Abstract

This document describes deployment scenario of multi-homed Network in Motion (NEMO) and attempts to identify issues that arises when supporting multi-homing in NEMO. It is also the objective of this document to build a full taxonomy covering multi-homed scenarios in NEMO, so as to facilitate explorations into this aspect of NEMO.

Copyright Notice

Copyright (C) The Internet Society (2003). All Rights Reserved.

Status of this Memo

This document is an Internet-Draft and is in full conformance with all provisions of Section 10 of RFC2026.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF), its areas, and its working groups. Note that other groups may also distribute working documents as Internet-Drafts.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

The list of current Internet-Drafts can be accessed at http://www.ietf.org/ietf/1id-abstracts.txt.

The list of Internet-Draft Shadow Directories can be accessed at http://www.ietf.org/shadow.html.

This Internet-Draft will expire on November 24, 2003.
Table of Contents

1. Motivations ............................................ 3

2. Taxonomy .................................................. 5
   2.1 Explanations of Terms and Illustrations .......... 5
   2.1.1 Abbreviations ..................................... 5
   2.1.2 Illustrations ...................................... 5
   2.2 Classifications of Multi-homed Mobile Network. ... 7
      2.2.1 (0,0,0): Single MR, Single HA, Single Prefix ... 8
      2.2.2 (0,0,1): Single MR, Single HA, Multiple Prefixes . 9
      2.2.3 (0,1,0): Single MR, Multiple HAs, Single Prefix ... 9
      2.2.4 (0,1,1): Single MR, Multiple HAs, Multiple Prefixes 10
      2.2.5 (1,0,0): Multiple MRs, Single HA, Single Prefix ... 10
      2.2.6 (1,0,1): Multiple MRs, Single HA, Multiple Prefixes 11
      2.2.7 (1,1,0): Multiple MRs, Multiple HAs, Single Prefix ... 11
      2.2.8 (1,1,1): Multiple MRs, Multiple HAs, Multiple Prefixes 12
   2.3 Alternative Classifications .......................... 13

3. Deployment Scenarios ...................................... 15

4. Analysis .................................................... 17

5. Security Considerations ................................. 21

6. Acknowledgements ......................................... 22

References .................................................. 23

Authors’ Addresses .......................................... 24

Intellectual Property and Copyright Statements .......... 25
1. Motivations

The problem of Network Mobility Support (NEMO) is identified in various previous works [1]. In essence, the problem of network in motion is to provide continuous Internet connectivity to nodes in a network that moves as a whole. Nodes within the network that moves may not be aware of the network changing its point of attachment to the Internet. This differs from the traditional problem of mobility support as addressed by Mobile IPv4 [3] and Mobile IPv6 [4].

In Mobile IP, each mobile node has a permanent home domain. When the mobile node is attached to its home network, it is assigned a permanent global address known as a home-address (HoA). When the mobile node is away, i.e. attached to some other foreign networks, it is usually assigned a temporary global address known as a care-of-address (CoA). The idea of mobility support is such that the mobile node can be reached at the home-address even when it is attached to other foreign networks. This is done in [3][4] with the introduction of an entity at the home network known as a home agent (HA). Mobile nodes register their care-of-addresses with the home agents using messages known as Binding Updates. The home agent is responsible to intercept messages that are addressed to the mobile node’s home-address, and forward the packet to the mobile node’s care-of-address using IP-in-IP Tunneling [5].

Extending the concept of mobility support for individual hosts to mobility support for a network of nodes, the objective of a network in motion solution is to provide a mechanism where nodes in a mobile network can be reached by their permanent addresses, no matter where on the Internet the mobile network is attached to. There exist a few prior attempts to provide network mobility support, most of them based on using bi-directional tunnels between the mobile routers and the home agents of the mobile routers [6][7][8][9].

