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Route Optimization Scheme based on Path Control Head
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Status of this Memo

Abstract

In this memo, we propose a unified Route Optimization (RO)
that can solve several types of RO problem by using Path Co
Header (PCH) Piggybacking. In our scheme, Home Agent (HA) d
piggyback the PCH on the packet which is reversely forwarde
Mobile Router (MR). That enables any PCH-aware routing faci

the route to make a RO tunnel with MR using the Care-of add
MR contained in the PCH. By applying to some already known
problems, we show that our scheme can incrementally optimiz
routes via default HA-MR tunnel through the simple PCH
interpretation.

Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHA
"SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONA
this document are to be interpreted as described in RFC-211

Table of Contents

1. Introduction

NEMO Basic Support Solution[15] would suppose to support transparent mobility to mobile network nodes(MNNs) in mobil networks by using MR-HA bi-directional tunneling. However, inherently due to the use of the bi-directional tunnel, the some types of route optimization problem [14] that need our attention. Until now, one solution is proposed to solve onl type of route optimization problem such as nested tunnel optimization.

In this memo, we propose a route optimization scheme based PCH(Path Control Header) piggybacking by HA. The scheme is unified solution that can solve a several types of route optimization problem with applying the same principle to th routing facilities such as HA, MR and Correspondent Router(

In the proposed scheme, HA does piggyback PCH on the packet is reversely forwarded from MR through bi-directional MR-HA PCH is a hop-by-hop option header so that it can be process all of the routing facilities on the path that is from HA t forwards the packet with PCH to CN for the route optimizati on the path makes a RO(Route Optimization) tunnel between M itself using the information which is the CoA of MR that is contained in PCH.

This memo describes how we can apply PCH based scheme on tw

problem spaces listed in [14]. One is to CR based route optimization in routing infrastructure and the other is to nested tunnels optimization for which many of solutions in have been proposed. The basic operation and signaling will detailed in section 3 and 4.

Our proposed RO scheme, PCH piggybacking by HA, is a simple effective one in solving the problems of route optimization network mobility support. By taking the functional extensio routing facilities such as HA, MR and CR, we can dynamicall incrementally optimize the routes over CN-HA-MR without the transparency to CN.

We expect that the basic concept of this scheme can be used support other mobility-related route optimizations as a uni solution, not limited to network mobility.

2. Terminology

It is assumed that readers are familiar with NEMO terminolo described in [2][14], and the terms described in [4][5]. In addition, we define a few of terms used in describing the o of our solution.

Path Control Header (PCH)

IPv6 hop-by-hop option header piggybacked on the rev forwarded packet by HA for the route optimization. T header contains, as an option data, a form of array global addresses that are the addresses of Mobile Ro the nested path which means from TLMR to any nested nested mobile networks.

RO Tunnel (ROT)

Any tunnel that created by the scheme of route optim proposed by this document is referred to a "RO Tunne

Nested RO Tunnel (NROT)

Any RO tunnel that do require the source routing usi
Routing Header Type 0 (RH0). This kind of RO tunnel
used in optimizing the nested tunnels to guarantee t
correct routing over nested MRs.

Correspondent Router (CR)

Any router in the Internet that can play a role of a
correspondent agent for a set of correspondent nodes
maybe an access router serving the routing service t
of subnets or a border router located in AS-level or
level.

3. Basic Operations

3.1 PCH Piggybacking by HA

To route optimization, HA does piggyback PCH on the packet
reversely forwarded from MR through bi-directional MR-HA tu
PCH is a hop-by-hop option header so that it can be process
all of the routing facilities on the path that is from HA t
The mentioned routing facility means an entity which can pl
role of transparent correspondent agent. The router in the
that implements such a function of transparent correspondent
we call it a CR, provides the packet redirection service to
nodes behind it by intercepting the packets sent from them

redirecting to the RO tunnel. The RO tunnel between CR and
be established when CR gets know the existence of HA by pro
the packet with PCH.

In fig.1, HA de-capsulates the encapsulated packet forwarde
MR via MR-HA tunnel and then forwards the PCH piggybacked p
CN for the route optimization. Any existing CR on the path
to CN can catch the path control information as examining P
the packet. Therefore, the CR can initiate the procedure of
RO tunnel between itself and MR using the CoA of MR which i
contained in PCH. After setting up RO tunnel, the packets o
will be redirected to RO tunnel at CR.

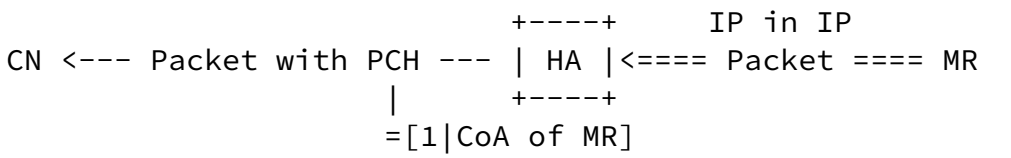


Fig.1 PCH piggybacking by HA

This scheme is simple and effective in respects of RO. It o
requires a little effort of HA to provide the RO tunnel bet
and MR. HA does PCH piggybacking on the packet which taking
optimized path of MR-HA tunnel. In here, we can say that CR
an access router that providing the routing service for a f
subnets or a border router that runs BGP routing protocol i

Fig.2 shows the structure of PCH. PCH has address informati
option data. In here, the address information represents th
of IPv6 addresses. The address contained in PCH indicates t
of MR in MR-HA relationship. Through PCH, CR gets know the
MR so that CR can initiate the signaling for RO tunnel.

