Design a new Proposed Route Optimization Scheme based NEMO-Centric MANEMO (NCM)

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Abstract— **Route Optimization (RO) refers to any approach that optimizes the transmission of packets between a Mobile Network Node/Mobile Router and a Corresponding Node/Home Agent. RO would mean that a binding between the address of an MNN/MR and the location of the mobile network is registered at the CE/HA. Technically, route optimization mechanism comes up with a complementing solution for the pinball problem by avoiding the MRHA Bidirectional Tunnel (BT) that is to be used. This paper discusses the RO issues for NEMO and more specifically issues of Nested NEMO such as tunneling redundant, HA dependency, processing delay, bottleneck, traffic congestion, ER selection, and scalability in the design consideration. In order to address NEMO RO suboptimal, this work utilizes the NCM protocol plus to PHA. The proposed MANEMO RO scheme is a layer three solution to support RO for mobile networks. Additionally, the paper proposes the design to address Nested NEMO issues in a post disaster scenario by using Proxy Home Agent (PHA) in the infrastructure with using Neighbor Discovery protocol (TDP/NINA) for localizing communications. Thus, the signaling message flow and the algorithm are written to give proposed scheme more flexibility.**

Keywords-component RO, MANEMO, Pinball Issues, NEMO, Proxy

INTRODUCTION

MIPv6 is a protocol that allows a Mobile Node (MN) to move from its home network to another network without changing the MN's home address. The Mobile IPv6 protocol was introduced by the Internet engineering task force (IETF) to support the host mobility (individual IP devices) [9]. Packets may be routed to the MN using the home address regardless of the MN's current point of attachment to the Internet (RFC 3775)[9]. MIPv6 is a protocol that does not require widespread alterations throughout the existing Internet architecture. Therefore MIPv6 uses the centralized agent known as Home Agent (HA) that it would typically be located in the MN's home network. The HA intercepts any packets destined to be delivered to a MN and forwards those packets to the ever changing actual location of the MN [15]. In MIPv6 any MN can independently establish a connection with their HAs. This ensures that any MIPv6 MN can support its own mobility via any IPv6-enabled access network. The movement of an MN away from its home link is thus transparent to transport and higher-layer protocols and applications (RFC 3775)[9]. A lot of works which have been proposed and discussed in various documents appear as Internet Engineering Task Force (IETF). Most of these works are still in progress especially with Mobile Ad hoc NEMO (MANEMO) and all the subjects related to its. With MIPv6, RO mostly improves the end-to-end path between the MN and CN, with an additional benefit of reducing the load of the Home Network. But MIPv6 still has pending problems as aforementioned. The disadvantages of MIPv6 are MIPv6 is not ideal for all mobility scenarios as passengers on public transport, every MIPv6's host is required to support and run additional software and each host must have a respective HA that will manage its mobility. On the other hand, NEMO BS (RFC 4886) protocol allows MRs to change their point of attachment to the Internet topology. An MR obtains its CoA at the egress interface and establishes a MR-HA's BT to the HA. It routes all packets intercepted at the ingress interface to the BT. A packet's source address must belong to the MNP. Only packets sent to and from a mobile network are routed to the tunnel by the MR. NEMO has various applications such as Personal Area Networks (PANs), Networks in sensors and computers deployed in vehicles, access networks in public transportation, and ad hoc networks connected to the Internet via an MR. Contrary to MIPv6, NEMO BS does not define any solution to avoid routing via the HA. The issues related to NEMO RO have been discussed by the IETF (RFC 4888) [12]and the solution space analyzed in (RFC 4889)[13]. The RFC (4888) [12] has investigated problems such sub-optimal routing that results in various inefficiencies associated with packet delivery. With Nested NEMO these inefficiencies get compounded. RO is even more important to NEMO BS (RFC 3963)[5] than it is to MIPv6 (RFC 3775)[9]. RFC (4889) [13], it has discussed the solution space for NEMO RO problem statement. RO in NEMO is used in a broader sense than that already defined for IPv6 Host Mobility in [15] to loosely refer to any approach that optimizes the transmission of packets between a MNN and a CN. This document has classified, at a generic level, the solution space of the possible approaches that could be taken to solve the RO-related problems for NEMO. NEMO RO addresses the problems discussed in (RFC 4888)[12]. Different scenarios that would require an RO mechanism in the NEMO context are explained. These scenarios are: Non-Nested NEMO RO, Nested Mobility Optimization, Infrastructure- based optimization, and Intra- NEMO optimization. Besides that, some of the approaches to achieve the binding to the location

