Mobile IP Working Group
INTERNET-DRAFT

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Toward a Unified Hierarchical Mobility Management Framework
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Status of this Memo

Abstract

As the number of Mobile Nodes increases in the Internet, it becomes clear that a hierarchical mobility management protocol is necessary. The macro-mobility is the mobility between domains. The micro-mobility is the mobility within one domain. Several proposals that separate macro and micro-mobility has been proposed recently (CellularIP[4], HAWAI[3], HMIP[1],...).

All these proposals agree that Mobile IP is suitable to handle macro-mobility (inter-domain mobility) but they all propose a different micro-mobility scheme. As a result, a Mobile Node won't be able to roam seamlessly if it does not understand the different

micro-mobility management protocols of the domain that it visits.

In this document, we present a framework that allows the deployment of various micro-mobility management protocols in different parts of the Internet while still providing connectivity to Mobile Nodes.

We propose to decompose the Internet mobility management protocol into three components. The first one, the access protocol, specifies the registration procedures between the Mobile Node and the domain it is attached to. It is standard and unique. The second one, the micro-mobility protocol, manages local mobility and varies from one domain to another. The third one, the macro-mobility protocol, manages mobility across domains. We suggest to use Mobile IP as the macro-mobility protocol.

This Internet Draft first describes the architecture of the proposed framework. It then show how micro-Mobile IP and Cellular IP could be deployed within this framework.

1- Introduction

There have been several hierarchical and cellular Mobile IP proposals recently. This shows a huge interest for a scalable mobility management scheme. There are at least 3 proposals that we know of :
- Ericsson/Columbia Cellular IP [4] (http://comet.ctr.columbia.edu/cellularip/)
- Lucent HAWAII [3] (http://www.bell-labs.com/user/ramjee/papers/draft-ramjee-micro-mobility-hawaii-00.txt)
- INRIA HMIPv6 [1] (http://sirac.inrialpes.fr/Infos/Personnes/Claude.Castelluccia/hmip.ps.gz)

All these proposals agree that Mobile IP is suitable to handle macro-mobility, but they all propose a different micro-mobility scheme.

From then, 2 directions are possible :

1- define a single micro-mobility protocol is defined and standardized from the existing and forthcoming proposals.

2- define a framework that allows each proposal to be deployed and that provides inter-operability is defined.

We argue that the second solution is preferable for the following reasons. First we believe that there is probably not an "optimal"

micro-mobility scheme for every network. Different protocols might be necessary for different networks' needs. Second, defining an open system leads to more competition and flexibility. Each network operator is then free to deploy its own micro-mobility protocol (and to patent it:-)). New protocols can be deployed very easily. Last but not least it eases drastically the standardization process ; the different proposals do not have to be merged into a single one.

In this document, we propose a framework that allows the deployment of different micro-mobility proposals. We assume that Mobile IP is used as the macro-mobility protocol.

Our final goal is to define a framework that allows a Mobile Node to roam seamlessly from one network to another, from one domain to another... One condition to achieve this goal is to make sure that the mobility management procedures performed by the Mobile Nodes are independent of the mobility management protocols used in the core of the network.

2- General concepts

In this document, we define a domain as an arbitrary structure. A domain can be an ISP network, a campus network, a company network, a set of LANs or even a single LAN. A domain is connected to the rest of the Internet via one or several interconnection routers that we call Border Routers in this document.

Our proposal differentiates the macro (inter-domain) mobility from the micro (intra-domain) mobility. As a result, a host communicating with a Mobile Node is only aware of its inter-domain mobility. The Mobile Node's intra-domain mobility is completely hidden. It also defines a standard Mobile Node registration protocol that is independent of the mobility management protocols used in the core network. As a result, different mobility management protocols can be used in the different parts of the Internet while still providing connectivity to the Mobile Node Hosts.

We propose a mobility management framework that uses Mobile IP for inter-domain mobility but allows the deployment of any micro-mobility protocol. As a matter a result, different domains can deploy different micro-mobility protocols.