PCH(Path Control Header) : IPv6 Hop-by-Hop Options Heade
Option Type : 00 0 XXXXX
00 - skip over this option and continue processing the
0 - Option Data does not change en-route
XXXXX = Path Control Option ID (to be assigned by IAN

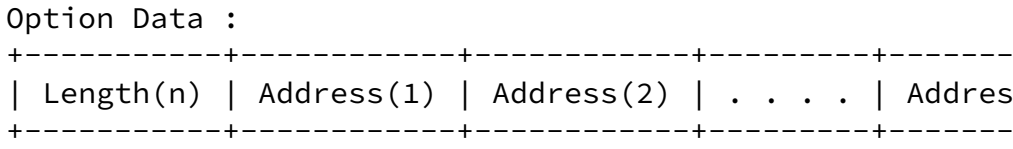


Fig.2 Type and data format of PCH option

In fig.3 that shows the case of forming nested tunnels, PCH
contain two CoAs, each of MR1 and MR2. HA2 gets know the fa
its MR2-HA2 tunnel is nested under outer MR1-HA1 tunnel aft
taking a look at the packet with PCH1. The nested HA just a
CoA of its MR on the received PCH to make its PCH. In fig.3
does piggyback PCH which includes the CoA of MR1(the exit p
the outer tunnel) and the CoA of MR2(the exit point of its
In this case, one CR on the path between HA2 and CN will ab
make RO tunnel with MR2 by using the nested information car
PCH.

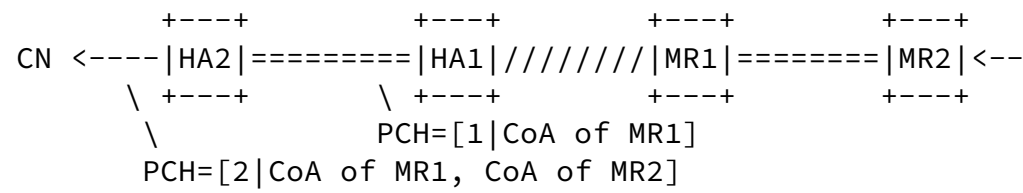


Fig.3 Nested PCH piggybacking by HAs

3.2 Making a RO Tunnel

The CR can make a RO tunnel after getting the piggybacked P
HA. The signaling to construct a RO tunnel between CR and M
done with 3-way handshake as in fig.4. The messages defined
are carried by Mobility Header(MIPv6). We define new messag
BR(Binding Request) to notify MR of the need of RO tunnel
BU(Binding Update) and BA(Binding Acknowledgement) are same
defined in MIPv6 and NEMO. Additionally, we define new mobi
option to carry a set of network prefixes. CR can use this
to inform MR of the routing information of networks which a
reachable from RO tunnel. By referring those of routing inf
MR reversely forwards the packets to pre-established RO tun

because they are destined to the network that is reachable
tunnel.
CR does the same thing for the prefix of mobile network tha
bound through BU from MR. CR intercepts the packets destine
prefix and redirects them to pre-established RO tunnel.

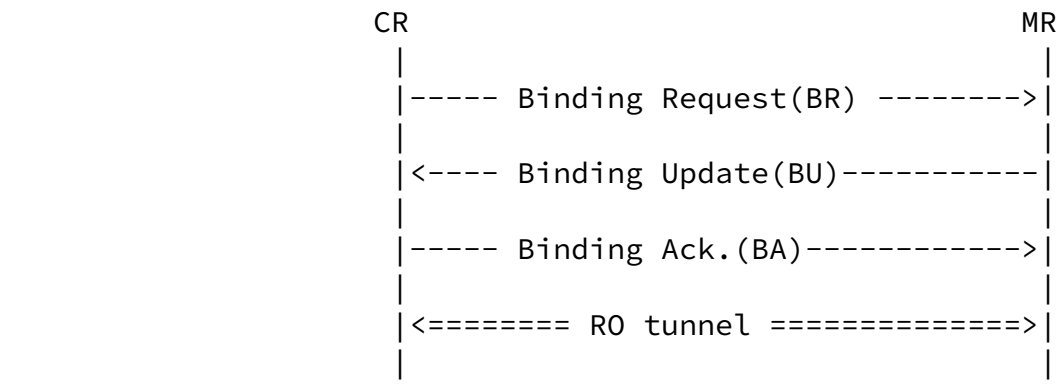


Fig.4 The signaling procedure for RO Tunnel

4. Route Optimization

4.1 Route Optimization by CR

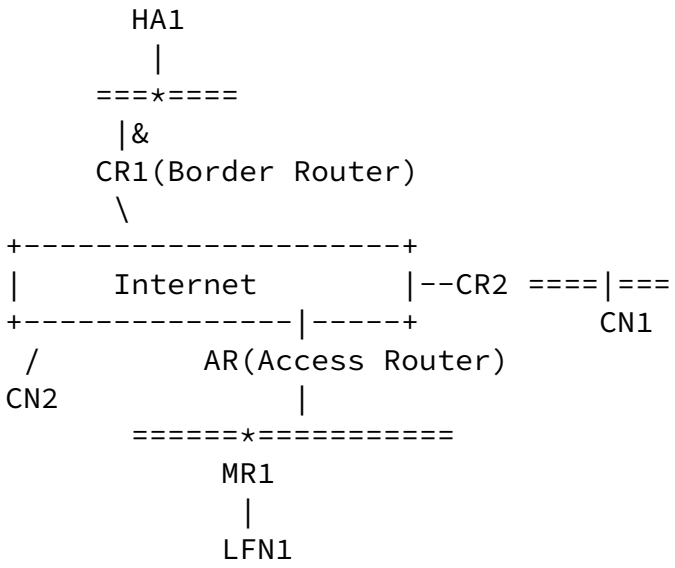


Fig.5 CR-based Route Optimization : Network Configura

As in fig.5 and 6, CR1 and CR2 can simultaneously establish
tunnel with MR through one PCH piggybacking by HA1. This is
possible because both are on the path that is from HA1 to C
that case, the packets sent from CNs in all of subnets atta
CR2 are redirected to RO tunnel at CR2. CR1 can serve the p
sent from any CNs(in here, CN2) that are scattered in the I
The packets reached on CR1 indicate that there is no CR in
that is from CN2 to CR1, or CR but still not received PCH.
packets from CN2 are redirected at CR1 and reversely the pa
from MR1 are forwarded via HA1. At next time, the CR on the
path can make a RO tunnel by picking PCH up on the reversel
forwarded packets from HA1. As a result of PCH piggybacking
we can serve the incremental route optimization to all of C