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of root MR are also discussed such as NDP, Hierarchical Registrations, and MANET routing. An analysis of the NEMO RO solution space with different scenarios in which a RO solution applies is discussed at this RFC. The intent of this work is to enhance our common understanding of the RO problem and solution space. However, all these solutions have not been applied and implemented so there is no standard solution for any problem from NEMO RO problems statement (RFC 4888)[12]. [17], have defined the MANEMO architecture including possible topology configuration and addressing assignment. The issues of MANEMO [14] have already been summarized above. As mentioned before, the addressing architecture of MANEMO is divided into two parts. Moreover [18] also has deeply discussed these two approaches (NEMO addressing approach and AUROCONF approach). Under NEMO addressing, two possible scenarios can be set whether the MR has its physically available ingress interface or not. [18], have been identified the MANEMO problems. The difference of communication model between MANET and MANEMO is that MANET protocols maintain local routing information so that they can communicate directly inside this ad hoc network. Even if there are multi-paths between nodes, most of the MANET routing protocols select the shortest path in default. However, the default MANEMO communication path is between two MRs through the Internet. Each MR transmits packets to ER even if the destination node is located nearby. Actually, MANEMO is still possible to maintain the neighbouring MRs. The major benefit of this work is that it illustrates MANEMO problems domain. Also, this Internet draft gives for us proposed solution guideline for MANEMO technology. However, within most of the MANET and AUTOCONF schemes, the change of any MR's attachment affects the neighboring nodes and sometimes the entire network. Again, this draft does not show any scenario applied for the MANEMO solution and until now there is no standardization for the solution

MANEMO SOLUTION REQUIREMENTS

A MANEMO should enable the discovery of multihop topologies at layer 3 from mere reachability and elaborate links for IPv6 usage.

B. MANEMO should enable packets transmitted from nodes visiting the MFS to reach the Internet via an optimized path towards the nearest ER, and back.

C. MANEMO should enable IP connectivity within the MANEMO areas whether the host has Internet connectivity or not.

D. MANEMO should enable packets transmitted from nodes visiting (VMN/MR) the MFS to reach the Internet with a topologically correct address (CoA).

E. MANEMO must enable inner movements within MFS to occur, and ensure that propagating details of this movement are kept at a minimum.

F. MANEMO must maintain local connectivity within the two separated MFSs and connectivity between the split MFSs.

G. Ad-hoc function should be supported by MANEMO, for isolated wireless area (c) and multi-hop access to the Internet (b).

H. MANEMO should provide multicast communication among the hosts inside its area and on the Internet.

DESIGN CONSIDERATIONS

Generally, Different scenarios that will require a RO mechanism in the NEMO context are explained in [7], in which these scenarios are classified as: Non-Nested NEMO RO, Nested Mobility Optimization, Infrastructure-based optimization and Intra-NEMO Optimization. MANEMO technology comes to address NEMO and MANET problems, by integrating both techniques to produce a unified solution. This paper focuses on the most important issues of NEMO as:

- Tunneling overhead and Home Agent dependency:

  A mobile network (sub-NEMO) is said to be nested when it is attached to a larger mobile network (parent-NEMO). The aggregated hierarchy of mobile networks becomes a single Nested NEMO as pointed out in Figure 1.1-a. NEMO BS protocol has proposed that each MR establishes a BT with its HA, then all communications between MNN and its CN should be routed to BT. Therefore, when multiple MRs are connected together, redundant tunnels and un-optimized paths are often found. In addition, whenever packets are routed over an MR, an additional IPv6 header is inserted in the packet for tunneling. Therefore, fragmentation may occur due to the availability of multiple tunnels between end nodes. As an instance, we suppose that MNN1 is attached under MR3. So if MNN1 would be communicated with its CN (MNN1_CN), then the path from a MNN1 to CN becomes MNN1aMR3aMR2aMR1aARaHA1a HA2aHA3aCN. If MNN1 is VMN, one extra HA is added to the path above. This is a well-known constraint of the NEMO BS protocol as illustrated in Figure 1.1-b. However, NEMO BS protocol does not provide any RO mechanism and mandates all traffic from/to an MR going through an HA.