2.1 Design Goals/Constraints

The goals of our work is to propose a hierarchical mobility management that :

1- does not require any modifications at the Correspondent Nodes

(Correspondent Nodes are running Mobile IP).
2- allows the deployment of different micro-mobility schemes transparently to the Correspondent Nodes and the Mobile Nodes.
3- does not degrade routing performance.
4- is as secure as Mobile IP.
6- works in IPv4 and IPv6.
7- is power-efficient (i.e. minimizes the power).

2.2 Conceptual Model

In the proposed framework, the mobility management protocol is composed of three components as illustrated in Figure 1.

- The first one, the access mobility management protocol, specifies the registration procedures between the Mobile Node and the domain it is attached to. It is standard and independent of the micro and macro-mobility management protocols used in the core of the network. This protocol is ``light'', i.e. minimises the operations performed by the Mobile Node Hosts (which probably have limited capacity and power).

- The second one, the micro-mobility management protocol, is the protocol that handles the local mobility (within the domain) of the Mobile Node.

- The third one, the macro-mobility management protocol, is the protocol that handles the macro-mobility (inter-domain) of the Mobile Node. We propose to use Mobile IP as macro-mobility management protocol.

3- Proposed Framework

3.1 Overview

Our proposal is based on the deployment of Mobility Supports.

A Mobility Support is a router or a set of routers that maintains a binding per Mobile Nodes currently visiting the domain. The Mobility Support plays a central role in our proposal. It is involved in the macro and micro-mobility management. For example, the Mobility Support sends Binding Updates on behalf of the Mobile Nodes it is serving (macro-mobility management). It also intercepts packets addressed to the Mobile Nodes it is serving and is in charge of redirecting them to their current location (micro-mobility management).

Note that there is no constraint on the physical location of the Mobility Support. However for efficiency reasons, it is

preferable to connect it as close as possible to the border router of the network that it is serving.

In our proposal, the Mobile Node registration protocol is unique and independent of the micro-mobility management protocol of the domain. The nature and the position of the Mobility Support depend on the micro-mobility management protocol. The only requirements that we impose on the Mobility Support are :

(1) it must process registration messages coming from the Mobile Nodes (the processing depends of the micro-mobility protocols),

(2) it must send Mobile IP Binding Updates to the Mobile Node's Home Agent and Correspondent Nodes (according to the Mobile Node IP specification) and

(3) it must intercept and redirect the packets addressed to the Mobile Nodes (the way packets are forwarded to the Mobile Node Hosts depends of the local micro-mobility protocol.

