Binding Acknowledgment, Binding Refresh Request, and Care-of Test Init and Care-of Test message.

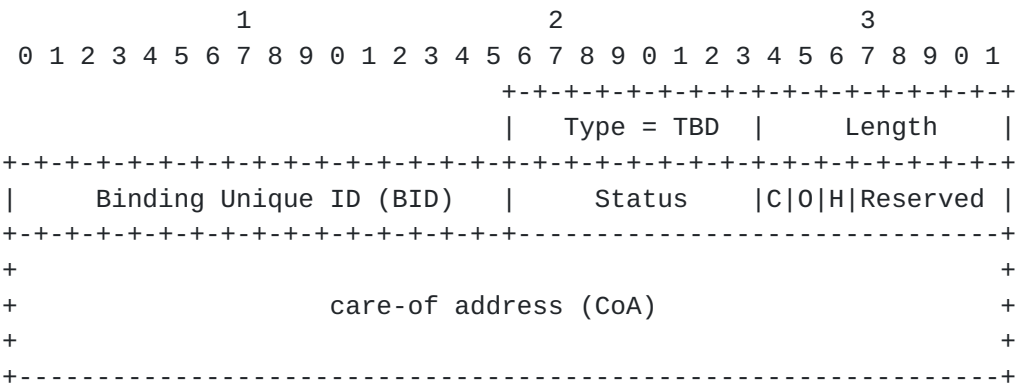


Figure 1: BID Sub-Option

Type

Type value for Binding Unique Identifier is TBD

Length

Length value MUST be 4 when C flag is unset. Otherwise, the Length value MUST be set to 20.

Binding Unique ID (BID)

The BID which is assigned to the binding carried in the Binding Update with this sub-option. BID is 16-bit unsigned integer. A value of zero is reserved.

Status

When the Binding Unique Identifier sub-option is included in a Binding Acknowledgment, this field overwrites the status field correspondent to each binding in the Binding Acknowledgment. If this field is zero, the receiver **MUST** use the registration status stored in the Binding Acknowledgment message. This Status field can be used to carry error information for a Care-of Test message. The status is 8-bit unsigned integer. The possible status codes are the same as the status codes of Binding Acknowledgment.

Care-of address (C) flag

When this flag is set, a mobile node can store a Care-of Address corresponding to the BID in the Binding Unique Identifier sub-option. This flag must be used whenever a mobile node sends multiple bindings in a single Binding Update, i.e. bulk registration or **MUST** be used as a substitute for an alternate care-of address option. This flag is valid only for binding update for the home agent.

Overwrite (O) flag

When this flag is set, a mobile node requests a home agent to replace all the bindings to binding entries stored in a Binding Update. This flag is valid only for binding update for the home agent.

Home Binding (H) flag

This flag indicates that the mobile node is attached to the home link. This flag is valid only for binding update for the home agent.

Reserved

5 bits Reserved field. Reserved field must be set with all 0.

Care-of Address

When C flag is set, a Care-of Address matched to the BID is stored. This field is valid only if a Binding Unique Identifier sub-option is stored in Binding Update message. Otherwise, this field can be omitted. The receiver **SHOULD** ignore this field if the sub-option is presented in other than Binding Update.

4.3. New Status Values for Binding Acknowledgment

New status values for the status field in a Binding Acknowledgment are defined for handling the multiple Care-of Addresses registration:

MCOA INCOMPLIANT (TBD)

Registration failed because Binding Unique Identifier sub-option is not compliant.

MCOA BID CONFLICT (TBD)

It indicates that a regular binding (i.e. without the BID set) is already registered for the home address, and is conflicting with a received Binding Update which BID is set.

MCOA PROHIBITED(TBD)

It implies the multiple care-of address registration is administratively prohibited.

MCOA BULK REGISTRATION NOT SUPPORTED (TBD)

The bulk binding registration is not supported.

MCOA FLAG CONFLICTS (TBD)

The flags of the sub-options presented in a Binding Unique Identifier sub-options conflicts.

5. Mobile Node Operation

5.1. Management of Care-of Addresses and Binding Unique Identifier

There are two cases when a mobile node has several Care-of Addresses:

1. A mobile node uses several physical network interfaces and acquires a care-of address on each of its interfaces.
2. A mobile node uses a single physical network interface, but multiple prefixes are announced on the link the interface is attached to. Several global addresses are configured on this interface for each of the announced prefixes.

The difference between the above two cases is only a number of physical network interfaces and therefore does not matter in this document. The Identification number is used to identify a binding. To implement this, a mobile node MAY assign an identification number for each care-of addresses. How to assign an identification number is up to implementers.

A mobile node assigns a BID to each care-of address when it wants to register them simultaneously with its Home Address . The value should be generated from a value comprised between 1 to 65535. Zero and negative values MUST NOT be taken as a BID. If a mobile node has only one care-of address, the assignment of a BID is not needed until it has multiple care-of addresses to register with.

5.2. Return Routability: Sending CoTI and Receiving CoT

When a mobile node wants to register bindings to a Correspondent Node, it MUST have the valid care-of Keygen token per care-of address, while the HoTI and HoT can be exchanged only once for a Home Address.