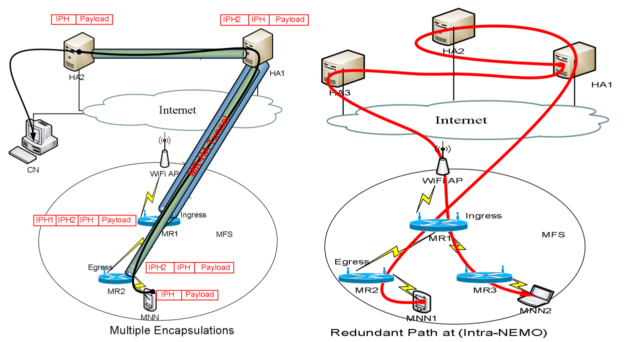

Figure (1.1) NEMO-centric MANEMO (NCM) issues

- Longer Route Leading to Increased Delay and Additional Infrastructure Load.
- Increased Packet Overhead.
- Increased Processing Delay.

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                    ---------/          /----------.
           -------/         |          |           /-------
MNN -----( -  - | -  -  - | -  -  - | -  -  - |  -  - (------ CN1
        MR3-------\        |          |           \-------MR3_HA
                 MR2--------\          \----------MR2_HA
                           MR1---------MR1_HA
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Figure (1.2) Nested NEMO processing

DESIGN PROPOSED SOLUTION

Under MANEMO, the actual solution for NEMO RO relies on the data packets exchanged between two end nodes which may not need as many levels of encapsulation as that in NEMO BS. This would mean less packet overheads and higher data efficiency [RFC 4889][13]. Therefore, routing to multiple HAs should be avoided as much as possible [17]. For decreasing the number of HAs on the path in order to remove the sub-optimality of paths caused by multiple tunnels established between multiple MRs and their HAs, a solution will seek to minimize the number of HAs along the path, by bypassing some of the HAs from the original path. Additionally, decreasing the number of tunnels in order to reduce the amplification effect of nested tunnels due to the nesting of tunnels between the VMN and its HA within the tunnel between the parent MR and the parent MR's HA, this proposed solution seeks to minimize the number of tunnels, possibly by collapsing the amount of tunnels required through some form of signaling between MRs, or between MRs and their HAs, or by using routing headers to route packets through a discovered path. The goals that our design solution should satisfy for sub-optimal routing problems are:

- Reduction in the levels of indirection (i.e., numbers of HAs that must be visited) and therefore reduction in the level of tunneling overhead encountered.
- Reduction in the reliance on communicating with an HA when performing inter-MR communication, or to achieve all of these improvements.

This paper is involved with infrastructure optimization based by utilizing a Proxy Home Agent (PHA) fig(1.3) in order to address sub-optimally issues that are redundant tunneling packet overhead (multiple encapsulations), processing/packet delay, and scalability. NEMO BS protocol that MANEMO used to connect MNNs within MFS to Internet through ER. Since NEMO BS suggested that each MR should establish BT with its own HA, tunneling overhead will be generated whenever multiple MRs are connected to each other. In order to avoid the redundant tunnel, we suppose using PHA technique with MANEMO technology. PHA is applied in Global Home Agent to Home agent protocol (HAHA) [16]. The principal concept of the PHA is to separate HAs from the home link so as to distribute them to the Internet architecture. The aim of HA deployment is to provide an efficient RO scheme that is compatible with MIPv6's MNs and with NEMO BS's MRs, is transparent for CNs, reduces latency and avoids sub-optimal routing [11]**.** A PHA can act either as a HA for the MN/MR, or as an MN/MR for the HA, or an MN/MR for CN, or MN/MR for CR, or an MN/MR for other proxies. In particular, the PHA terminates BT and the associated encryption, extracts the packets and retransmit them to the destination. The main scenario assumed is an MR/MNN roaming on smaller-scale operation (two disaster areas).
The proposed work is created to address hierarchical NEMO through using PHA in the infrastructure. To generate RO in Nested NEMO, either one of the MRs' HAs acts as a PHA or adds a new HA to the infrastructure to acts as a PHA. In the first case, when one of the HAs acts as a PHA, that means only the functionality of this HA will be modified. On the other hand, adding a new device (HA) which supports PHA to the Internet also generates a RO for Nested topologies. Modifying just the functionality for one HA that already existed in the Internet has more benefits than other cases because HA changing functionalities is the easiest entities that could be modified [RFC 4889][13]. However, adding an HA to act as a PHA is also a good solution that provides the same results of case one with a light limitation. Multiple HAs are distributed to the current infrastructure and each MR sends binding to the PHA through ER at the MFS. The MR makes binding with its target HA (MR_HA), simultaneously, MR_HA acts as PHA whenever the MR_HA received "P" (P=1) flag within ER's packet and then PHA creates a copy of BU with the other HAs (in the current Internet), in order to improve the end-to-end path. In