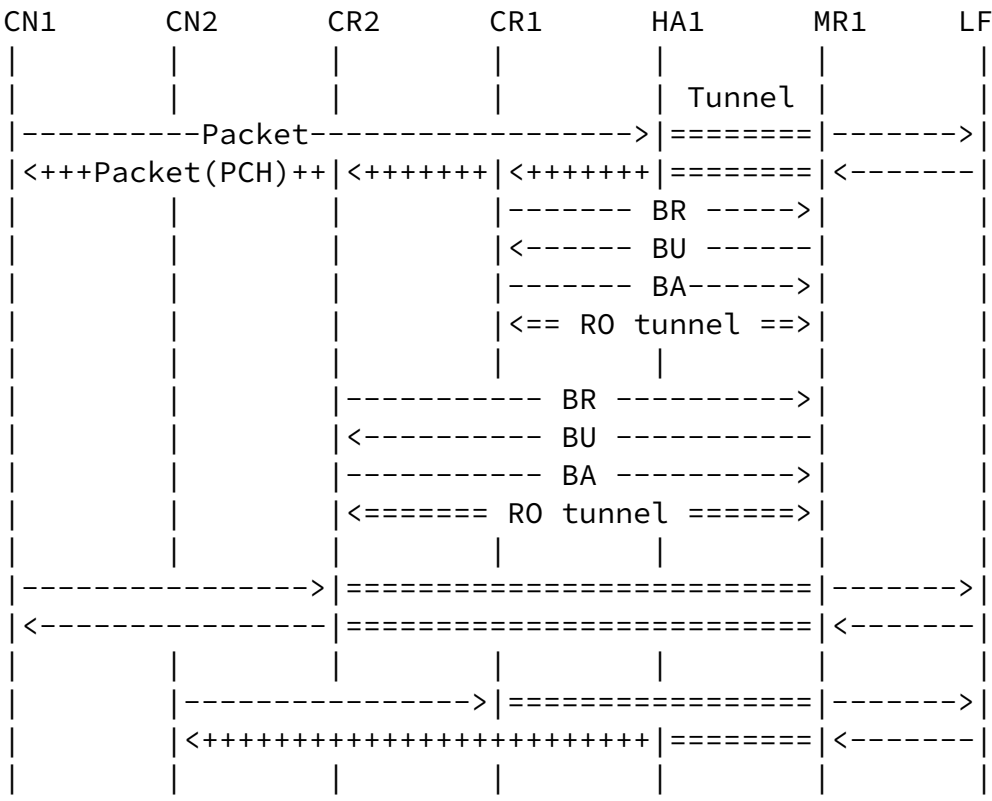


Fig.6 CR-based Route Optimization : Message Flow

4.2 Route Optimization over MR-to-MR

As in fig.7 and fig.8, we can get the RO tunnel over MR-to-
using PCH piggybacking. MR per se interprets PCH piggybacke
the HA of the other MR and initiates the signaling for RO t
with the other MR. As a result of that, the nodes behind on
directly communicate with the nodes behind the other MR wit

routing overhead.

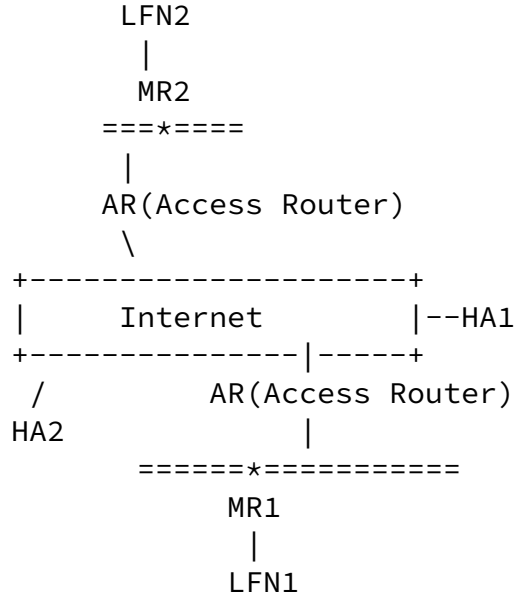
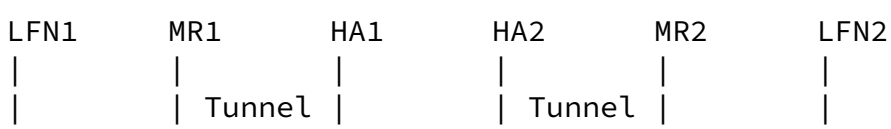