If the Mobile Node manages bindings with BID, it MUST include a Binding Unique Identifier sub-option in a Care-of Test Init message. It MUST NOT set the any flags in the sub-option. The receiver (i.e. correspondent node) will calculate a care-of Keygen token as specified in [\[RFC-3775\]](#) and reply a Care-of Test message and the Binding Unique Identifier sub-option as described in [Section 6.2](#). When the mobile node receives the Care-of Test message, the Care-of Test message is verified as same as in [\[RFC-3775\]](#). If a Binding Unique Identifier sub-option is not presented in CoT in reply to the CoTI containing the Binding Unique Identifier sub-option, the correspondent node does not support the Multiple Care-of Address registration. Thus, the mobile node MUST NOT use a Binding Unique Identifier sub-option in the future Binding Update. The Mobile Node

MAY skip resending regular CoTI message and keep the received care-of Keygen token for the regular Binding Update, because the correspondent node just ignores and skip the Binding Unique Identifier sub-option and calculates the care-of Keygen token as [\[RFC-3775\]](#) specified.

5.3. Binding Registration

When a mobile node sends a Binding Update, it MUST decide whether it registers multiple care-of addresses or not. However, this decision is out-of scope in this document. If a mobile node decides not to register multiple care-of addresses, it completely follows the [RFC3775](#) specification.

For the multiple Care-of Addresses registration, the mobile node MUST include a Binding Unique Identifier sub-option(s) in the Mobility Option field of a Binding Update as shown in Figure 2. The BID is copied from a corresponding Binding Update List entry to the BID field of the Binding Unique Identifier sub-option. When ESP is used for binding update, the care-of address MUST be stored in the Care-of Address field by setting C flag as a substitute for the alternate care-of address option. The alternate care-of address option MUST be omitted. Additionally for binding registration to a correspondent node, the mobile node MUST have both active home and care-of Keygen tokens for Kbm (see [Section 5.2.5 of \[RFC-3775\]](#)). The care-of Keygen tokens MUST be maintained for each care-of address that the mobile node wants to register to the correspondent node, as described in [Section 5.2](#). After computing an Authenticator value for the Binding Authorization sub-option, it sends a Binding Update which contains a Binding Unique Identifier sub-option. The Binding Update is protected by a Binding Authorization Data sub-option placed after the Binding Unique Identifier sub-option.

```
IPv6 header (src=CoA, dst=HA)
  IPv6 Home Address Option
  ESP Header (for home registration)
  Mobility header
    -BU
    Mobility Options
      - Binding Unique Identifier sub-option
      - Binding Authorization sub-option
        (for Route Optimization)
```

Figure 2: Binding Update for Binding Registration

5.4. Binding Bulk Registration

The bulk registration is an optimization for registering multiple care-of addresses only to a home agent by using a single Binding Update. If a mobile node, for instance, does not want to send a lot of control messages through an interface which bandwidth is scarce, it can use this bulk registration and send a Binding Update containing multiple or all the valid care-of addresses.

A mobile node sets the C flag in a Binding Unique Identifier sub-option and stores the particular care-of address in the Binding Unique Identifier sub-option. The mobile node stores multiple sets of a Binding Unique Identifier sub-option in a Binding Update as shown in Figure 3. When multiple Binding Unique Identifier sub-options are presented in a Binding Update, the flag field of all the sub-options MUST have the same value. For example, if C flag is set, the same flag MUST be set to all the sub-options. Otherwise, the mobile node will receive errors [MCOA FLAG CONFLICTS] by a Binding Acknowledgment. In the bulk registration, all the other binding information such as Lifetime, Sequence Number, binding Flags are shared among the bulked Care-of Addresses. The alternate care-of address option MUST be omitted when ESP is used to protect a binding update. In the bulk registration, the Sequence Number field of a Binding Update SHOULD be carefully configured. If each binding uses different sequence number, a mobile node MUST use the largest sequence number from the binding update list used for the bulk registration. If it cannot select a sequence number for all the bindings due to sequence number out of window, it MUST NOT use the bulk registration for the binding which sequence number is out of window and uses a separate Binding Update for the binding.

```
IPv6 header (src=CoA, dst=HA)
  IPv6 Home Address Option
  ESP Header
  Mobility header
    -BU
    Mobility Options
      - Binding Unique Identifier sub-options
        (C flag is set, O flag is optional,
         BID and CoA are stored)
```

Figure 3: Binding Update for Binding Bulk Registration

If the mobile node wants to replace existing registered bindings on the home agent with the bindings in the sent Binding Update, it can set O flag. [Section 6.3](#) describes this registration procedure in detail.

5.5. Binding De-Registration and Returning Home

When a mobile node decides to delete all the bindings for its home address at a visiting network, it simply sends a regular de-registration Binding Update which lifetime is set to zero. A Binding Unique Identifier sub-option is not required.

If a mobile node wants to delete a particular binding(s) from its home agent and correspondent nodes (e.g. from foreign link), the mobile node simply sets zero lifetime for the sending binding update. The Binding Update **MUST** contain a relative Binding Unique Identifier Sub-option(s). The receiver will remove only the care-of address(es) that matches to the specified BID. For the bulk de-registration, the care-of addresses field of each sub-option **SHOULD** be omitted, because the receiver will remove all the care-of addresses which matches the specified BID.

When a mobile node returns home, it **SHOULD** de-register all bindings with the home agent by sending a regular de-registration binding update to flush all the registered bindings. However, there are several scenarios for returning home described in [Appendix A](#) (Figure 7, Figure 8, Figure 9). We have discussed this feature in Monami6 working group now. This part might be updated in the next revision.

As shown in Figure 7 in [Appendix A](#), a mobile node de-registers all the binding from the home agent, while it **MAY** still keep the bindings of the other interface active attached to foreign links only at the Correspondent Nodes. By doing this, the mobile node still receives packets from the Correspondent Node at the interface attached to a foreign link thanks to route optimization. If the correspondent nodes does not use route optimization, the mobile node receives such packets at the interface attached to the home link.