In bi-directional tunnels between mobile routers and home agents, the mobile router controlling a mobile network performs routing of packets to and from the mobile network when it is in its home domain. When the mobile router and its mobile network move to a foreign domain, the mobile router registers its care-of-address with its home agent. An IP-in-IP tunnel is then set up between the mobile router and the home agent. Every packet going to the mobile network will be intercepted by the home agent and forwarded to the mobile router through the IP-in-IP tunnel. The mobile router then forwards the packet to a host in its mobile network. When a node in its mobile network wishes to send a packet out of the network, the mobile router intercepts the packet and forward the packet to the home agent through the IP-in-IP tunnel. The home agent then sends the packet out to the intended recipient.
It is the interest of this memo to investigate if such a bi-directional tunneling approach can be extended to a mobile network that is multi-homed. More specifically, we wish to identify issues that may arise in bi-directional tunneling between mobile router and home agent when the mobile network is multi-homed. To this end, this memo first builds up a taxonomy on multi-homed mobile network. Next, different deployment scenario are described for different configurations of the multi-homed mobile network.
2. Taxonomy

2.1 Explanations of Terms and Illustrations

This section describe items and abbreviations used in the illustrations of this Internet Draft.

2.1.1 Abbreviations

Referring to the terminology of Network Mobility [2], the following abbreviations are used in figures illustrated throughout this draft:

- MR: Mobile Router
- HA: Mobile Network Home Agent
- AR: Access Router
- MNN: Mobile Network Node

2.1.2 Illustrations

In all figures illustrated in this draft, the following convention will be used.

```
-|_|
 R
```

R is a router.

```
P
|--|--|
 L  R
```

R advertised the Network Prefix p in the network link L.
R advertised the Network Prefixes p1 and p2 in the network link L and p1 and p2 are different. [Todo: Different how? 64 first bits different is enough or not?]

R is a router with two or more global addresses on one interface, or with two or more interfaces on the same link, or two or more interfaces on different links.

So the [=] symbol can be one of this cases:

- Multi-Addressed MR.
2.2 Classifications of Multi-homed Mobile Network.

There are various configurations of a multi-homed mobile network, depending on how many mobile routers are present, how many egress interfaces and home addresses the mobile routers have, how many subnet prefixes are advertised to the mobile network nodes, etc. In order to facilitate discussions on multi-homed mobile network, it is necessary to identify what kind of configuration the mobile network is in. Here, we identify three key parameters differentiating different multi-homed configurations. With these parameters, we can refer to each configuration by the 3-tuple \((w,x,y)\), where \('w'\), \('x'\), \('y'\) are defined as follows:

- \('w'\) differentiates the case of single mobile router (with multiple egress interfaces or multiple home addresses) versus the case of multiple mobile routers, where

\(w=0\) implies a mobile network has only a single mobile router. In this case, the mobile router either has multiple egress interfaces or multiple home addresses bound to a single egress interface.
w=1 implies a mobile network has more than one mobile router advertising an egress route.

- 'x' differentiates the case of a single home agent for the mobile network versus the case of multiple home agents for the mobile network, where

  x=0 implies that a single home agent is assigned to manage binding updates of the mobile network.

  x=1 implies that more than one home agents (possibly in different administrative domains) manage the binding updates of the mobile network.

- 'y' differentiates the case of single mobile network prefix versus multiple mobile network prefixes that is/are advertised to the mobile network node, where

  y=0 implies that a single subnet prefix is advertised to the mobile network nodes.

  y=1 implies that more than one subnet prefixes are advertised to the mobile network nodes.

It can be seen that the above three parameters are fairly orthogonal to one another. Thus different values of 'w', 'x' and 'y' give rise to different combinations of the 3-tuple (w,x,y). A total of 8 possible configurations can be identified. These are described further in the following sub-sections.

### 2.2.1 (0,0,0): Single MR, Single HA, Single Prefix

The (0,0,0) mobile network has only one mobile router advertising a single subnet prefix. In addition, the mobile router associates with only one home agent at any one time. This makes the mobile network very similar to a non-multi-homed mobile network, except for the fact that the mobile router may either (i) use more than one egress links at the same time, or (ii) use more than one home address at the same time.

Since only one subnet prefix is advertised, the mobile network nodes are (usually) not multi-homed.
2.2.2 (0,0,1): Single MR, Single HA, Multiple Prefixes

The (0,0,1) mobile network has only one mobile router, which associates to only one home agent at any one time. However, two or more subnet prefixes are advertised to the mobile network nodes. No associations is assumed between the subnet prefixes and the home addresses of the mobile router.