Fig.7 MR-to-MR Route Optimization : Network Configura



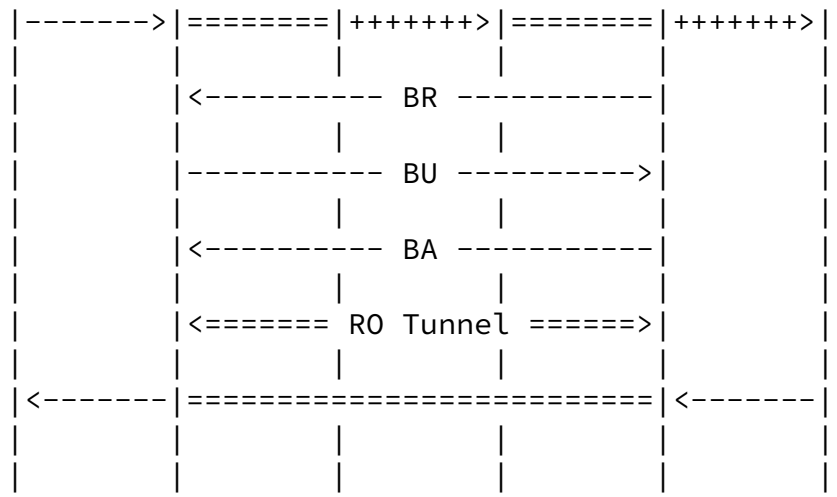
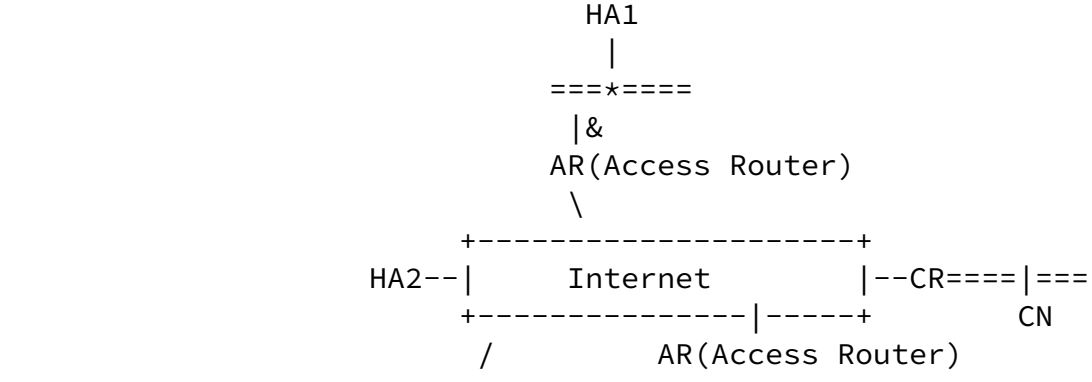


Fig.8 MR-to-MR Route Optimization : Message Flow

4.3 Nested Tunnels Optimization

Fig.9 and 10 show the network configuration and message flo
the nested tunnels optimization using PCH piggybacking. In
mobile networks, RO tunnel is called Nested RO Tunnel(NROT
because we introduces the source routing concept in handlin
nested tunnel optimization. To the correct routing in the n
network configuration, we take advantage of IPv6 Routing He
Type 0(RH0) in NROT.



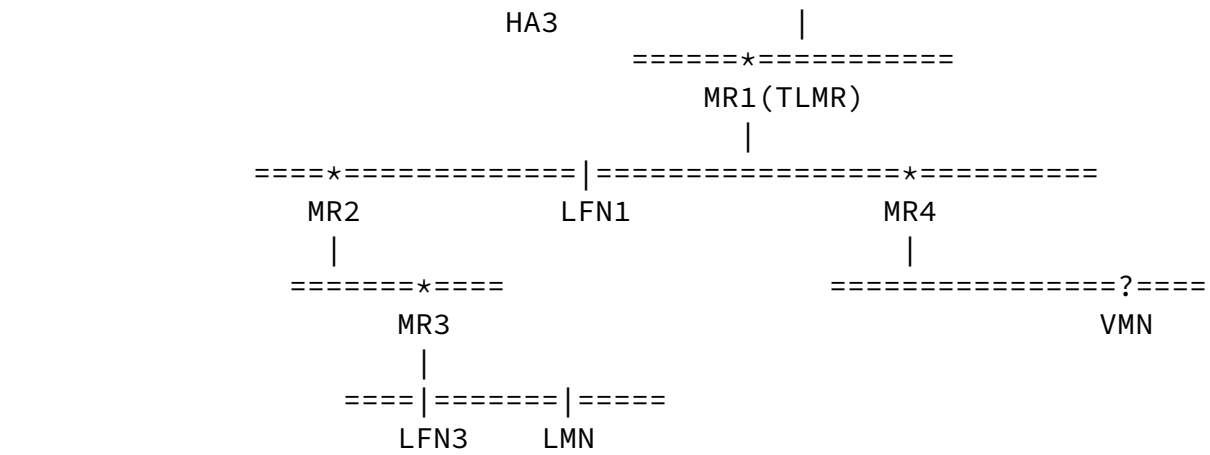
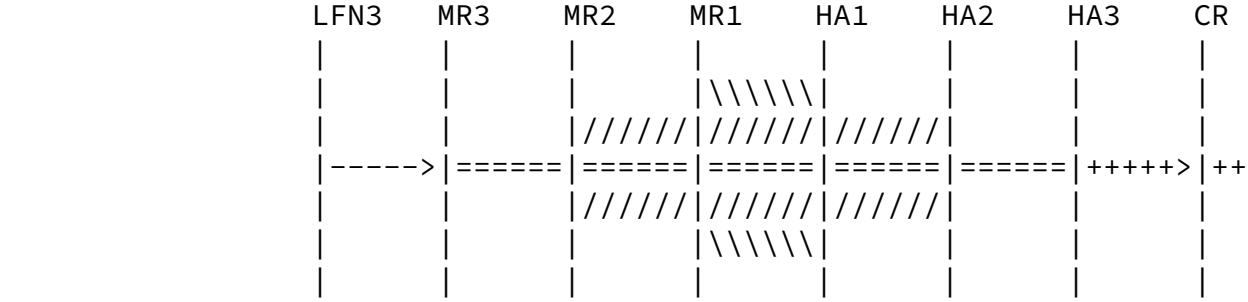


Fig.9 Nested Tunnels Optimization : Network Configurat

In fig.10, CR gets know the existence of nested tunnels thr
information (MR1's CoA and MR2's CoA, MR3's CoA) and then i
the signaling for NROT to MR3 via nested tunnels. At this t
Binding Request(BR) message contains Nested Routing Path Op
Option). NRP Option is used to inform MR3 of the nested pat
information. If MR3 receives BR message having NRP option,
gets know that it is nested. Therefore, the tunnel between
MR3 becomes a NROT.