In Figure 8, a mobile node does not want to return home even if one of interfaces is attached to the home link. The mobile node **MUST** disable the interface attached to the home link. Otherwise, address duplication will be observed because the home agent still defend the Home Address by the proxy neighbor advertisement and the mobile node also enables the same Home Address on the home link. After disabling the interface attached to the home link, the mobile node **MUST** delete the binding for the disabled interface by sending a de-registration binding update. The de-registration binding update is sent from one of active interfaces attached to foreign links. As a result, the mobile node no longer receives packets at the interface attached to the home link. All packets are routed to other interfaces attached to a foreign link.

Alternatively, the Mobile Node may choose to activate both the interfaces attached to the home link and the foreign link, and communicates with all of the interfaces. The Mobile Node notifies the Home Agent using the H flag which means the Mobile Node is attached to the home link. The Mobile Node may notify the care-of address of the interface(s) attached to the foreign link(s) in the same message using bulk registration. The Home Agent then no longer uses Proxy Neighbor Advertisement to intercept packets and the Mobile Node can utilize both of interfaces attached to the home link and the foreign link simultaneously. The Home Agent can intercept packets by IP routing, but not by proxy Neighbor Discovery. The detailed operation of no NDP operation can be found in [[ID-NONDP](#)].

When the Mobile Node returns home, it de-registers a binding for the interface. While the bindings for the interfaces attached to the foreign link are still active. Intercepting packets, the Home Agent can decide whether it tunnels to the foreign interface or routes to the home interface of the Mobile Node. To do so, the Home Agent must know that the Mobile Node is back to the home link. However, if the binding is deleted, there is no way for the Home Agent to know that the Mobile Node is at the home, too. The Home Agent SHOULD invalidate the binding for the interface attached to the home link and MAY NOT delete it. It can alternatively mark that the Mobile Node is at the home link, too. As an example, the Home Agent inserts the Home Address of the Mobile Node in the Care-of Address field of the Mobile Node. The binding is named "Home Binding" in this documentation. The Home Agent MAY manage this home binding as same as the other binding entry in terms of lifetime validation, etc. The Mobile Node MAY send multiple binding de- registration to keep this home binding active. Alternatively, the Home Agent can use infinity lifetime for the lifetime of the home binding. When the Mobile Node leaves the Home Link, it can update the home binding to the normal binding. Before that, the Home Agent believes the Mobile Node is at the home and may route packets for the Mobile Node to the Home Link.

5.6. Receiving Binding Acknowledgment

The verification of a Binding Acknowledgment is the same as Mobile IPv6 ([section 11.7.3 of \[RFC-3775\]](#)). The operation for sending a Binding Acknowledgment is described in [Section 6.3](#).

If a mobile node includes a Binding Unique Identifier sub-option in a Binding Update with A flag set, a Binding Acknowledgment MUST carry a Binding Unique Identifier sub-option in the Mobility Options field. If no such sub-option is appeared in the Binding Acknowledgment replied to the Binding Update for the multiple care-of address registration, this indicates that the originator node of this Binding Acknowledgment might not recognize the Binding Unique Identifier sub-

option. The mobile node SHOULD stop registering multiple care-of addresses by using a Binding Unique Identifier sub-option.

If a Binding Unique Identifier sub-option is present in the received Binding Acknowledgment, the mobile node checks the registration status for the Care-of address(es). The status value MUST be retrieved as follows. If the status value in the Binding Unique Identifier sub-option is zero, the mobile node uses the value in the Status field of the Binding Acknowledgment. Otherwise, it uses the value in the Status field of the Binding Unique Identifier sub-option.

If the status code is greater than or equal to 128, the mobile node starts relevant operations according to the error code. Otherwise, the originator (home agent or correspondent node) successfully registered the binding information and BID for the mobile node.

- o If the Status value is [MCOA PROHIBITED], the mobile node MUST give up registering multiple bindings to the peer sending the Binding Acknowledgment. It MUST return to the regular Mobile IPv6 [[RFC-3775](#)] for the peer node.
- o If the Status value is [MCOA BULK REGISTRATION NOT SUPPORT], the mobile node SHOULD stop using bulk registration to the peer sending the Binding Acknowledgment.
- o If [MCOA FLAG CONFLICTS] is specified, it indicates that the different flag values are used in Binding Unique Identifier sub-options in a Binding Update. If the C flag is set, all sub-options MUST have C flag. It is same for O flag. How to handle other error status codes is specified in [[RFC-3775](#)].
- o If [MCOA BID CONFLICT] is specified, the binding entry specified by the Binding Unique Identifier sub-option is already registered as a regular binding. In such case, the mobile node SHOULD stop sending Binding Updates with BID, or SHOULD use O flag for the peer to reset all the registered bindings.

[5.7.](#) Receiving Binding Refresh Request

The verification of a Binding Refresh Request is the same as in Mobile IPv6 ([section 11.7.4 of \[RFC-3775\]](#)). The operation of sending a Binding Refresh Request is described in [section 6.4](#).

If a mobile node receives a Binding Refresh Request with a Binding Unique Identifier sub-option, this Binding Refresh Request requests a new binding indicated by the BID. The mobile node SHOULD update only the respective binding. The mobile node MUST put a Binding Unique

Identifier sub-option into the Binding Update sent to refresh the entry.

If no Binding Unique Identifier sub-option is present in a Binding Refresh Request, the mobile node sends a Binding Update according to its Binding Update List. On the other hand, if the mobile node does not have any Binding Update List entry for the requesting node, the mobile node needs to register either a single binding or multiple bindings depending on its binding management policy.