Since a plurality of subnet prefixes are advertised, mobile network nodes can generally be multi-homed themselves, where each mobile network node is allocated one address in each subnet prefix.

2.2.3 (0,1,0): Single MR, Multiple HAs, Single Prefix

The (0,1,0) mobile network has only one mobile router advertising a single subnet prefix. The mobile router, however, associates to multiple home agents, possibly one home agent per home addresses. No assumption is made on whether or not the home agents belongs to the same administrative domain.

Since only one subnet prefix is advertised, the mobile network nodes are (usually) not multi-homed.
2.2.4 (0,1,1): Single MR, Multiple HAs, Multiple Prefixes

The (0,1,1) mobile network has only one mobile router. However, the mobile router advertises more than one subnet prefix, and also associates to multiple home agents at the same time, possibly one home agent per home address. No assumptions is made on whether or not the home agents belongs to the same administrative domain.

Since a plurality of subnet prefixes are advertised, mobile network nodes can generally be multi-homed themselves, where each mobile network node is allocated one address in each subnet prefix.

2.2.5 (1,0,0): Multiple MRs, Single HA, Single Prefix

The (1,0,0) mobile network has more than one mobile router advertising global routes. These mobile routers, however, advertise the same subnet prefix and associate to the same home agent. Since only one subnet prefix is advertised, the mobile network nodes are (usually) not multi-homed.
(1,0,1): Multiple MRs, Single HA, Multiple Prefixes

The (1,0,1) mobile network has more than one mobile router advertising different global routes and different subnet prefixes. However, these mobile routers associate to the same home agents.

Since a plurality of subnet prefixes are advertised, mobile network nodes can generally be multi-homed themselves, where each mobile network node is allocated one address in each subnet prefix.

(1,1,0): Multiple MRs, Multiple HAs, Single Prefix

The (1,1,0) mobile network has more than one mobile router advertising different global routes. The mobile routers are also associated to more than one home agents at any one time.
assumptions is made on whether or not the home agents belongs to the same administrative domain. However, the mobile routers advertise the same subnet prefix. Since only one subnet prefix is advertised, the mobile network nodes are (usually) not multi-homed.

\[
\begin{array}{ccc}
\text{MR2} & \text{AR} & \text{HA2} \\
p & \_ & \_ \\
<\_\_\_\_ & \_\_\_\_ & \_\_\_\_ \\
\_\_\_\_ & \_\_\_\_ & \_\_\_\_ \\
\_\_\_\_ & \_\_\_\_ & \_\_\_\_ \\
\_\_\_\_ & \_\_\_\_ & \_\_\_\_ \\
n & \_ & \_ \\
\end{array}
\]

2.2.8 (1,1,1): Multiple MRs, Multiple HAs, Multiple Prefixes

The (1,1,1) mobile network has more than one mobile router advertising different global routes and different subnet prefixes. The mobile routers are also associated to more than one home agent at any one time. No assumptions is made on whether or not the home agents belongs to the same administrative domain.

Since a plurality of subnet prefixes are advertised, mobile network nodes can generally be multi-homed themselves, where each mobile network node is allocated one address in each subnet prefix.

\[
\begin{array}{ccc}
\text{MR2} & \text{AR} & \text{HA2} \\
p2 & \_ & \_ \\
<\_\_\_\_ & \_\_\_\_ & \_\_\_\_ \\
\_\_\_\_ & \_\_\_\_ & \_\_\_\_ \\
\_\_\_\_ & \_\_\_\_ & \_\_\_\_ \\
\_\_\_\_ & \_\_\_\_ & \_\_\_\_ \\
p1 & \_ & \_ \\
\end{array}
\]
2.3 Alternative Classifications

In the mailing list, Pascal Thubert (Cisco System) proposed an alternative classification. He has a set of 4 categories, based on two orthogonal parameters: the number of home agents, and the number of subnet prefixes advertised. Since the two parameters are orthogonal, the categories are not mutually exclusive. The four categories are:

- **Tarzan**: Single HA for Different Care-ofs of Same Prefix
  
  This is the case where one mobile router registers different care-of-addresses to the same home agent for the same subnet prefix. This is equivalent to the case of $x=0$, i.e. the $(0,0,\ast)$ mobile network.