In NROT, the entry point of tunnel adds RH0 at encapsulatio
Reversely, the exit point of tunnel deletes RH0 at decapsul

For the packets tunneled from CR to MR3, the packet forward
done with source routing of RH0 (MR1->MR2->MR3). For the pa
tunneled from MR3 to CR, the reverse source routing (MR2->M
occurs. Fig.11 and 12 shows the content of RH0 at the packe
delivery.



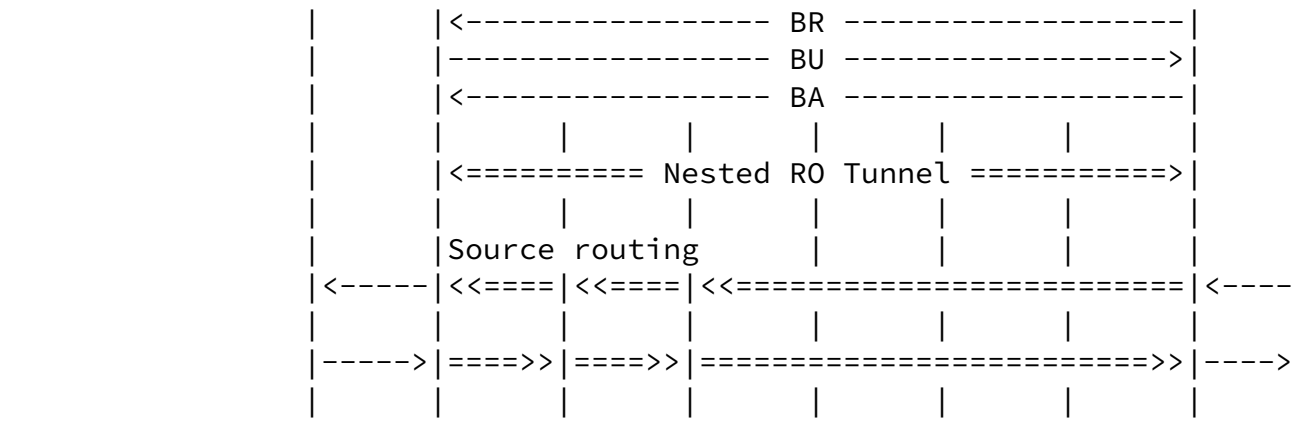
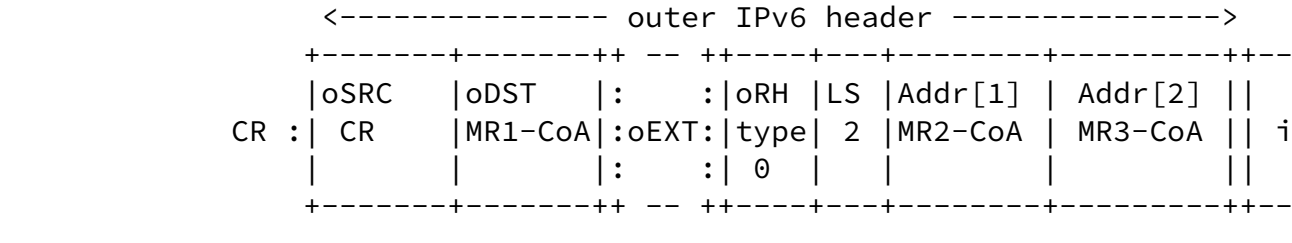