5.8. Sending Packets to Home Agent

When a multihomed mobile node sends packets to its home agent, there are conceptually two ways to construct packets.

1. Using Home Address Option. (required additional 24 bytes)
2. Using IPv6-IPv6 tunnel. (required additional 40 bytes)

Beside the additional size of packets, no difference is observed between these two. The routing path is always the same and no redundant path such as dog-leg route occurs. However, in this document, the mobile node is capable of using multiple care-of addresses for outgoing packets. This is problem in home agent side because they must verify the Care-of address for all the packets received from the mobile node (i.e. ingress filtering). When it uses the Home Address option, the home agent MAY check the care-of address in the packet with the registering binding entries. This causes additional overhead to the home agent. Therefore, the mobile node SHOULD use the bi-directional tunnel even if it registers a binding(s) to the home agent.

5.9. Bootstrapping

When a mobile node bootstraps and registers multiple bindings at the first time, it SHOULD set 0 flag in the Binding Unique Identifier sub-option. If old bindings still exists at the Home Agent, the mobile node has no way to know which bindings are remained as a garbage. This scenario happens when a mobile node reboots without correct deregistration. If 0 flag is used, all the bindings are replaced to the new binding(s). Thus, the garbage bindings are surely replaced by new bindings registered with the first Binding Update. If the mobile node receives the Binding Acknowledgment with the status code set to 135 [Sequence number out of window], it MUST retry sending a Binding Update with the last accepted sequence number which is notified by the Binding Acknowledgment.

For Correspondent nodes, the mobile node cannot use the 0 flag

because of no bulk registration support. Thus, if necessary, it MUST send a regular binding first to overwrite the remaining bindings at the correspondent node. Then, it can re-register the set of bindings by using Multiple Care-of Address Registration.

6. Home Agent and Correspondent Node Operation

6.1. Searching Binding Cache with Binding Unique Identifier

If either a correspondent node or a home agent has multiple bindings for a mobile node in their binding cache database, it can use any of the bindings to communicate with the mobile node. How to select the most suitable binding from the binding cache database is out of scope in this document.

Whenever a correspondent node searches a binding cache for a home address, it SHOULD use both the Home Address and the BID as the search key if it knows the corresponding BID. In the example below, if a correspondent node searches the binding with the Home Address and BID2, it gets binding2 for this mobile node.

```
binding1 [a:b:c:d::EUI,  care-of address1,  BID1]
binding2 [a:b:c:d::EUI,  care-of address2,  BID2]
binding3 [a:b:c:d::EUI,  care-of address3,  BID3]
```

Figure 4: Searching the Binding Cache

A correspondent node basically learns the BID when it receives a Binding Unique Identifier sub-option. At the time, the correspondent node MUST look up its binding cache database with the Home Address and the BID retrieved from the Binding Update. If the correspondent node does not know the BID, it searches for a binding with only a Home Address as performed in Mobile IPv6. In such case, the first matched binding is found. But which binding entry is returned for the normal search depends on implementations. If the correspondent node does not desire to use multiple bindings for a mobile node, it can simply ignore the BID.

6.2. Receiving CoTI and Sending CoT

When a correspondent node receives a CoTI message which contains a Binding Unique Identifier sub-option, it MUST process it with following steps.

First of all, the CoTI message is verified according to [\[RFC-3775\]](#). The Binding Unique Identifier sub-option MUST be, then, processed as follows:

- o If a correspondent node does not understand a Binding Unique Identifier sub-option, it just ignores and skip this option. The calculation of a care-of Keygen token will thus be done without a BID value. The correspondent node returns a CoT message without a Binding Unique Identifier sub-option. The mobile node can thus

know whether the correspondent can process the Binding Unique Identifier sub-option or not, by checking if such option is present in the CoT message.

- o If either or both C and O flag is set in the sub-option, the Correspondent Node SHOULD NOT calculate a care-of Keygen token and MUST include a Binding Unique Identifier sub-option which status value set to [MCOA INCOMPLIANT] in the returned Care-of Test message.
- o Otherwise, the correspondent node MUST include a Binding Unique Identifier sub-option which status value MUST be set to zero in the returning a CoT message.
- o All the Binding Unique Identifier sub-options SHOULD be copied from the received one except for the Status Field for CoT. The Care-of address field of each Binding Unique Identifier sub-option, however, can be omitted, because the mobile node can match a corresponding binding update list by using BID.

6.3. Processing Binding Update

If a Binding Update does not contain a Binding Unique Identifier sub-option, its processing is same as in [\[RFC-3775\]](#). But if the receiver already has multiple bindings for the home address, it MUST replace all the existing bindings by the received binding. As a result, the receiver node MUST have only a binding for the mobile node. If the Binding Update is for de-registration, the receiver MUST delete all existing bindings from its Binding Cache.

If a Binding Update contains a Binding Unique Identifier sub-option(s), it is validated according to [section 9.5.1 of \[RFC-3775\]](#) and the following step.

- o If the home registration flag is set in the Binding Update, the home agent MUST carefully operate DAD for the received Home Address. If the home agent has already had a binding(s) for the Mobile Node, it MUST avoid running DAD check when it receives the Binding Update.

The receiver node MUST process the Binding Unique Identifier sub-option(s) in the following steps. When a correspondent node sends a Binding Acknowledgment, the status value is always stored in the Status field of the Binding Acknowledgment and keep the Status field of Binding Unique Identifier sub-option to zero. For the Home Agent, the status value can be stored in the Status field of either a Binding Acknowledgment or a Binding Unique Identifier sub-option. If the status value is specific to one of bindings in the bulk

registration, the status value MUST be stored in the Status field in the corresponding Binding Unique Identifier sub-option.