- **JetSet**: Multiple HA for Different Care-ofs of Same Prefix
  
  This is the case where the mobile router registers different care-of-addresses to different home agents for the same subnet prefix. This is equivalent to the case of $x=1$, i.e. the $(0,1,\ast)$ mobile network.

- **Shinkansen**: Single Prefix Advertised by Mobile Router(s)
  
  This is the case where one subnet prefix is announced by different mobile routers. This is equivalent to the case of $y=0$, i.e. the $(1,\ast,0)$ mobile network.

- **DoubleBed**: Multiple Prefixes Advertised by Mobile Router(s)
  
  This is the case where more than one subnet prefixes are announced by the different mobile routers. This is equivalent to the case of $y=0$, i.e. the $(1,\ast,1)$ mobile network.

Thubert’s classifications is problem-oriented, as oppose to the 8 classifications in this draft, which are configurations oriented. We see also that one can draw association between some of the 8 classifications in this draft with the each of the 4 categories put forward by Thubert. Hence, in a rough manner, one can say the 4 classes drawn by Thubert is actually a subset of the 8 configurations defined, though such an associations is a vague one since both partitioned the multi-homed mobile network differently (problem-oriented versus configuration-oriented).

It is, however, the authors’ belief that by analyzing each configurations, problems and issues of multi-homed mobile network can be more thoroughly identified. It may well be that after analysis,
we come to the same 4 specific problems Thubert has identified. Even so, the exercise of analysis each configuration should be helpful to the understanding of each problem.
3. Deployment Scenarios

[ To be re-organized -- cwng ]

One example of the (0,0,*) mobile network is that a single Internet Service Provider (ISP) offers two different wireless public access methods such as IEEE 802.11 and GPRS. A mobile router with both access interfaces (i.e. 802.11 and GPRS capabilities) may subscribe to the same ISP and is allowed to use both access methods. The ISP will choose to provide a single home agent for the same mobile router for ease of management.

This configuration is useful for maintaining connectivity between several interfaces. An example will be to use 802.11 in town and GPRS in the countryside. In addition, it can also provide some multi-homing benefits (such as Fault-Tolerance / Policy Sharing) to MNNS without having to involve the MNNs.

Extending the above example to a (0,1,*) mobile network, the mobile router may subscribe to different ISPs for different access technologies. For instance, it may subscribe to 802.11 public access services using one ISP, and subscribe to GPRS services from another ISP. In this case, the two different ISPs will provide two different home agents for the same mobile router. Since the two ISPs are independent, under normal situation, each ISP will delegate different subnet prefixes to the mobile network, thus forming a (0,1,1) mobile network.

An example of the (1,*,*]) mobile network is when a mobile network contains more than one device with independent routes to the global Internet. An excellent illustration is the Wireless Personal Area Network (W-PAN) where a mobile phone on the W-PAN connects to the Internet via GPRS services, and a Personal Digital Assistant (PDA) on the same W-PAN connects to the Internet via 802.11 public access. If the ISPs provide both access technologies, then the subscriber can subscribe to a all-in-one package where the ISP provides a single home agent to manage the mobile network, and delegates a single subnet prefix to the mobile network. This forms a (1,0,0) mobile network. Alternatively, the subscriber can subscribe to two ISPs for each access mechanism, thus giving a (1,1,1) mobile network.

The (1,*,0) configuration provides easily a router redundancy and/or HA redundancy for big mobile networks, such as within a train or a plane, or critical mobile networks, such as those deployed in ambulances, fire engines, or military vehicles.
Deployment example for (0,1,0) [-JetSet]

[The Jet]

|   ---   |                |   ---   |
|        |               |        |
|        | <---------->   |        |
|        |       \_\_\_ |        |
| HA1    |   MN inside the |   HA2  |
| Paris  |   plane.       |   New York |

In this example, the MR sends the same PBU to both HAs in different cities, and communicates with both simultaneously. Thus a Correspondent Node near Paris can choose the Paris’s HA to send its packets, and the MR inside the plane should send its packet to the New York’s HA (which is nearer).