Fig.10 Nested Tunnels Optimization : Message Flow



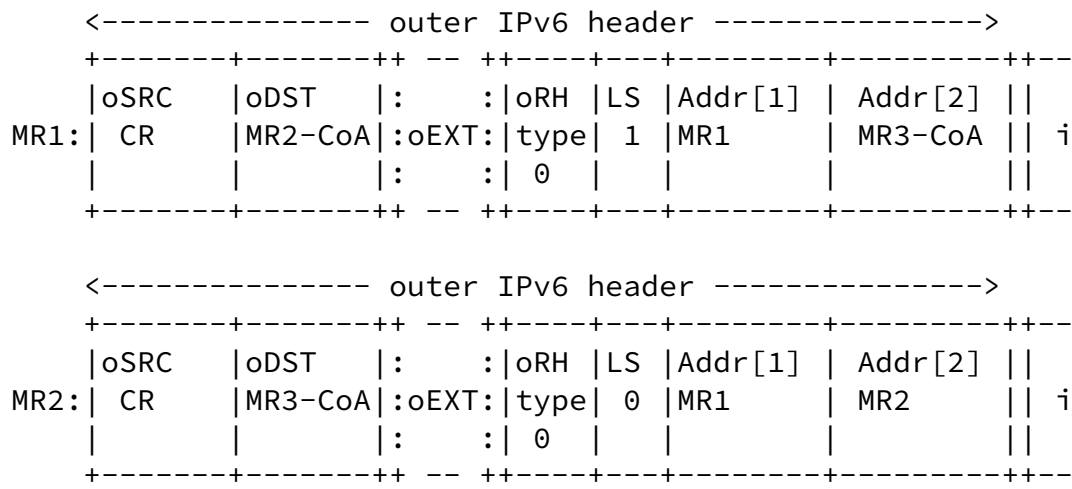


Fig.11 Forward Packet Delivery (CR->MR3) via NROT

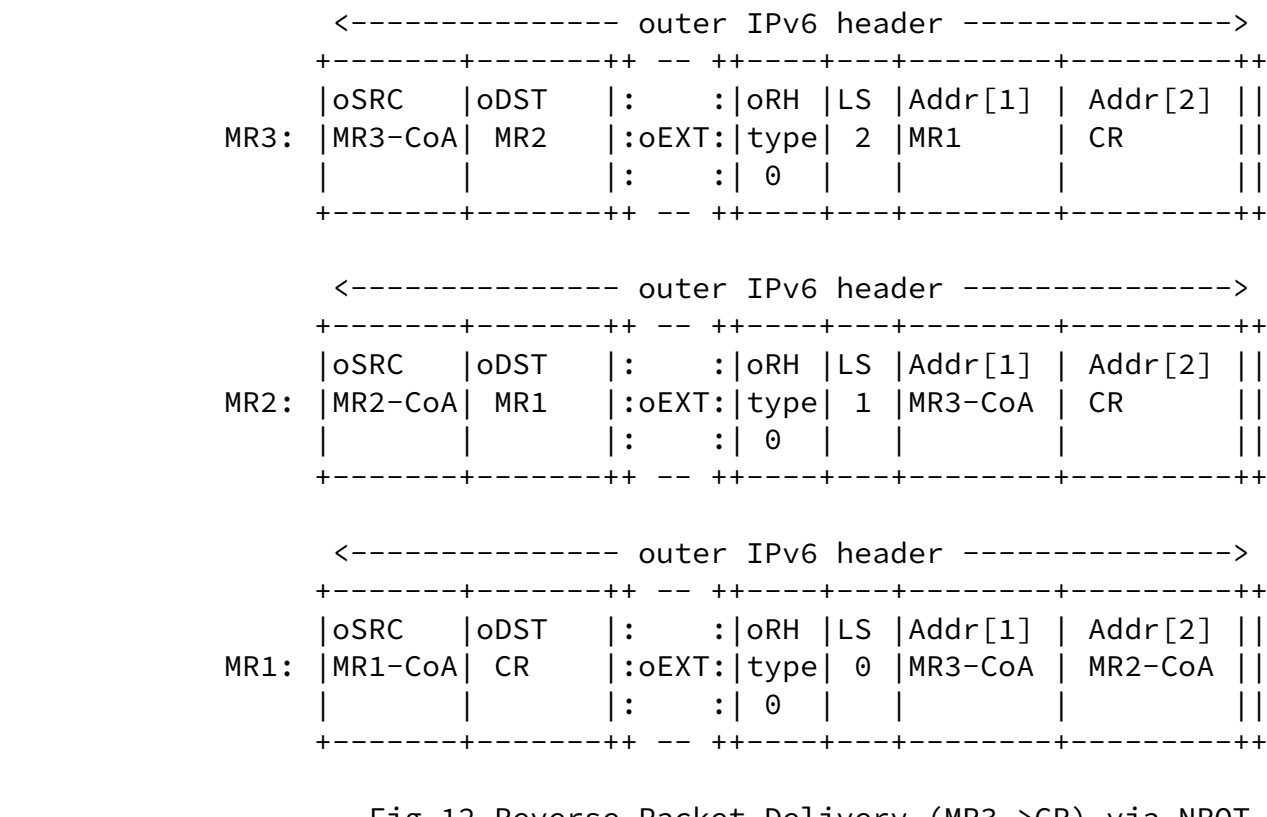


Fig.12 Reverse Packet Delivery (MR3->CR) via NROT

5. Extensions

The proposed scheme requires some extensions for existing M
NEMO Basic Support protocols.

5.1 MIPv6 Extension

The proposed scheme requires some extensions for existing M
protocol [1]. As you see in section 3.2, new mobility messa
is required. And also, new two mobility options are needed.
describe the purpose and usage of them in here.

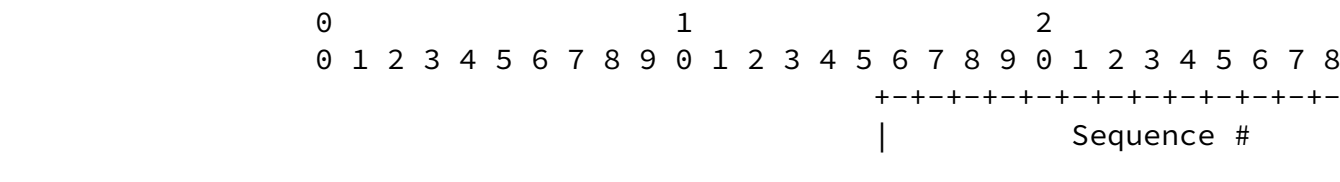
Binding Request Message (BR Message): This message is us
notify MR of the need of RO tunnel. If the sender of thi
message detects the nested tunneling(i.e. PCH contains o
addresses), it should put NRP(Nested Routing Path) Optio
this message to inform MR of its nested path information
Otherwise, this message includes no special information
for triggering the signaling of RO tunnel.

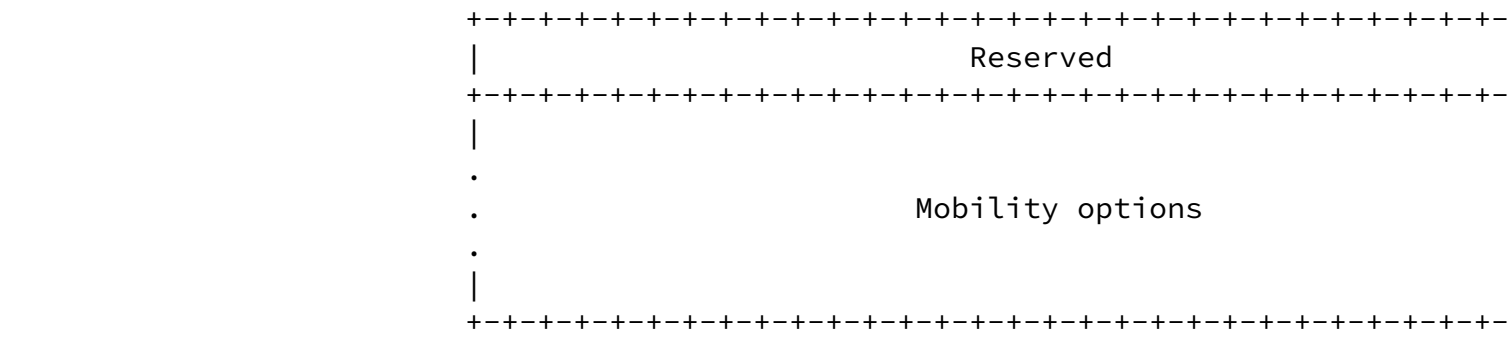
Nested Routing Path Option (NRP Option): The initiator o
signaling of RO tunnel should add this mobility option i
message to set up the Nested RO Tunnel with nested MR. T
option contains the list of addresses that represents th
topology of nested MRs. That is used for MR to assign th
routing path that is necessary to nested tunnels optimiz