- o The length value is examined. The length value MUST be either 4 or 20 depending on C flag. If the length is incorrect, the receiver MUST reject the Binding Update and returns the status value set to [MCOA INCOMPLIANT].
- o When C flag is specified, the care-of address MUST be given in the Binding Unique Identifier sub-option. Otherwise, the receiver MUST reject the Binding Unique Identifier sub-option and returns the status value set to [MCOA INCOMPLIANT].
- o When multiple binding Unique Identifier sub-options are presented, the receiver MUST support the bulk registration. Only a home agent can accept the bulk registration. Otherwise, it MUST reject the Binding Update and returns the status value set to [MCOA BULK REGISTRATION NOT SUPPORT] in the Binding Acknowledgment.
- o When multiple binding Unique Identifier sub-options are presented, the flags field of all the Binding Unique Identifier sub-option stored in the same Binding Update MUST be equal. Otherwise, the receiver MUST reject the Binding Update and returns the status value set to [MCOA FLAG CONFLICTS] in the Binding Acknowledgment.
- o If the Lifetime field of the Binding Update is zero, the receiver node deletes the binding entry which BID is same as BID sent by the Binding Unique Identifier sub-option. If the receiver node does not have appropriate binding which BID is matched with the Binding Update, it MUST reject this de-registration Binding Update for the binding cache. If the receiver is a Home Agent, it SHOULD also return the status value set to [not Home Agent for this mobile node, 133].
- o If O flag is set in the deregistering Binding Update, the receiver can ignore this flag for deregistration. If the H flag is set, the home agent stores a Home Address in the Care-of Address field of the binding cache entry. The home agent no longer performs proxy NDP for this mobile node until this entry is deleted.
- o If the Lifetime field is not zero, the receiver node registers a binding with the specified BID as a mobile node's binding. The Care-of address is picked from the Binding Update packet as follows:
 - * If C flag is set in the Binding Unique Identifier sub-option, the care-of address must be taken from the care-of address field in each Binding Unique Identifier sub-option.

- * If C flag is not set in the Binding Unique Identifier sub-option, the care-of address must be taken from the Source Address field of the IPv6 header.
- * If C flag is not set and an alternate care-of address is present, the care-of address is taken from the Alternate Care-of address sub-option.
- o Once the care-of address(es) has been retrieved from the Binding Update, it starts registering binding(s).
 - * Only if O flag is set in the sub-option, the home agent first removes all the existing bindings and registers the received bindings.
 - * If the receiver has a regular binding which does not have BID for the mobile node, it de-registers the regular binding and registers a new binding including BID according to the Binding Update. In this case, the receiver MUST return [MCOA BID CONFLICT].
 - * If the receiver node has already registered the binding which BID is matched with requesting BID, then it MUST update the binding with the Binding Update and returns [0 Binding Update accepted].
 - * If the receiver does not have a binding entry which BID is matched with the requesting BID, it registers a new binding for the BID and returns [0 Binding Update accepted].

If all the above operations are successfully finished, the Binding Acknowledgment containing the Binding Unique Identifier sub-options MUST be replied to the mobile node if A flag is set in the Binding Acknowledgment. Whenever a Binding Acknowledgment is returned, all the Binding Unique Identifier sub-options stored in the Binding Update MUST be copied to the Binding Acknowledgment. The Care-of address field of each Binding Unique Identifier sub-option, however, can be omitted, because the mobile node can match a corresponding binding update list by using BID.

6.4. Sending Binding Refresh Request

When a node sends a Binding Refresh Request for a particular binding registering with BID, the node SHOULD contain a Binding Unique Identifier sub-option in the Binding Refresh Request.

6.5. Receiving Packets from Mobile Node

When a node receives packets with a Home Address destination option from a mobile node, it MUST check that the care-of address appeared in the Source Address field MUST be equal to one of the care-of addresses in the binding cache entry. If no binding is found, the packets MUST be silently discarded and MUST send a Binding Error message according to [RFC3775](#). This verification MUST NOT be done for a Binding Update.

7. Network Mobility Applicability

Support of multihomed mobile routers is advocated in the NEMO working group (see R12 "The solution MUST function for multihomed MR and multihomed mobile networks" in [[RFC-4886](#)]). Issues regarding mobile routers with multiple interfaces and other multihoming configurations are documented in [[RFC-4980](#)].

Since the binding management mechanisms are the same for a mobile host operating Mobile IPv6 and for a mobile router operating NEMO Basic Support ([RFC 3963](#)), our extensions can also be used to deal with multiple care-of addresses registration sent from a multihomed mobile router. Figure 5 shows the example format of a Binding Update used by a mobile router.

```
IPv6 header (src=CoA, dst=HA)
  IPv6 Home Address Option
  ESP Header
  Mobility header
    -BU
  Mobility Options
    - Binding Unique Identifier sub-option
    - Mobile Network Prefix sub-option
```

Figure 5: NEMO Binding Update

8. IPsec and IKEv2 interaction

Mobile IPv6 [[RFC-3775](#)] and the NEMO protocol [[RFC-3963](#)] require the use of IPsec to protect signaling messages like Binding Updates, Binding Acknowledgments and return routability messages. IPsec may also be used protect all reverse tunneled data traffic. The Mobile IPv6-IKEv2 specification [[RFC-4877](#)] specifies how IKEv2 can be used to setup the required IPsec security associations. The following assumptions were made in [[RFC-3775](#)], [[RFC-3963](#)] and the MIP6-IKEv2 specification with respect to the use of IKEv2 and IPsec.