our case, we considered a single MR_HA that received the binding from its MR to act as the Proxy HA[11].see fig(1.4)

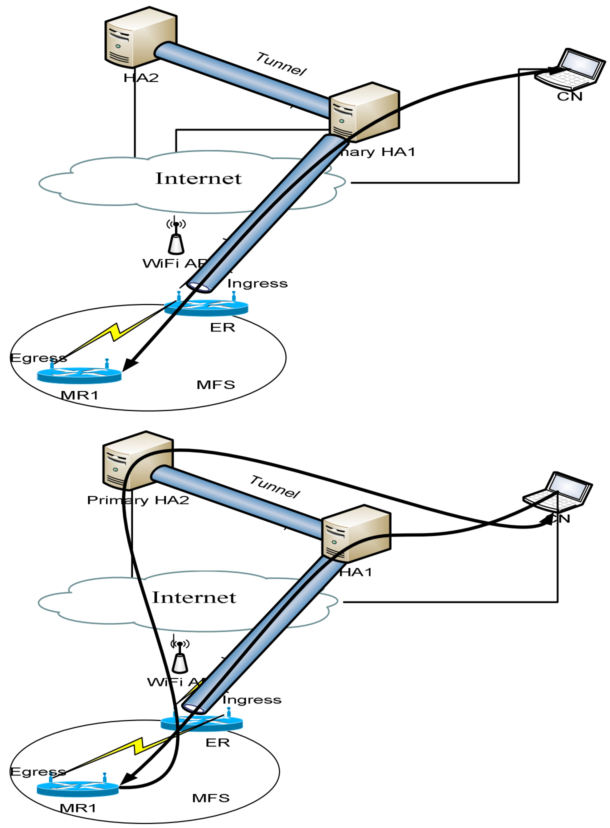


Figure (1.4) Global HA-HA protocol simple work a) PHA works-MR selects the closest HA b) PHA works-MR selects non-primary HA

The main feature of this proposed solution is the distribution of HAs within the current Internet topology to reduce distances to end-nodes[11]. The HAs advertise the same network prefix from different locations through anycast type of routing; moreover, they also exchange information about their associations with MRs. Redundant tunnels and packets overhead deployments are possible using the traditional TDP/NINA routing protocols with NEMO BS by utilizing an additional mobility management called Proxy HA. In this new proposed design, HAs are distributed all over the Internet and exchange information about MRs that they can reach and the MNNs behind each MR. This development is achieved with the assistance of anycast routing in which each HA advertises the same IPv6 prefix. This proposed design in this stage, aims to address redundant paths and multiple encapsulations issues. Moreover, the PHA provides an Internet scale mobility that does not alter the existing architecture of the Internet. Since no modification is made to the MNNs, our work can be seamlessly inserted in a network, avoiding pinball and providing scalability of the Internet is simply to achieve.