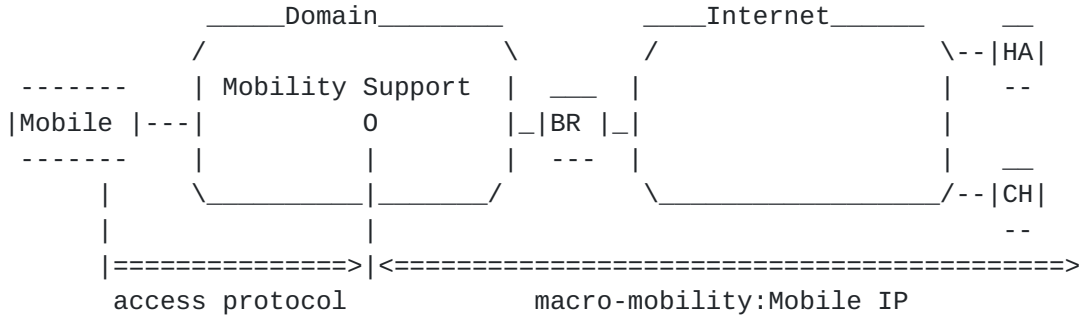

Figure1 : Registration

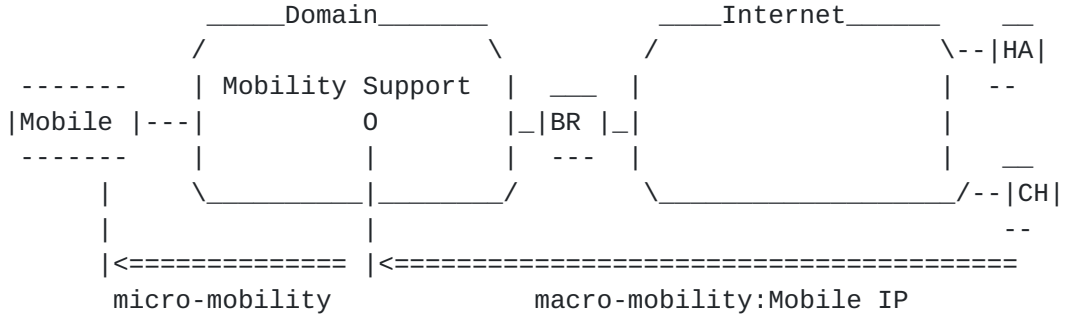

Figure2 : Packet delivery

In summary,
1- the protocol between the Mobile Node and the Mobility Support is unique
2- the intra-domain mobility management and routing is managed by the local micro-mobility management protocol
3- the inter-domain mobility and routing is managed by Mobile IP

3.2 Main operations

The main operations of the proposed architecture are the following :

3.2.1 Common operations : the Mobile Node-Mobility Support registration

When the Mobile Node detects a new Base Station, it gets a CoA (we call it PCoA, for Physical Care-of Address) and registers to the Mobility Support. This registration is performed by sending a (Home Address, Home Agent, PCoA, MS_p), where MS_p is the Mobility Support of the Mobile Node in the previous domain. This registration is acknowledged by the Mobility Support.

This registration phase is independent of the type of movement (inter or intra-domain).

3.2.2 Inter-domain movement

When a Mobile Node moves into a new domain, it registers to the new Mobility Support and the Mobility Support performs the following registration operations :

3.2.2.1 Macro-mobility registration :

Upon reception of a registration message from a Mobile Node, the Mobility Support must :

* get a VCoA (Virtual CoA-this could be the Mobility Support's address or an address on its subnet) for the Mobile Node and registers it to its Home Agent on behalf of the Mobile Node. This Binding Update must be acknowledged. This acknowledgement is forwarded to the Mobile Node.

* acknowledge the reception of the Mobile Node-Mobility Support registration message to the Mobile Node (this acknowlegement contains the VCoA).

* ask the previous Mobility Support (the Mobility Support of the previous domain. We note it MS_p) to redirect all

packets addressed to the Mobile Node to it. MS_p must acknowledge this request and send the list of current Correspondent Nodes and the list of the sequence numbers of the latest Binding Updates sent.

* create a entry that contains the binding between the Mobile Node's Home address, its home agent and its VCoA + list of (Correspondent Nodes, Sequence Numbers).

* send a (Home Address, VCoA) Binding Update to each Correspondent Node.

Note : a Mobile Node must receive two ackowledgements after an inter-domain movement : one from its Home Agent and one from its current Mobility Support otherwise it must assume that the registration has failed.

Upon reception of packets coming from the Home Agent or from the previous Mobility Support, the new Mobility Support sends Binding Updates to the Mobile Node's Correspondent Nodes. These Binding Updates contain the Mobile Node's PCoA if the Correspondent Node is local (i.e. within the visiting domain) or the Mobile Node's VCoA if the Correspondent Node is distant (outside the visiting domain).

3.2.2.2 Micro-mobility registration :

Upon reception of a registration message from a Mobile Node, the Mobility Support must :

* create a entry that contains the binding between the Mobile Node's PCoA and VCoA. This information is used by the Mobility Support to redirect the packets addressed to the Mobile Node (VCoA) to its current point of attachment (PCoA).

3.2.3 Intra-domain movement :

When a Mobile Node moves within a domain (i.e it changes of Base Station and/or subnet), the Mobile Node registers its new point of attachement to the Mobility Support. The Mobility Support then performs the following operations :

- macro-mobility registration

  * no operation is required.

- micro-mobility registration

Upon reception of a registration message from the Mobile Node, the Mobility Support :

* updates the corresponding entry in its cache,

* possibly sends Binding Updates to the Mobile Node's local Correspondent Nodes.