Reachable Network Prefixes Option (RNP Option): This opt
used to let MR know about the network prefixes which are
reachable via RO tunnel. By using this information assoc
with RO tunnel, MR can select the optimized path(i.e. RO
for the out-going packets. This option should be contain
message.

5.1.1 Binding Request Message (BR Message)

New BR Message is defined to notify MR of the need of RO tu
sender detects the nested mobility, it has to put NRP Optio
in this message to inform MR of its nested path information
format of this message is as follows:

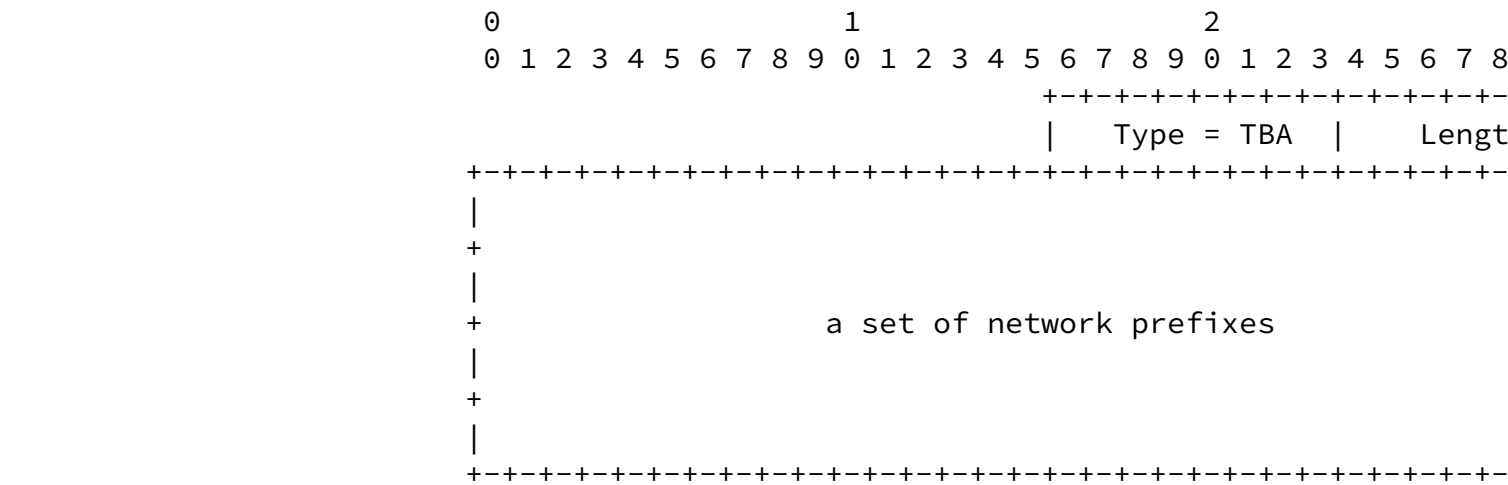




TBD

5.1.2 Reachable Network Prefixes Option (RNP Option)

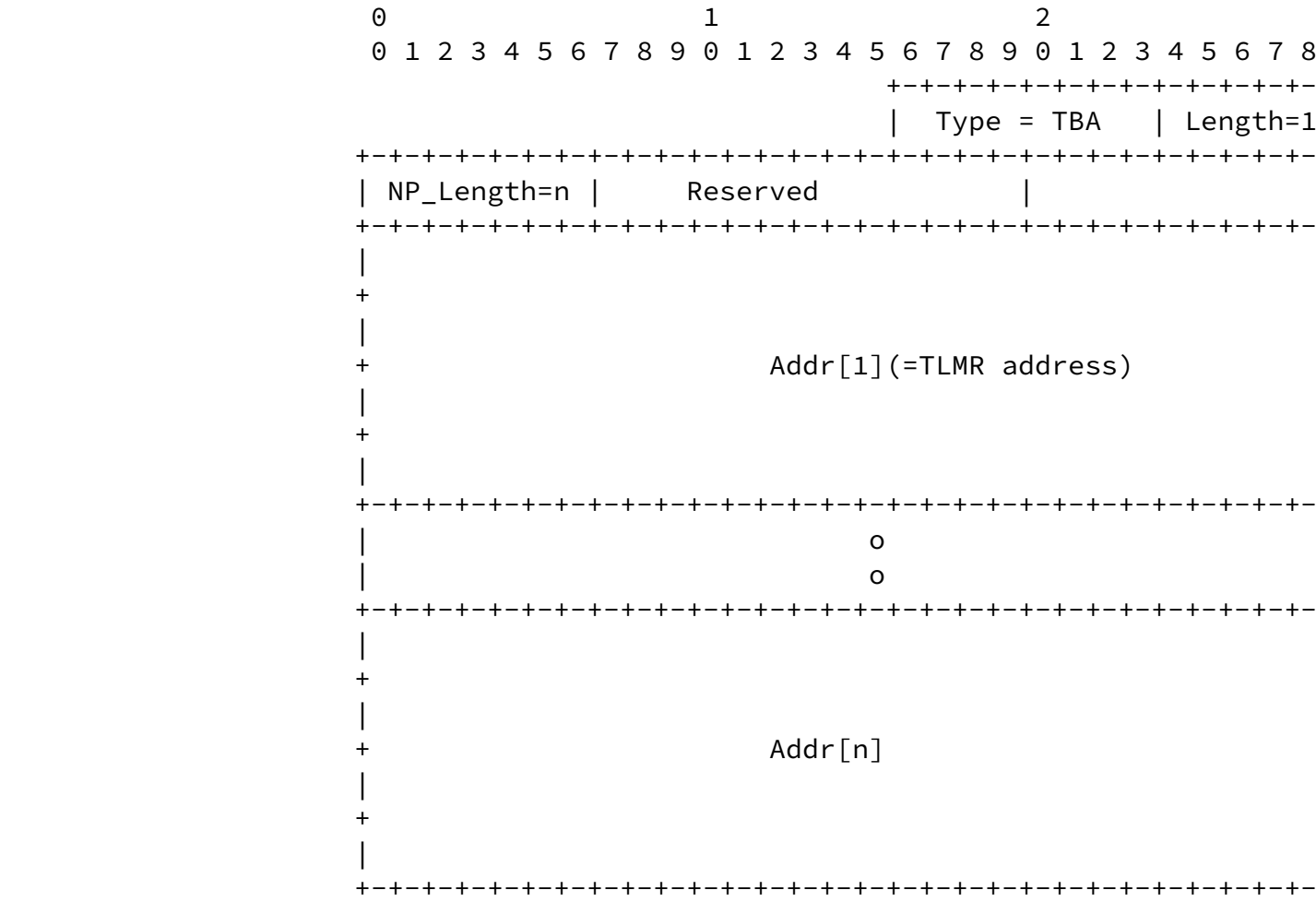
RNP Option is used to let MR know about the networks reacha
the tunnel. By using this information associated with the t
between CR and MR, MR can select the optimized path for the
going packets. This option should be contained either BR or
message for the route optimization in the reverse packet de
The format of this option is as follows:



TBD

5.1.3 Nested Routing Path Option (NRP Option)

CR adds new mobility option, NRP Option in BR message to se
Nested RO Tunnel with nested MR. The format of this option
follows:



NP_Length

8-bit unsigned integer that indicates the number of
slots.

Addr[1..n]

Vector of IPv6 global addresses of MRs on the nested
numbered 1 to n.

NRP Option is only valid in a Binding Request message. The
of this option is to inform MR that it can do optimize the
tunnels overhead. Using this information, MR can route pack

CR via the MRs on the nested path by using type 0 RH option
header.

5.2 MR Extension

For route optimization, MR MUST understand BR message sent
routing facilities such as CR. According to MIPv6 Spec.[1],
maintain Binding Update List(BU List). In managing BU List,
following information MUST be maintained additionally to us
tunnel defined in this proposed solution.

RO Tunnel (ROT) flag: When it is set, it indicates that
associated BU entry is for ROT tunnel. All of ROT tunnel
contain a set of network prefixes that is carried from R
Option.

Nested RO Tunnel (NROT) flag: When it is set, it indicat
the associated BU entry is for NROT tunnel. In this case
entry should contain the nested path information carried
NRP Option.

Nested Path Information (NPI) Vector: The address vector
information is transferred in NRP Option. This informati
only valid when NROT flag is set.

Network Prefixes (NP) Vector: The address vector informa
transferred in RNP Option. This information is only vali
either ROT flag or NROT flag is set.