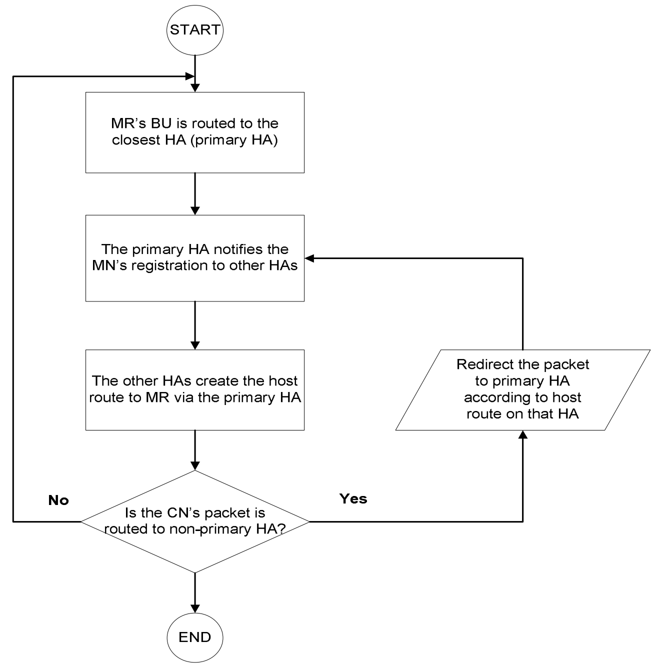


Figure (1.3) Proxy Home Agent basic operation

EXTENDED BINDING CACHE AND TIO MESSAGE

This proposed research is extended to the binding cache of MFS_MR specifically BC_ER in order to maintain the addresses of mobile devices under MFS. Intra NEMO and multiple IGWs are improved (as shown in the previous section). These improvements are done through applying ER mechanism (including extension of ER's memory cache). Table 1.1 demonstrates the information that added into Binding Cache_ER. While this study used H/O manager producer for ER's movement, this table adds one column for HA's delay. The HA's delay is added in order to get closer HA distance for ER. Thus, RTT (between MR and PHA) will be reduced.

TABLE 1.1
BINDING CACHE TABLE FOR (ER) IN MFS

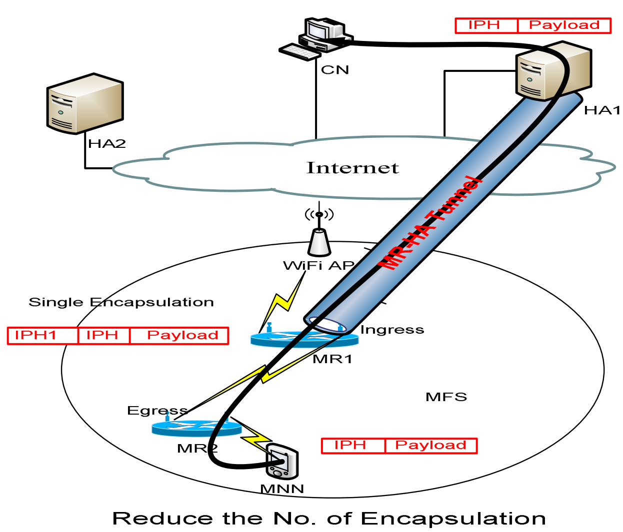
Nodes	**Prefix from (NINA)**	**HoA from (TDP)**	**CoA from (TDP)**	**HA's Delay**
MR-1	MNP2, MNP3	MR2_HoA, MR3_HoA	MR2_CoA, MR3_CoA	T1
MR-2	MNP1,MNP3	MR1_HoA, MR3_HoA	MR1_CoA, MR3_CoA	T2
MR-3	MNP1, MNP2	MR1_HoA, MR2_HoA	MR1_CoA, MR2_CoA	T3

This Binding Cache at MRs maintains the relationship among CoA, HoA, and PHA associated with MR. Also TIO format is modified in this proposed study as shown in table 1.2 where 1 bit is specified for 'P' flag (HA acts as PHA) and another 1 bit is specified for 'G' flag (MR acts as ER). Additionally, sub-option field is assigned for uniform path metric that carried metrics of the network connection like bandwidth, lowest path, throughput, and time delay of the link. Finally, ER transmits its address for all MRs in MFS via TIO message.