Note that authentication is only necessary between the Mobile Node and the Mobility Support, the Mobility Support and the Home Agent, successive Mobility Supports, the Mobility Support and the Correspondent Nodes. The Base Stations are just relays and therefore do not need to be authenticated.

The Mobile Node must periodically send registration messages to the Mobility Support to refresh its cache's entry. Identically the Mobility Support must refresh the Mobile Node's VCoA to its Home Agent and Correspondent Nodes by sending Binding Updates.
Note that the two refresh periods must not have the same value.

3.3 Packet delivery

When a (external) Correspondent Node first sends packets to a Mobile Node, these packets are addressed to the Mobile Node's Home address. These packets are intercepted by the Mobile Node's Home Agent (if the Mobile Node is away) and forwarded (by encapsulation) to the Mobile Node's current VCoA. The encapsulated packets are intercepted by the Mobile Node's current Mobility Support and forwarded to the current Mobile Node's PCoA. The Mobility Support also sends a (Home Address, PCoA) or a (Home Address, VCoA) Binding Update to the Correspondent Node according to whether it is local or distant, and records the Correspondent Node in its Mobile Node's list of Correspondent Nodes.

Upon reception of this Binding Update, the Correspondent Node updates the Mobile Node's (Home Address, CoA) entry and sends the forthcoming packets to the Mobile Node's new CoA. If the CoA is a VCoA, the packets are intercepted by the Mobile Node's Mobility Support and forwarded to the Mobile Node current PCoA. If the CoA is a PCoA, the packets are routed directly to the Mobile Node's current location.

Note that the forwarding method from the Mobility Support to the Mobile Node's current PCoA is dependent of the micro-mobility used in the domain.

When a Mobile Node sends a packet to a Correspondent Node, it must include a HomeAddress option and use its VCoA as source address

(except if the Correspondent Node is local. In this case, it uses its PCoA).

4 Examples

In this section, we describe in more details the architecture and operations that are performed with different micro-mobility management protocols. We consider two micro-mobility management protocols namely micro-Mobile IP and Cellular IP.

4.1 Mobile Node - Mobility Support registrations

This phase is common to all micro-mobility proposals.

When the Mobile Node detects a Base Station, it possibly gets a CoA (we call it, PCoA, for Physical Care-of Address) and registers to the Mobility Server. This registration is performed by sending a (Home address, Home Agent, PCoA, MS_p), where MS_p is the previous Mobility Support of the Mobile Node. If the Mobile Node did not change of Mobility Support, the MS_p field is then set to Mobility Support.

The serving Mobility Support and the CoA is obtained via some kind of DHCP server or auto-configuration mechanisms. Note also that the Mobile Node's operations are independent of the mobility type (whether is intra or inter-domain).

This registration must be acknowledged.

4.2 Micro-Mobile IP (uMIP)

The INRIA micro-Mobile IPv6 (uMIP) proposal [Cast98] is based on the deployment of Mobility Networks.. A Mobile Network of a domain is a LAN that defines an address space for the Mobile Nodes roaming within this domain. A Mobility Network contains one or several Mobility Supports. In uMIP, the Mobility Supports are called Mobility Agents. A Mobility Agent is a router of the Mobile Network that maintains a binding per Mobile Node currently visiting the domain and sends Binding Updates on behalf of these Mobile Nodes. Note that there is no constraint on the physical location of the Mobility Network. However for efficiency reasons, it is preferable to connect it to the border router of the network that it is serving. The mobility Network can actually be any sub-network of the domain. It does not have to be dedicated to Mobile Nodes but instead can support ordinary (fixed) hosts.

Deploying a Mobility Agent in a separate Mobility Network instead of implementing it on the Border Router has two main advantages.

First, it does not require any modification to the routers and is therefore easier to deploy. Second, it is more scalable since (1) it does not add additional processing constraints on the Border Router and (2) several Mobility Agents could be deployed for scalability and/or robustness motivations. However the Mobility Agent can be implemented within the Border Router if this is desirable.

The main operations of the uMIP proposal are the following.

4.2.1 Inter-domain mobility

When a Mobile Node moves into a new domain, the following registrations are performed :

- Mobile Node - Mobile Support registration:

The Mobile Node registers to the Mobility Agent as described in section 4.1.