- o There is only one primary care-of address per mobile node.
- o The primary care-of address is stored in the IPsec database for tunnel encapsulation and decapsulation.
- o When the home agent receives a packet from the mobile node, the source address is verified against the care-of address in the corresponding binding cache entry. If the packet is a reverse tunneled packet from the mobile node, the care-of address check is done against the source address on the outer IPv6 header. The reverse tunnel packet could either be a tunneled HoTi message or tunneled data traffic to the correspondent node.
- o The mobile node runs IKEv2 (or IKEv1) with the home agent using the care-of address. The IKE SA is based on the care-of address of the mobile node.

The above assumptions may not be valid when multiple care-of addresses are used by the mobile node. In the following sections, the main issues with the use of multiple care-of address with IPsec are addressed.

8.1. Use of Care-of Address in the IKEv2 exchange

For each home address the mobile node sets up security associations with the home agent, the mobile node must pick one care-of address and use that as the source address for all IKEv2 messages exchanged to create and maintain the IPsec security associations associated with the home address. The resultant IKEv2 security association is created based on this care-of address.

If the mobile node needs to change the care-of address, it just sends a Binding Update with the care-of address it wants to use, with the corresponding Binding Unique Identifier sub-option, and with the 'K' bit set. This will force the home agent to update the IKEv2 security association to use the new care-of address. If the 'K' bit is not supported on the mobile node or the home agent, the mobile node MUST

re-establish the IKEv2 security association with the new care-of address. This will also result in new IPsec security associations being setup for the home address.

8.2. Transport Mode IPsec protected messages

For Mobile IPv6 signaling message protected using IPsec in transport mode, the use of a particular care-of address among multiple care-of addresses does not matter for IPsec processing.

For Mobile Prefix Discovery messages, [RFC-3775] requires the home agent to verify that the mobile node is using the care-of address that is in the binding cache entry that corresponds to the mobile node's home address. If a different address is used as the source address, the message is silently dropped by the home agent. This document requires the home agent implementation to process the message as long as the source address is one of the care-of addresses in the binding cache entry for the mobile node.

8.3. Tunnel Mode IPsec protected messages

The use of IPsec in tunnel mode with multiple care-of address introduces a few issues that require changes to how the mobile node and the home agent send and receive tunneled traffic. The route optimization mechanism described in [RFC-3775] mandates the use of IPsec protection in tunnel mode for the HoTi and HoT messages. The mobile node and the home agent may also choose to protect all reverse tunneled payload traffic with IPsec in tunnel mode. The following sections address multiple care-of address support for these two types of messages.

8.3.1. Tunneled HoTi and HoT messages

The mobile node MAY use the same care-of address for all HoTi messages sent reverse tunneled through the home agent. The mobile node may use the same care-of address irrespective of which correspondent node the HoTi message is being sent. RFC 3775 requires the home agent to verify that the mobile node is using the care-of address that is in the binding cache entry, when it receives a reverse tunneled HoTi message. If a different address is used as the source address, the message is silently dropped by the home agent. This document requires the home agent implementation to decapsulate and forward the HoTi message as long as the source address is one of the care-of addresses in the binding cache entry for the mobile node.

When the home agent tunnels a HoT message to the mobile node, the care-of address used in the outer IPv6 header is not relevant to the HoT message. So regular IPsec tunnel encapsulation with the care-of

address known to the IPsec implementation on the home agent is sufficient.

8.3.2. Tunneled Payload Traffic

When the mobile sends and receives multiple traffic flows protected by IPsec to different care-of addresses, the use of the correct care-of address for each flow becomes important. Support for this requires the following two considerations on the home agent.

- o When the home agent receives a reverse tunneled payload message protected by IPsec in tunnel mode, it must check that the care-of address is one of the care-of addresses in the binding cache entry. According to [RFC 4306](#), the IPsec implementation on the home agent does not check the source address on the outer IPv6 header. Therefore the care-of address used in the reverse tunneled traffic can be different from the care-of address used as the source address in the IKEv2 exchange. However, the Mobile IPv6 stack on the home agent MUST verify that the source address is one of the care-of addresses registered by the mobile node before decapsulating and forwarding the payload traffic towards the correspondent node.
- o For tunneled IPsec traffic from the home agent to the mobile node, The IPsec implementation on the home agent may not be aware of which care-of address to use when performing IPsec tunnel encapsulation. The Mobile IP stack on the home agent must specify the tunnel end point for the IPsec tunnel. This may require tight integration between the IPsec and Mobile IP implementations on the home agent.

9. Security Considerations

As shown in [Section 8](#), the Multiple Care-of Addresses Registration requires IPsec protected all the signaling between a mobile node and its home agent.