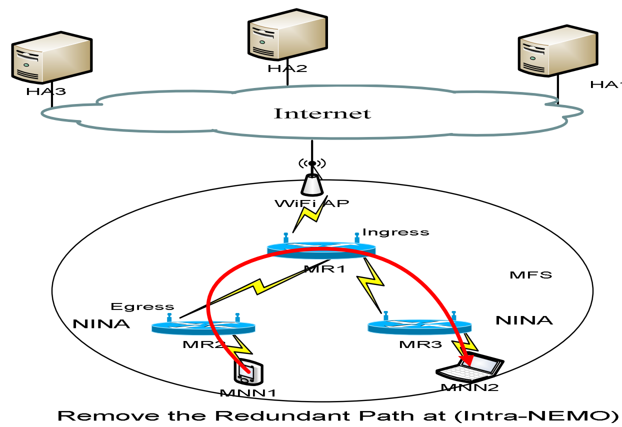
TABLE 1.2
TIO FORMAT MESSAGE

Type	**Length** |**G**|**H**|**P**|	**Reserved**	**Sequence**
Tree Pref.	Boot Time Random		
MR Preference		Tree Depth (L)	Tree Delay
Path Digest			
Tree ID			
Sub-option(s) **Uniform Path Metric**			
ER_CoA			
ER_HoA			

The design solution for this proposed study aims to address most RO issues related to the hierarchical MRs, therefore; Figure 1.5 shows the architecture of the design solution.
At Figure 1.6a, the proposed design addresses the multiple IP-in-IP encapsulations issue through utilizing the edge router as GW cooperating with PHA. Besides, Figure 1.6b shows the design solution for redundant path issue through extended TIO and Binding cache for MRs.



(a)



(b)

Figure (1.5) (a),(b) shows the architecture of the design solution

OPERATION OF THE PROPOSED ARCHITECTURE

In order to explain and describe the mechanisms of this RO proposed scheme, signaling flow is presented in Figure 1.6 below:

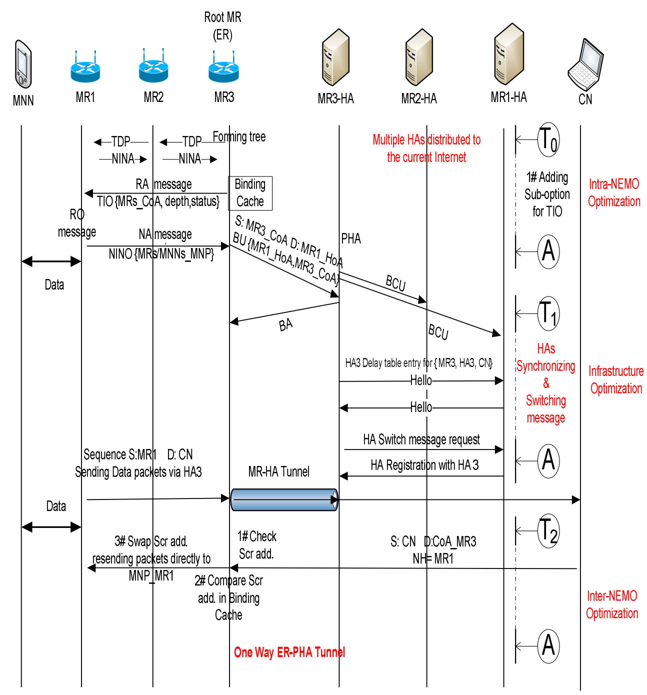


Figure (1.6) Signalling flow sequence

Generally, NEMO RO entities are involved with signalling messages as [RFC 4489] either MNNa CN, or MRaCN, or MRaCR, or Infrastructure Entities (PHA). Thus, signalling flow procedure of PHA in our proposed scheme is described as follows:

- All MRs at MFS act as GW a Multiple HAs are distributed to Internet regardless of the topology
- Using anycast type of routing among the HAs (these links are dedicated afaster and more secure)
- MR's BU (CoA registration) is routed to the ER of MFS
- ER sends (MR's BU) to ER's HA that act as (PHA)
- PHA transmits a copy of BU to the other HAs
- When actual HA received this CBU, it sends request to PHA to begin switching message between it and PHA
- PHA responds (actual HA for MR) switch message by registration message (that give permission to exchange information between them)
- PHA then sends the packets directly (passing all other HAs) to CN
- When CNaMNN/MR
- CN transmits data to ER with NH (Next Hop = MNN)
- ER receives a packet
- Call ER _route selection
- ER registers Time Delay (TDelay) at its BC for all active MNNs/MRs that have ongoing communication sessions with CNs/HAs
- ER compares all TDelay and select the lowest TDelay from HAa choose the nearest HA as PHA for next packet.