- micro-mobility registration operations : Upon reception of a registration message from a Mobile Node, the Mobility Agent :

o creates an entry that contains the binding between the Mobile Node's PCoA and VCoA. This information is used by the Mobility Agent to redirect the packets addressed to the Mobile Node (VCoA) to its current point of attachment (PCoA).

o sends a (Home Address, PCoA) to the domain's Correspondent Nodes to optimize the Correspondent Node-Mobile Node routing.

- macro-mobility registration operations (these operations is actually independent of the micro-mobility protocol in used):

Upon reception of the Mobile Node-Mobility Support registration message, the Mobility Agent :

* gets a VCoA (an address belonging to the Mobile Network) for the Mobile Node and registers it to its Home Agent on behalf of the Mobile Node. This Binding Update is acknowledged by the Home Agent and forwarded to the Mobile Node.

* acknowledges the reception of the Mobile Node-Mobility Support registration message to the Mobile Node (this acknowlegement contains the VCoA).

* asks the previous Mobility Agent to redirect all packets addressed to the Mobile Node to it. The Previous Mobility Agent acknowledges this request and sends the list of current Correspondent Nodes and the sequence numbers of the latest Binding Updates that were sent.

* creates an entry that contains the binding between the Mobile Node's Home address, its home agent and its VCoA + list of (Correspondent Nodes, Sequence numbers).

* sends a (Home Address, VCoA) Binding Update to each Correspondent Node.

4.2.2 Intra-domain mobility :

When a Mobile Node moves within a domain (i.e it changes of Base Station and/or subnet), the following registrations are performed :

- Mobile Node-Mobility Support registration : see Section 4.1.

- macro-mobility :

  * nothing is sent except the periodic registration refresh messages.

- micro-mobility registration :

  * The Mobility Agent updates the Mobile Node entry of its cache.

  * The Mobility Agent sends a (Home Address, PCoA) Binding Update to each of the Mobile Node's local Correspondent Nodes.

4.2.3 Packet delivery

When a (external) Correspondent Node first sends packets to a Mobile Node, these packets are addressed to the Mobile Node's Home address. These packets are intercepted by the Mobile Node's Home Agent (if the Mobile Node is away) and forwarded (by encapsulation) to the Mobile Node's current VCoA. The encapsulated packets are intercepted by the Mobile Node's current Mobility Agent and forwarded (via encapsulation) to the current Mobile Node's PCoA. The Mobility Agent adds an entry in its cache and sends a (Home Address, PCoA) or a (Home Address,

VCoA) Binding Update to the Correspondent Node according whether it is local or distant.

Upon reception of this Binding Update, the Correspondent Node updates the Mobile Node's binding(Home Address, CoA) entry and sends the forthcoming packets to the Mobile Node's current position. If the CoA is the Mobility Agent's address, the packets are intercepted by the Mobility Agent and forwarded to the Mobile Node current PCoA (via encapsultion). If the CoA is a PCoA, the packets is routed directly to the Mobile Node's current location...

4.3 Cellular IP

When Cellular IP is used as micro-mobility protocol, the Mobility Support is located within the Border Router of the domain. The VCoA assigned to the Mobile Nodes is the address of the Mobility Support/Border Router.

The main operations of the proposed architecture are the following :

4.3.1 Inter-domain movement

When a Mobile Node moves into a new domain, the following registrations are performed :

- Mobile Node-Mobility Support registration :

The Mobile Node sends a registration message to the Mobility Support (Border Router) as specified in 4.1.

- micro-mobility registration :

This registration message is intercepted by the Base Station, the Mobile Node is attached to. The Base Station encapsulates the message within a Route-Update packet as described in [CellIP] and forwards it to the Border Router/Mobility Support. The Route-Update packet creates and updates entries in each node's cache from the Mobile Node to the Mobility Support.

This registration is acknowledged. (The current Mobility Support is broadcast by the base stations using a router advertissement).