10. IANA Considerations

The following Extension Types MUST be assigned by IANA:

- o Binding Unique Identifier sub-option type
- o New Status of Binding Acknowledgment
 - * MCOA INCOMPLIANT (TBD)
 - * MCOA BID CONFLICT (TBD)
 - * MCOA PROHIBITED(TBD)
 - * MCOA BULK REGISTRATION NOT SUPPORTED (TBD)
 - * MCOA FLAG CONFLICTS (TBD)

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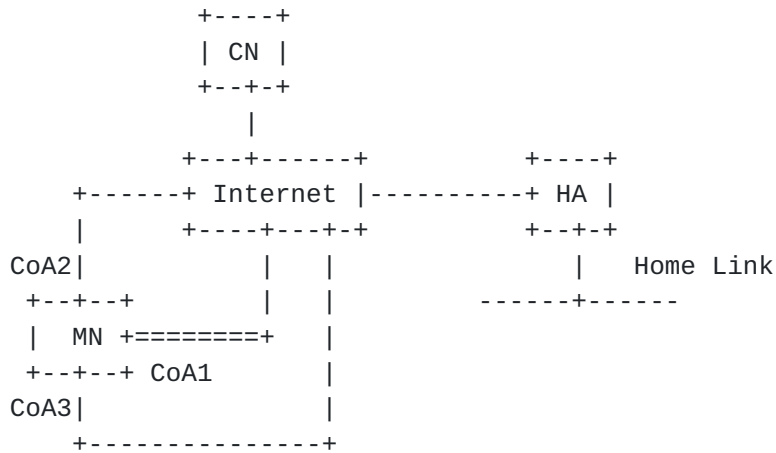
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Appendix A. Example Configurations

In this section, we describe typical scenarios when a mobile node has multiple network interfaces and acquires multiple Care-of Addresses bound to a Home Address. The Home Address of the mobile node (MN in figures) is a:b:c:d::EUI. MN has 3 different interfaces and possibly acquires care-of addresses 1-3 (CoA1, CoA2, CoA3). The MN assigns BID1, BID2 and BID3 to each care-of address.



Binding Cache Database:

home agent's binding (Proxy neighbor advertisement is active)

binding [a:b:c:d::EUI care-of address1 BID1]

binding [a:b:c:d::EUI care-of address2 BID2]

binding [a:b:c:d::EUI care-of address3 BID3]

correspondent node's binding

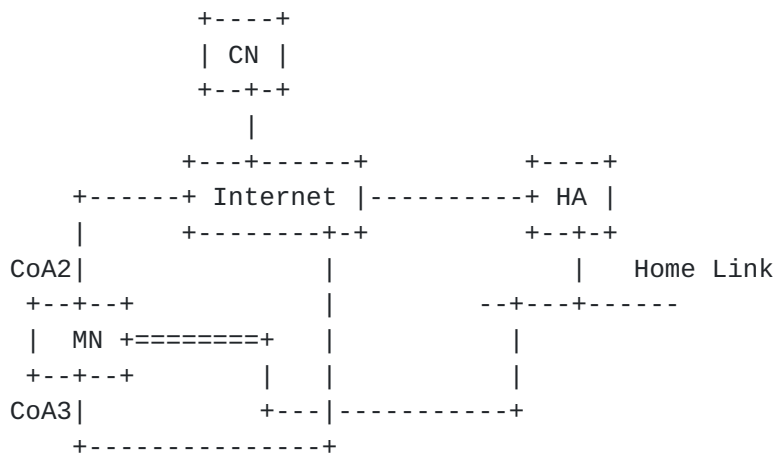
binding [a:b:c:d::EUI care-of address1 BID1]

binding [a:b:c:d::EUI care-of address2 BID2]

binding [a:b:c:d::EUI care-of address3 BID3]

Figure 6: Multiple Interfaces Attached to a Foreign Link

Figure 6 depicts the scenario where all interfaces of the mobile node are attached to foreign links. After binding registrations, the home agent (HA) and the Correspondent Node (CN) have the binding entries listed in their binding cache database. The mobile node can utilize all the interfaces.



Binding Cache Database:

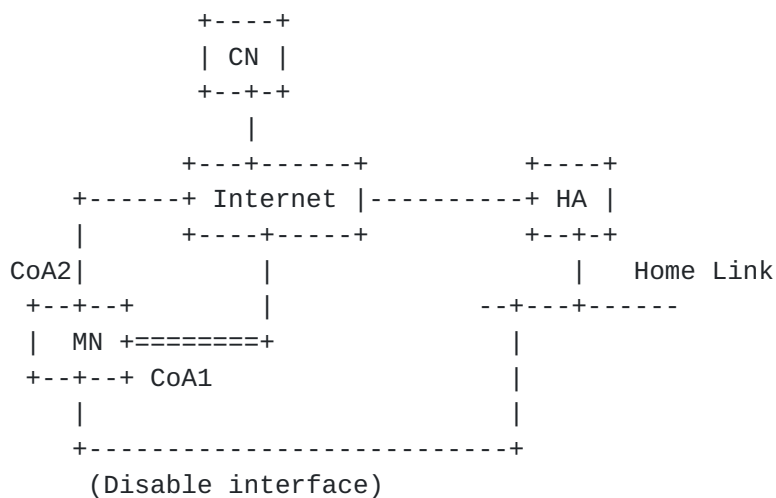
```

home agent's binding (Proxy neighbor advertisement is inactive)
  none
correspondent node's binding
  binding [a:b:c:d::EUI  care-of address2  BID2]
  binding [a:b:c:d::EUI  care-of address3  BID3]

```

Figure 7: One of Interface Attached to Home Link and Returning Home

Figure 7 depicts the scenario where MN returns home with one of its interfaces. After the successful de-registration of the binding to HA, HA and CN have the binding entries listed in their binding cache database of Figure 7. MN can communicate with the HA through only the interface attached to the home link. On the other hand, the mobile node can communicate with CN from the other interfaces attached to foreign links (i.e. route optimization). Even when MN is attached to the home link, it can still send Binding Updates for other active care-of addresses (CoA2 and CoA3). If CN has bindings, packets are routed to each Care-of Addresses directly. Any packet arrived at HA are routed to the primary interface.