The successful establishment of RO tunnel allows the ready
enabled tunnel interface that would be associated with the

correspondent entry of BU List. That tunnel interface shoul
setup to add IPv6 RH0(Routing Header Type 0) optional heade
encapsulation of tunneled packets if the NROT flag is set.

Lastly, MR should maintain the RO tunnels in its own contex
other words, MR can tear down less necessary RO tunnels acc
to its own criterion such as Least Recently Used(LRU) in ca
the resource shortage.

5.3 HA Extension

For route optimization, HA should maintain the state of PCH
piggybacking for per traffic flow. The traffic flow can be
classified by the destination address of the packets. HA do
piggyback PCH on one packet per the traffic flow. The piggy
state should be managed by soft-state. The piggybacking sta

per traffic flow becomes set when the first packet is piggy
and reset when the state timer is expired. HA doesn't need
piggyback PCH on the packets belong the traffic flow while
correspondent state is set. The overhead of managing the
piggybacking state can be minimized by the careful implemen

According to MIPv6 Spec.[1], HA MUST maintain Binding Cache
Like MR extension. Additionally, HA manages the following
information in associated BC entry for route optimization.

Route Optimization (RO) flag: When it is set, it indicat
the associated BU entry is RO enabled. RO may be enabled
disabled by administrative means.

Piggybacking State Table (PST): An entry of this table
represents a record that contains ('flow-id' = destinati
address, 'time-info' = UTC time). It indicates that the
packet belong the traffic flow(='flow-id') was piggyback
PCH at time('time-info').

For the packets forwarded via RO enabled tunnel from MR, HA
decapsulates them, and checks the need of PCH piggybacking.
entry that contains the destination address of the packet e
PST, PCH is not piggybacked to the packet at forwarding. Ot
HA creates new entry in PST for that traffic flow and piggy

PCH on the packet at forwarding. We can use one global time
delete the records which were long sustained in PST.

6. Security Considerations

TBD

In particular, considering security concerns is very import
applying the Internet protocol. At this moment, Public Key
Infrastructure (PKI) can be a solution to support the integ
the origin-authentication of PCH because the participants i
scheme are limited to some of routing facilities. We know t
potential security problem of our scheme must be deeply con
We leave the detailed security consideration into the futur
item with high priority.

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