IMPACT OF TOTAL SIGNALLING COST (CSIGNALLING(TOTAL)) VS. NUMBER OF LOCATION UPDATE COST (Δ_{LU})

Signalling Cost for this proposed scheme, Recursive scheme (R-SU), and NEMO Basic Support Protocol vs. number Location Update Cost for different number of MRs is illustrated in Figure (4.5). We fixed Tmn = Tmr= 60 sec, Nmr = 50, 100 and 150, and vary $\delta_{LU}$from 0.4 to 6. The effect of Nmr and δ_{LU} on signalling cost is shown in Figure (1.7). Generally, total signalling cost increases with increase of Nmr and increase of δ_{LU} cost

$LU_{mr} = L.S_{LU}.(h_{(mr \rightarrow ER)}-(N_{mr}+1)+\theta)$………1

$\Psi_{vmn}^{LU} = N_{mn}\,(LU_{vmn}+y_{vmn})/T_{vmn}$ ...2

$C_{PD\,(Total)} = \{C_{l\,(Total=CoA+Trans)}\} + C_{l\,(Normal)} + C^{N}_{l\,(Tunnel)}$ …………………...3

$C_{bw\,(MFS)} = \{C_{bw}\} . C_{m\,(Total)}$ …….4

((Eqns. (1), (2), (3), (4)) while the signaling cost for proposed RO scheme remains lower than NEMO BS by 42% to 67%. This is because proposed RO scheme does not update all HAs for MRs handoffs (just PHA is updated and it transmitted copy of this updated to other HAs), while NEMO Basic Support Protocol needs to update MN_HA and MR_HA for all handoff.

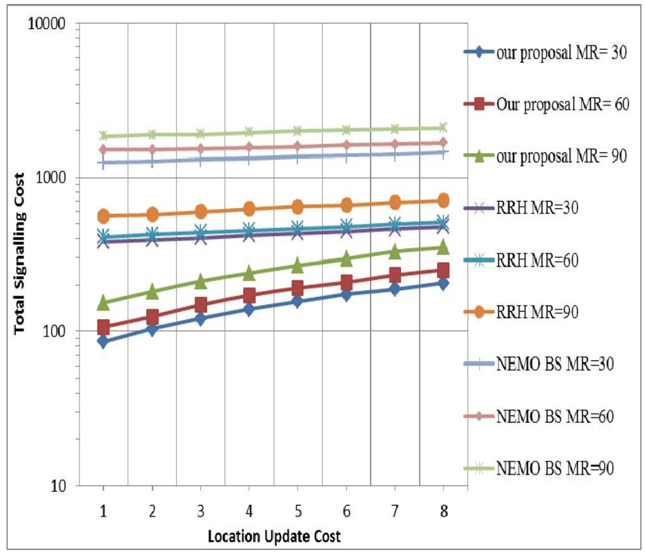


Figure (1.7) Signalling Cost for Our proposal, RRH, and NEMO BSP vs. number Location Update Cost for different MRs ,and SLU = 0.4.1.2,2,2.8,3.6,…,6

CONCLUSION

This paper demonstrated the design proposed for MANEMO RO scheme which is composed from NCM and PHA. Since the proposed solution addresses issues related to Pinball routing problems such as multiple encapsulations packets and redundant tunnels along the path, this proposed solution is always applied for Nested NEMO networks environments. Thus, the RO-PHA proposed scheme creates just one way tunnel whenever the MR/CN wants to communicate with CN/MR., the paper also presented the new proposed RO mechanism by reducing multiple tunnels and thus minimizing number of Home Agents (HAs) under category of Infrastructure Optimization (PHA). Router Advertisement (RA) messages from Tree Discovery Protocol (TDP) is extended to carry more information about MRs/MNNs within MANEMO wireless areas. In addition, MRs and PHA functionalities are slightly modified through extending their Binding Cache (BC). Moreover, the high processing gathering with high memory are required for any HA device that will work as Proxy Home Agent.