- macro-mobility registration :

Upon reception of the Mobile Node-Mobility Support registration

message, the Mobility Support/Border Router :

* registers the Mobile Node to its Home Agent using its address (the Mobility Support's address). This is performed by sending a (Home Address, Mobility Support) Binding Update. This Binding Update is acknowledged. The acknowledgement is forwarded back to the Mobile Node's PCoA (via the Cellular IP routing process).

* acknowledges the reception of the Mobile Node-Mobility Support registration message to the Mobile Node (this acknowlegement contains the VCoA).

* asks the previous Mobility Support (the Mobility Support of the previous domain. We note it MS_p) to redirect all packets addressed to the Mobile Node to it. MS_p acknowledges this request and sends the list of current Correspondent Nodes and the sequence numbers of the lattest Binding Updates that were sent.

* creates a entry that contains the binding between the Mobile Node's Home address, its home agent and its VCoA + list of (Correspondent Nodes, Sequence Number).

* sends a (Home Address, VCoA) Binding Update to each Correspondent Node. These Binding Updates contain the Mobile Node's PCoA if the Correspondent Node is local (i.e. within the visiting domain) or the Mobility Support/Border Router's address if the Correspondent Node is distant (outside the visiting domain).

4.3.2 Intra-domain movement :

When a Mobile Node moves within a domain (i.e it changes of Base Station and/or subnet), the following registrations are performed :

- Mobile Node-Mobility Support registration :

The Mobile Node sends a registration message to the Mobility Support (Border Router) as specified in 4.1.

- micro-mobility

This registration message is intercepted by the Base Station, the Mobile Node is attached to. The Base Station encapsulates the message within a Route-Update packet as described in

[CellIP] and forwards it to the Border Router/Mobility Support.

The Route-Update packet creates and updates entries in each node's cache from the Mobile Node to the Mobility Support.

- macro-mobility

No macro-mobility registration is necessary....besides the regular Binding Update refresh Binding Update messages.

4.3.3 Packet delivery

When a (external) Correspondent Node first sends packets to a Mobile Node, these packets are addressed to the Mobile Node's Home address. These packets are intercepted by the Mobile Node's Home Agent (if the Mobile Node is away) and forwarded (by encapsulation) to the Mobile Node's current Mobility Support/Border Router. The encapsulated packets are received by the Mobile Node's current Mobility Support/Border Router, decapsulated and forwarded (via the CellularIP routing mechanisms) to the current Mobile Node's PCoA. The Mobility Support/Border Router also sends a (Home Address, Border Router) to the external Correspondent Nodes.

Upon reception of this Binding Update, the Correspondent Node updates the Mobile Node's (Home Address, CoA) entry and sends the forthcoming packets to the Mobile Node's current Mobility Support. The packets are received by the Mobility Support, and forwarded to the Mobile Node current PCoA.

5. Security Considerations

As in Mobile Node IP, all registration messages have to be authenticated. As in Mobile Node IP, we propose to use IPSEC to authenticate the registration messages and the binding updates.

There is two levels of security :

- The macro-mobility registration messages must be authenticated between the Mobility Support and the Correspondent Nodes.
- The micro-mobility registration messages must be authenticated between the Mobility Support and the Mobile Nodes.

Our proposal does not introduce more security problems that those introduced by Mobile IP.

6. Conlusion

We propose a framework that allows the deployment of various micro-

mobility management protocols in different parts of the Internet while still providing connectivity to Mobile Nodes.

In the proposed framework, the mobility management protocol is composed of 3 components:

- The first one, the access mobility management protocol, specifies the registration procedure between the Mobile Node and the domain it is attached to. It is standard and independent of the micro and macro-mobility management protocols used in the core of the network. This protocol is ``light'', i.e. minimises the operations performed by the Mobile Nodes (which probably have limited capacity and power).

- The second one, the micro-mobility management protocol, is the protocol that handles the local mobility (within the domain) of the Mobile Node.

- The third one, the macro-mobility management protocol, is the protocol that handles the macro-mobility (inter-domain) of the Mobile Node. We propose to use Mobile IP as macro-mobility management protocol.

The complete specification of these different components are on its way and will be published soon. The access protocol uses Mobile IPv6 registration messages.

7. Acknowledgments

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