Example for a (*,*,1) mobile network is a car network, where there may be different logical subnets:

- the User Network which provides Internet connectivity to passengers;

- the Control Network which exchanges car information (e.g. position, movement, intern constants) with the others cars, or with the society who use this car; and

- the Safeguard Network which shares state information of the car with the emergency/repairing companies, or the emergency agencies in case of accidents.

Because of these differences it can be useful to attribute a different network prefix for each network to clearly separate each entity and each network prefix should be send to a different subnet link.
4. Analysis

This section, we attempt to analyze what are the problems faced in each of the 8 categories. It shouldn’t matter if some of the categories share the same problem(s).

- (0,0,0) Mobile Network
  The (0,0,0) mobile network has only one mobile router registering more than one care-of-addresses to the same home agent, and advertising only one prefix. The mobile router can either have more than one care-of-addresses bound to the same home-address, or it can have various care-of-address and home-address pairs.

  Either way, this is a MIPv6 problem. Multiple pairs of different care-of-address and home-address is perfectly alright with MIPv6. The fact that they specify the same subnet prefix in binding updates shouldn’t cause a problem either. Having a home-address tied to multiple care-of-address may be a problem for MIPv6. This will require a solution like [10].

- (0,0,1) Mobile Network
  The (0,0,1) mobile network is similar to the (0,0,0) mobile network, and thus face the same problem when there is only one home-address bound to multiple care-of-addresses. However, the (0,0,1) has one NEMO-specific problem if more than one subnet prefixes are being taken care-of by a single home-address and care-of-address pair. This is assuming prefix-scoped binding update is used, which does not allow more than one prefix be specified in a single binding update.

- (0,1,0) Mobile Network
  The (0,1,0) mobile network has one mobile router registering to multiple home agents. There is the question of whether a mobile router can register the same home-address to different home agents simultaneously with the ‘H’ bit set. If not, the mobile router can only register different home-address and care-of-address pairs to different home agents. In any case, this is a MIPv6 issue.

  The NEMO-specific problem is the fact that a subnet prefix has a care-of in different home agents. It might be possible that only one home-agent will actively advertise a route to the subnet
prefix. The case of multiple home agents at different domains advertising a route to the same subnet prefix may pose a problem in the routing infrastructure as a whole. The implications of this aspect needs further exploration.

- **(0,1,1) Mobile Network**

  The (0,1,1) mobile network has one mobile router registering to multiple home agents multiple subnet prefixes. The same question of whether the same home-address can be simultaneously registered to multiple home agents.

  This (0,1,1) network can avoid the problem of registering care-ofs for the same prefix to different home agents by registering care-of for one prefix at one home-agent.

- **(1,0,0) Mobile Network**

  The (1,0,0) mobile network has two or more active egress mobile routers, registering to same home agents, and advertising the same prefix. May not have any problem at all if the mobile routers are manually configured to announce the same prefix. It is also possible that prefix delegation is used to ensure all routers advertise the same subnet prefix since all routers are handled by the same home agent. The home-agent will see two HoA-CoA pairs taking care of the same subnet prefix.

- **(1,0,1) Mobile Network**

  The (1,0,1) mobile network has multiple active egress mobile routers registering to the same home-agent, and advertising multiple prefixes. If a mobile router is advertising more than one prefix, we have the same problem as (0,0,1) as in how to register more than one subnet prefix to the same home-agent.

  On the other hand, if each mobile router take cares of a separate (and only one) subnet prefix, then there should not be any NEMO-specific problem.

- **(1,1,0) Mobile Network**

  The (1,1,0) mobile network has multiple mobile routers registering to different home agents, but advertising the same prefix. There is the same issues as in (0,1,0) of a subnet prefix having a care-of in different home agents. In addition, there is a question how to perform prefix delegation such that two home agents will delegate the same prefix to different mobile routers. Certain level of home-agent co-ordination may be required here.
(1,1,1) Mobile Network

The (1,1,1) mobile network has multiple mobile routers, registering to multiple home-agents and advertising prefixes. This may be a case of multiple non-multi-homed network superimposed together, i.e. each mobile router take cares of one prefix, and register to separate home agents.

On the other hand, if one mobile router takes cares of more than one prefix, we have similar problems as (0,0,1) and (1,0,1). In addition, if more than one mobile router takes care of the same prefix, we have similar issues as (1,1,0). In any case, we see that the problems within this configurations can be decomposed into problems from other configurations.