Binding Cache Database:

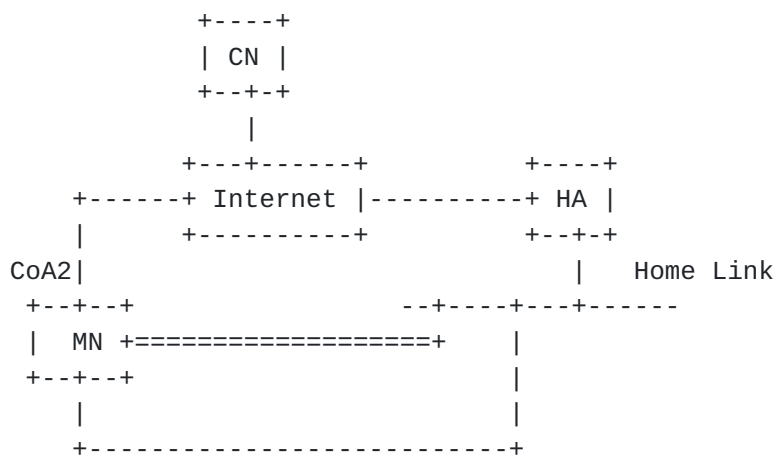
```

home agent's binding (Proxy neighbor advertisement is active)
  binding [a:b:c:d::EUI  care-of address1  BID1]
  binding [a:b:c:d::EUI  care-of address2  BID2]
correspondent node's binding
  binding [a:b:c:d::EUI  care-of address1  BID1]
  binding [a:b:c:d::EUI  care-of address2  BID2]

```

Figure 8: One of Interface Attached to Home Link and Not Returning Home

Figure 8 depicts the scenario where MN disables the interface attached to the home link and communicates with the interfaces attached to foreign links. The HA and the CN have the binding entries listed in their binding cache database. MN disable the interface attached to the home link, because the HA still defends the home address of the MN by proxy neighbor advertisements. All packets routed to the home link are intercepted by the HA and tunneled to the other interfaces attached to the foreign link according to the binding entries.



Binding Cache Database:

```

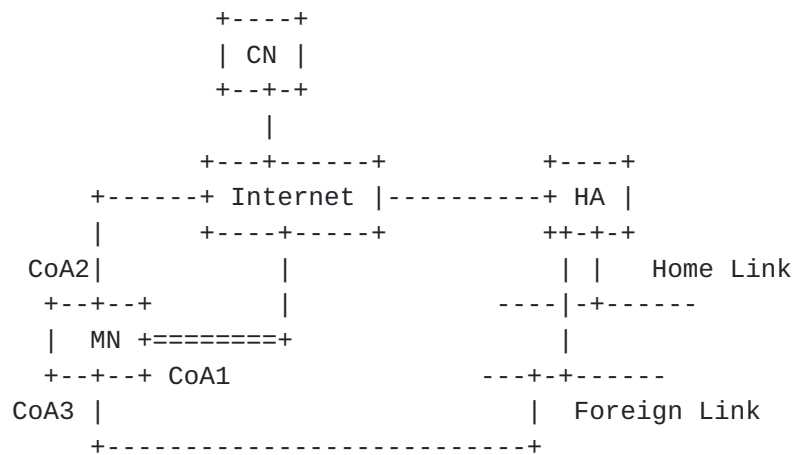
home agent's binding (Proxy neighbor advertisement is inactive)
  none
correspondent node's binding
  binding [a:b:c:d::EUI care-of address2 BID2]

```

Figure 9: Several Interfaces Attached to Home Link and Returning Home

Figure 9 depicts the scenario where multiple interfaces of MN are attached to the home link. The HA and CN have the binding entries listed in Figure 9 in their binding cache database. The MN can not use the interface attached to a foreign link unless a CN has a binding for the interface. All packets which arrive at the HA are routed to one of the MN's interfaces attached to the home link.

Figure 10 depicts the scenario where interfaces of MN are attached to the foreign links. One of foreign link is managed by the home agent. The HA and CN have the binding entries listed in Figure 10 in their binding cache database. The home agent advertises a prefix which is other than home prefix. The mobile node will generate a care-of address from the prefix and registers it to the home agent. Even if the mobile node attaches to a foreign link, the link is managed by its home agent. It will tunnel the packets to the home agent, but the home agent is one-hop neighbor. The cost of tunnel is negligible. If the mobile node wants to utilize not only an interface attached to home but also interfaces attached to foreign link, it can use this foreign link of the home agent to return a one hop foreign link on behalf of a home link. This is different from the general returning home, but this enable the capability of using interfaces attached to both home and foreign link without any modifications to Mobile IPv6 and NEMO basic support.



Binding Cache Database:

home agent's binding (Proxy neighbor advertisement is active)

binding [a:b:c:d::EUI care-of address1 BID1]

binding [a:b:c:d::EUI care-of address2 BID2]

binding [a:b:c:d::EUI care-of address3 BID3]

correspondent node's binding

binding [a:b:c:d::EUI care-of address1 BID1]

binding [a:b:c:d::EUI care-of address2 BID2]

binding [a:b:c:d::EUI care-of address3 BID3]

Figure 10: Emulating to Utilize Interfaces Attached to both Home and Foreign Links

Appendix B. Changes From Previous Versions

Changes from [draft-ietf-monami6-multiplecoa-03.txt](#)

- o Change the handling of Status field. All the status value is defined for BA
- o Alternate CoA option is omitted, but using C flag is recommended.
- o Adding examples of BU
- o Many editorial updates

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