REFERENCES

[1]. Adisorn L., Teerapat S., Anis L., and Kanchana K., (2009). "Velocity Effect on the Performance

of MANEMO",, The Third AsiaFI Winter School, Available (Online).
[2]. Ben M., Panagiotis G., and Chris E., (2010). "Intelligent Autonomous Handover in iMANETs" , ACM 978-1-60558-925-1/10/02.
[3]. Ben McCarthy, Christopher Edwards, and Martin Dunmore, (2008). "Using NEMO to Extend the Functionality of MANETs", IEEE Communications Society ICC.
[4]. Ben McCarthy, Matthew Jakeman, Chris Edwards and Pascal Thubert, (2008). "Protocols to Efficiently Support Nested NEMO (NEMO+)", ACM.
[5]. Devarapalli, Ryuji W., Petrescu A., and Thubert P., (2005). "Network Mobility (NEMO) Basic Support Protocol", RFC 3963.
[6]. Ernst T., (2007). "Network Mobility Support Goals and Requirements", RFC 4886.
[7]. Hajime Tazaki, Rodney Van M., Ryuji W., and Thirapon W., (2009). "Selecting an Appropriate Routing Protocol for In-Field MANEMO Experiments", ACM 978-1-60558-618.
[8]. Hajime Tazaki, Rodney V. M., Ryuji W. and Thirapon W., (2010). "MANEMO Routing in Practice: Protocol Selection, Expected, Performance, and Experimentation Evaluation", IEICE Trans. Commun., E93-B(8).
[9]. Johnson, C. Perkins and J. Arkko, (2004). RFC 3775, "Mobility Support in IPv6".
[10]. Kanchana K., Thirapon W., Manutsiri C., Anis L. and Hajime T., and Khandakar A., (2008). "DUMBO II: A V-2-I Emergency Network" , AINTEC'08, ACM 978-1-60558-127-9/08/11
http://www.interlab.ait.ac.th/dumbo.
[11]. Masafumi, Ernst Thierry, Ryuji W., and Jun Muri, (2006). "Routing Optimization for Nested Mobile Networks", IEICE TRANS. COMMUN., E89–B: 10.
[12]. Ng C., Thubert P., Watari M., and Zhao F., (2007). "Network Mobility Route Optimization Problem Statement", RFC 4888.
[13]. Ng C., Zhao F., Watari M. and Thubert P., (2007). "Network Mobility Route Optimization Solution Space Analysis", RFC 4889.
[14]. Seong-Yee P., HoonJae L., and Hyotaek L., (2008). "Route Optimization for NEMO Based on AODV", ICACT, ISBN 978-89-5519-136-3.
[15]. Ryuji Wakikawa, (2009). "Vehicular networks: Techniques, Standards, and Applications", book chapter11 (Mobile Ad hoc NEMO), LLC.
[16]. Ryuji W., Clausen T., McCarthy B., and Petrescu A., (2007). "MANEMO Topology and Addressing Architecture", draft-wakikawa-manemoarch-00, http://www.ietf.org/ietf/1id-abstracts.txt (work in progress).
[17]. Ryuji W., Thubert P., Boot T., Bound J., and McCarthy B., (2007). "problem statement and requirements for MANEO", draft-wakikawa-manemo-problem-statement-01.
[18]. Ryuji W., Thubert P., Boot T., Bound J., and McCarthy B., (2007). "problem statement and requirements for MANEO", draft-wakikawa-manemo-problem-statement-01.
[19]. Thubert P., Ryuji W., and Vijay D., (2006). "Global HA to HA protocol" , draft-thubert-nemo-global-haha-02.
[20]. Thubert P., (2009). "Nested Nemo Tree Discovery", draft-thubert-tree-discovery-08.txt
[21]. Thubert P., and Bernardos C., (2008). "Network In Node Advertisement" , draft-thubert-nina-03.txt