From the above analysis, we can identify the following problems relating to multi-homed mobile network:

- Multiple care-of-addresses to one home-address:
  * How to register two care-of-address binding to one home-address?
  * In single or multiple binding message(s)?
  * How to selectively update a care-of-address?
  * MIPv6 specific?
  * Wakikawa’s draft [10] specifically addresses this issue.

- Multiple prefixes taken care of by a single home-address:
  * How to register multiple prefix scope under the same home-address?
  * In single or multiple binding message(s)?
  * How to selectively update the care-of of a subnet prefix?
  * Similar to the ‘Tarzan’ problem illustrated by Thubert.

- A single home-address registered to multiple home agents:
  * Is this allowed?
  * MIPv6-specific?
A single subnet prefix registered to multiple home agents:

* Is this allowed?

* Is this allowed if the prefix is bound to the same home-address?

* Any routing issue?

* If prefix delegation is used, possibility of requiring home agents co-ordination.

  Similar to the ‘JetSet’ problem illustrated by Thubert.

A single prefix advertised by multiple mobile routers from multiple home agents:

* If prefix delegation is used, possibility of requiring home agents co-ordination.

  Similar to the ‘Shinkansen’ problem illustrated by Thubert.

[TBD: anymore]
5. Security Considerations

This document is an on-going work to classify the taxonomy in multi-homing of mobile networks. There should be a separate draft produced by the working group to analyze security threats for network in motion. As such, no special security considerations is listed here. However, since this memo also looks into the analysis of problems in a multi-homed mobile network, we will add problems related to security threat here as and when they are encountered. We also encourage interested readers to contribute to this part.
6. Acknowledgements

The authors would like to thank people who have given valuable comments on various multi-homing issues on the mailing list, and also those who have suggested directions in the 56th IETF Meeting.
References


Authors’ Addresses

Chan-Wah Ng
Panasonic Singapore Laboratories Pte Ltd
Blk 1022 Tai Seng Ave #06-3530
Tai Seng Industrial Estate
Singapore  534415
SG

Phone: +65 65505420
EMail: cwng@psl.com.sg

Julien Charbon
Keio University, Louis Pasteur University
Keio University.
5322 Endo
Fujisawa-shi, Kanagawa 252-8520
JP

Phone: +81-466-49-1100
Fax:  +81-466-49-1395
EMail: julien@sfc.wide.ad.jp
URI:  http://www.sfc.wide.ad.jp/~julien/
Intellectual Property Statement

The IETF takes no position regarding the validity or scope of any intellectual property or other rights that might be claimed to pertain to the implementation or use of the technology described in this document or the extent to which any license under such rights might or might not be available; neither does it represent that it has made any effort to identify any such rights. Information on the IETF’s procedures with respect to rights in standards-track and standards-related documentation can be found in BCP-11. Copies of claims of rights made available for publication and any assurances of licenses to be made available, or the result of an attempt made to obtain a general license or permission for the use of such proprietary rights by implementors or users of this specification can be obtained from the IETF Secretariat.

The IETF invites any interested party to bring to its attention any copyrights, patents or patent applications, or other proprietary rights which may cover technology that may be required to practice this standard. Please address the information to the IETF Executive Director.

Full Copyright Statement

Copyright (C) The Internet Society (2003). All Rights Reserved.

This document and translations of it may be copied and furnished to others, and derivative works that comment on or otherwise explain it or assist in its implementation may be prepared, copied, published and distributed, in whole or in part, without restriction of any kind, provided that the above copyright notice and this paragraph are included on all such copies and derivative works. However, this document itself may not be modified in any way, such as by removing the copyright notice or references to the Internet Society or other Internet organizations, except as needed for the purpose of developing Internet standards in which case the procedures for copyrights defined in the Internet Standards process must be followed, or as required to translate it into languages other than English.

The limited permissions granted above are perpetual and will not be revoked by the Internet Society or its successors or assignees.

This document and the information contained herein is provided on an "AS IS" basis and THE INTERNET SOCIETY AND THE INTERNET ENGINEERING TASK FORCE DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTY THAT THE USE OF THE INFORMATION
Acknowledgement

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